SECTION 2

TECHNICAL PRESENTATIONS

SECTION 2

PART 1

THE UNITED STATES TECHNICAL PRESENTATION ON ESV DEVELOPMENT

FAIRCHILD INDUSTRIES

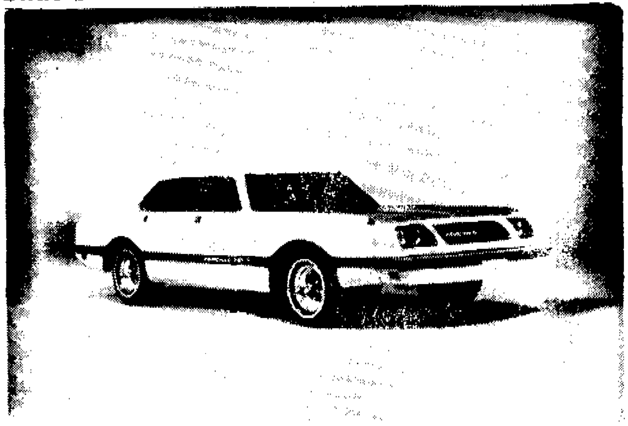
Dr. N. Grossman
Vice President

Good afternoon ladies and gentlemen. The presentation which you will be given is basically in two parts. We will have Mr. Sol Davis, who is our Chief of Systems Engineering, discuss the progress we've made to date on Crash Injury Reduction. He will be followed by Mr. William Wait, who is Chief of Systems Test, on Accident Avoidance. The material was all developed since the summer of 1970 when this contract was awarded to us. Now our primary area of competence is in the field of the design, development, test and production of military aircraft. We used much of the technology from that field in the design concepts introduced into the safety vehicle. However we were very fortunate in having the technical assistance and support of two of our subcontractors in areas where we lacked this competence. And so I would like to take this occasion to acknowledge with thanks the support of the Chrysler Corporation who were technical consultants to us and provided some of the hardware, and to the Digitek Corporation of Los Angeles, Calif. who provided the test facilities. So without further delay I would like to introduce the first speaker, Mr. Sol Davis.

Mr. S. Davis

Thank you Dr. Grossman, good afternoon ladies and gentlemen. It is my pleasure to present the Fairchild Experimental Safety Vehicle.

Slide 1



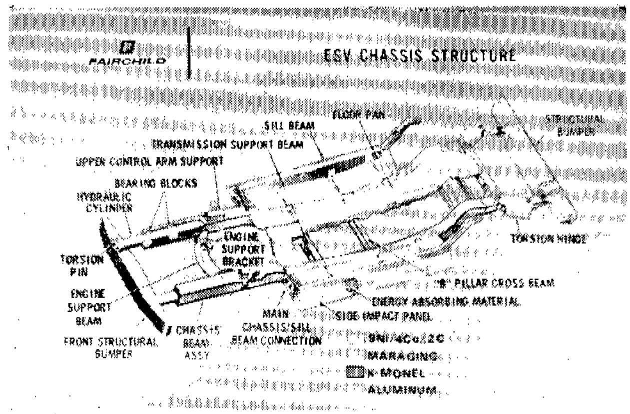
This three quarter view illustrates the program management decision that this Family Sedan should have the appearance and design of a real world automobile. The vehicle has a curb length of 220", it has a width of 80", and a height of 58" excluding the periscope. The chassis is mounted on a 121" wheelbase. The size of the car was dictated by the need to accommodate five 95th percentile occupants, and the padding required by the passive occupant restraint systems.

For the structural design approach we had several options based on our aerospace technology experience. We could have proceeded with a steel tubular truss structure covered with a non-structural material such as fabric – the way simple aircraft was built in the past. This technique would have offered a design easy to analyze and test, and cheap to manufacture. On the other extreme, we could have used sophisticated aerospace materials such as beryllium and titanium, which have very attractive strength-to-weight ratios. We chose the middle route: a structural design that would look and smell and feel like a real world car, within the manufacturing restrictions of a prototype vehicle. Our goal has been an integrated system design that would aid in the setting of future automotive safety standards.

I would like to go into the details of the structural configuration and then we will go into some performance characteristics.

This slide is color-coded to indicate some of the materials that we are using in the chassis structure. The dark blue is a 9-4-20 high strength steel, the yellow is a high strength maraging steel, the small red circles you see are torsion pins made of K-monel metal, and we have used some aluminum as indicated by the light blue.

Slide 2



Starting on the left of the figure we have the front bumper and the hydraulic cylinders. I would point out that the stroke of the hydraulic cylinders is 18" when the bumper is in the retracted position; in the extended position at speeds above 30 miles an hour we have a hydraulic stroke of 30". Continuing toward the right we have the front chassis beam assembly followed by the main chassis beams underneath the passenger compartment; in the rear you see our torsion hinge assembly in yellow. The arms of the torsion hinge assembly are designed not to yield. That is why they are made of the special maraging steel. I would point out that the particular design concept was dictated by the short time schedule of our program. In actual production we feel that an S frame could be designed by a repeated design/test/redesign program to give us the same results. Finally we see the rear bumper.

Slide 3

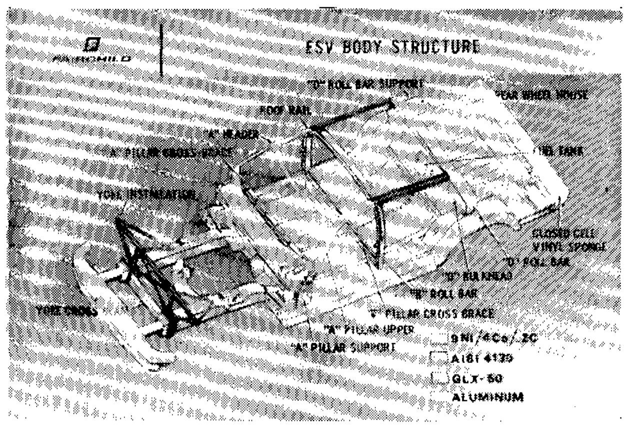
FAIRCHILD — STRUCTURAL MATERIAL PROPERTIES

TYPE OF STEEL	F_{TU}/F_{TY} (KSI)	% ELONG	CHARPY V NOTCH (FT-LBS)
9Ni/4Co/.20C	190/180	14	45
18Cr/15Mn STAINLESS	112/68	45	100
MARAGING STEEL	280/275	6	15
K-MONEL	140/100	25	30
GLX-50	65/50	22	15
TYPICAL AUTOMOTIVE 1008	**50/35**	**30-48**	**15-50**

In order to understand the choice of materials, we've made up a table showing some of the structural materials and their properties *(Slide 3)*. The first column shows the type of material, for example 9% nickel, 4% cobalt, .20% carbon steel. The next column shows the ultimate strength and the yield strength; for the 9-4-20 steel, it is 190,000 ksi for the ultimate strength and 180,000 ksi for yield. Also important in yielding structures is the percent elongation which is 14% for that particular steel. Also of use in evaluating materials for crashworthiness is the Charpy V notch value in foot-pounds.

We are using some stainless steels where we need very long elongations. As you note stainless steel has a 45% elongation. The maraging steel has an ultimate of 280,000 and a yield of 275,000 pounds per square inch, and the K-monel metal is somewhere between the strength of the stainless steel and the 9-4-20. The GLX-50 is a commercial grade of steel with a somewhat higher yield strength than the typical 1008 automotive steel which has only a 50,000/35,000 ratio of ultimate to yield. In order to get increased strength with minimum weight, our approach has been to go to higher strength steels rather than increase gauges.

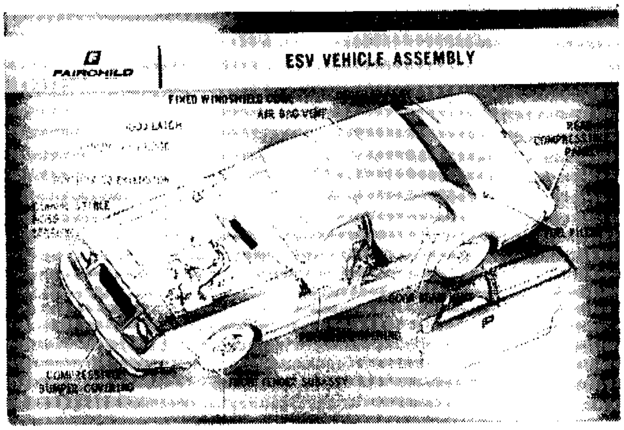
Slide 4



The next slide shows additional elements of the body structure *(Slide 4)*. You'll notice on the left side, in orange, is an AISI 4130 steel we use for our unique radiator bulkhead. This structure serves primarily for rollover protection; if you draw a line between the B pillar and the radiator bulkhead, that line limits the deformation at the A pillar to about 3 inches. We also see more of the 9-4-20 steel being used in the B pillar to improve rollover protection.

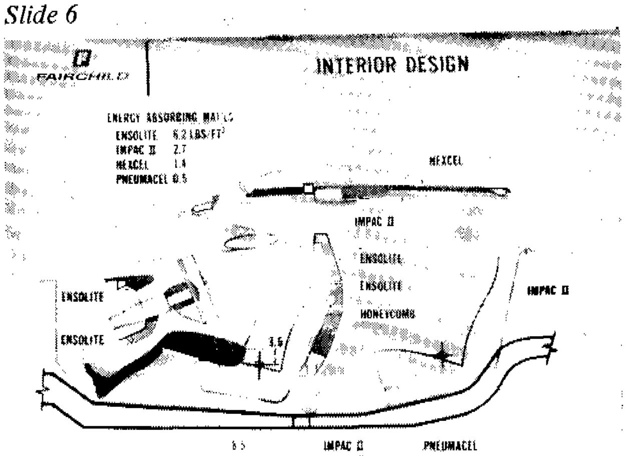
Here is the exterior view of the vehicle assembly which shows that we are primarily using conventional sheet metal on the outside of the car. Inside the doors you will find, not shown here, stainless steel side support beams which will be described later. They are stainless steel because we need very large elongation. This figure also shows the compressible nose section, just in front of the head lights. This will deform during a 10 mph frontal impact, and return elastically to its original position. Also shown in this figure on the roof is the position for

Slide 5



the periscope and for the airbag vent ports which we will discuss a little later.

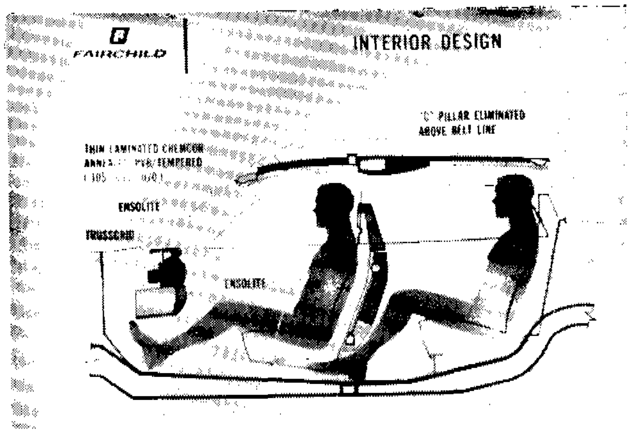
Slide 6



This is an interior view; let us look at the driver position first. The driver's seat range is 8½ inches fore and aft, 3½ inches up and down, in order to accommodate from the 5th percentile female through the 95th percentile male. The steering column is a conventional collapsible column with a forward and aft adjustment of the assembly to accommodate the range of drivers. Also shown in the driver's position is the blue impact area which is Ensolite. Let us look at the table at the top of the chart. This indicates some of the interior padding materials which we are using in our safety sedan. Ensolite, which weighs 6.2 lbs. per cubic foot, is a comparatively heavy material but it has much greater energy absorption per unit volume than any of the others. We are also using Impac II which weighs only 2.7 lbs. per cubic foot in less critical, secondary impact areas. We are using a Hexcel honeycomb which crushes at a prescribed pressure level, and it has a very attractive density of 1.4 lbs. per cubic foot. We are using Pneumacel in the actual seat cushions for comfort, and that has a density of 0.5 lbs. per cubic foot.

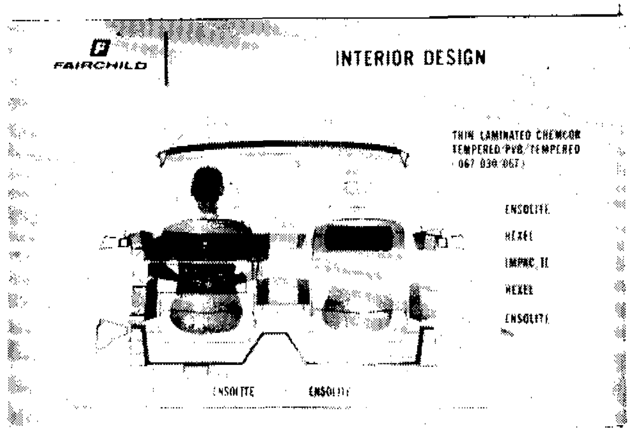
Getting back to the driver, the knee restraint for the driver is a one inch thickness of Ensolite backed up by a crushable panel. There is an airbag inside the deep dish steering wheel, and that bag would be activated at speeds above 15 mph. In this view you can also see the rear passenger. His airbag is mounted in the roof, and his knee restraint is basically Ensolite, backed up by that aluminum honeycomb panel. You can see the Impac II and the Hexcel honeycomb in the roof. It would be desirable to put in Ensolite there, but as it is considered a secondary impact area (it is very difficult to predict what will happen) we have chosen to save some weight there and go to somewhat less efficient Impac II material. Also shown here is the periscope subsystem made by Donnelly Mirrors.

Slide 7



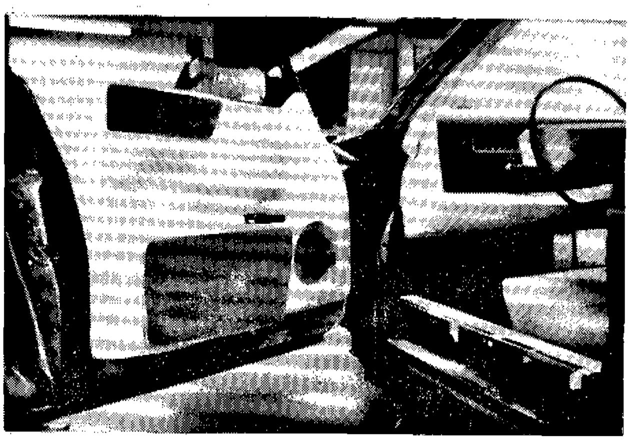
This view shows the front passenger position with the airbag mounted in the dash panel. The knee restraint is made of Ensolite, backed up with Trussgrid, a crushable honeycomb material. The windshield is a thin laminated Chemcor, such as we started to develop on our New York State Safety Car Program.

Slide 8



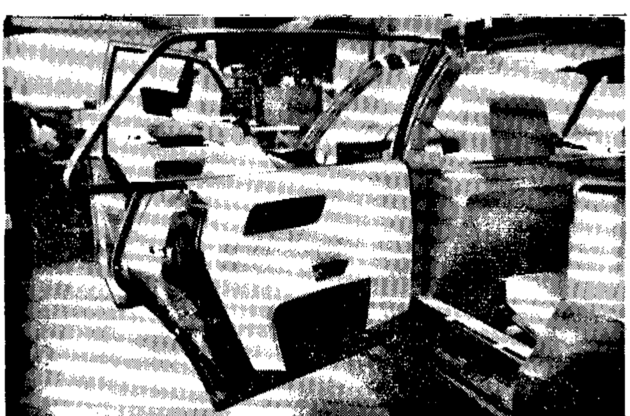
Here is a view that shows some of the side protection safety materials. We have a shoulder restraint. We have a hip restraint. These have been sized to consider the proportion of the weight in the body that has to load up these two areas. We're using a combination of Ensolite and Hexcel honeycomb. The Ensolite has the important characteristic of returnability, so that if you push on it lightly it will return to its original position. In a severe crash the Hexcel, if loaded up to its crushing level, will permanently deform and would have to be replaced. We also have a side support in the center, between the front passenger and the driver, which will serve to restrain them sideways if the crash is on the other side of the car.

Slide 9



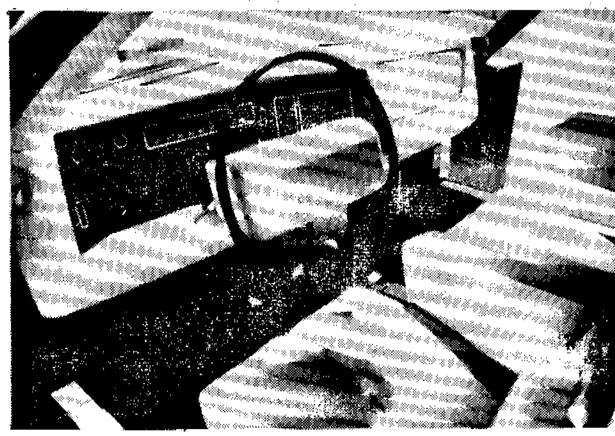
Here is a mockup, made by Loewy/Snaith, showing the front door with the shoulder restraint and the hip restraint and also showing access into the vehicle. We also see the recessed door knob and the window regulator.

Slide 10



Here is another view, showing the rear door. Notice the cutout on the door, which aids in getting in and out of the car at the rear seat. You'll also notice the very large rear door window that was done for two purposes: one was to increase visibility, and two, to try and get the head side impact area to be glass rather than a steel support post.

Slide 11



This is an interior mockup of the driver's position showing the location of the airbag and a partial view of the instrument panel.

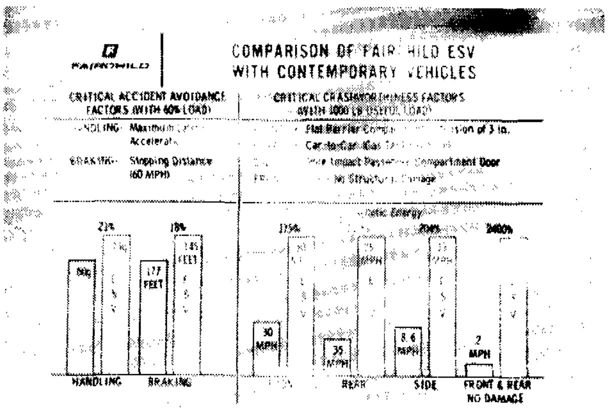
Slide 12

This mockup shows the unique rear system. The rear can accommodate three 95th percentile persons. The hip and arm supports that you see there move up when you want a person to occupy the center seat. It is a passive restraint in that it will normally be in the down position unless you physically push it up.

Now I'd like to discuss some of the performance characteristics and the details of the front impact subsystem which we consider to have the highest priority.

This slide indicates some of the performance that we have in the ESV in comparison to contemporary vehicles. On the left side we have typical accident

Slide 13



avoidance factors, for example, handling. The first two comparisons show that a typical car can sustain about .60 g's as the maximum lateral acceleration, and our ESV can get about .73 g's. Under braking, a typical stopping distance is 177 ft. for contemporary vehicles; our ESV is expected to stop from 60 mph in 145 ft.

But of greatest importance is the crashworthiness area, and we can see from the comparison for front impacts that contemporary vehicles have a capability of 30 mph for no more than 3 inches of intrusion whereby our ESV is expected to have a 50 mph capability. For rear impact, for example, if we use the rupture of the gasoline tank as the criteria, typical current vehicles can sustain about a 35 mph rear impact speed; our ESV should be able to take 75 mph by another ESV without gas tank rupture. For side impact, current vehicles have a capability of about 8.6 mph, our car will have a capability of 15 mph into a rigid pole. But the most dramatic improvement is in the front and rear no damage performance. Current vehicles, and by that I mean at the time the program was started, had a capability of perhaps 2 mph; we are going to have 10 mph front and rear capability with no damage.

We think that this kind of safety improvement is going to be dramatic. However, you don't get anything for nothing, and we just want to point out some of the weight increases we have had to incorporate into the vehicle which we have had very little control over.

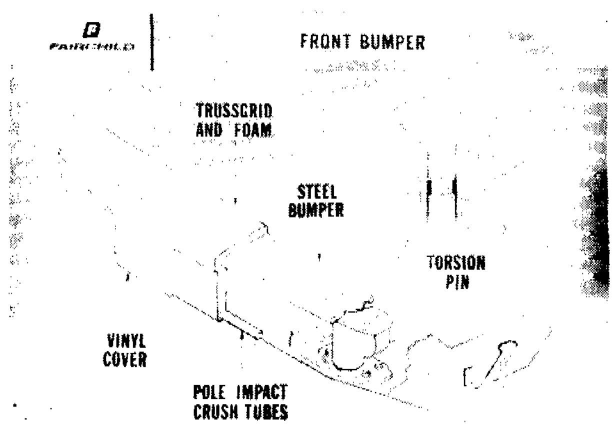
Slide 14

FAIRCHILD — MANDATORY WEIGHT INCREASES

ITEMS	WT-LBS
PASSIVE RESTRAINT	208
ANTI-LOCK BRAKES	72
PERISCOPE	45
SEAT ADJUSTER	19
ANTI POLLUTION (73 vs 71)	25
TOTAL	+369 LBS

For example, in order to accommodate the requirement for passive restraint (and that means the airbags and padding as opposed to a belt system), we have had to put in about 208 lbs. of weight. In order to improve the braking performance, using a Bendix-Chrysler type system there is a weight penalty of 72 lbs. We were forced to go to a periscope because the head restraints for the rear occupants effectively block out the backlight. The Donnelly Mirror Co. periscope system has added about 45 lbs. Seat adjusters to accommodate the range of the driver and be able to stay in place during the 50 mph crash conditions has added 10 lbs. Anti-pollution requirements to raise the engine capability from the 1971 emission requirements to the 1973 emission requirements have added 25 lbs. A total of 369 lbs. has been added in terms of things we had no control over in order to meet the requirements.

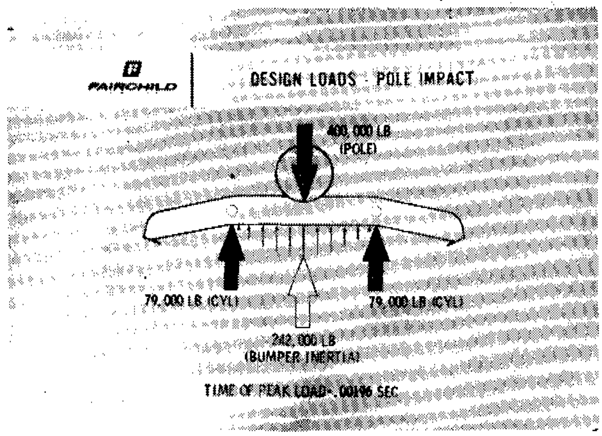
Slide 15



This is a close-up of the front bumper. The bumper itself is made of steel and is covered with Trussgrid and foam, and finally by a vinyl cover. You will see the two pole impact crush tubes which are made of stainless steel; these are there primarily to help absorb the kinetic energy of the bumper itself during a front pole impact at 50 mph. Also shown are the torsion pins that connect the hydraulic cylinders to the front bumper; these aid in getting us better performance in angular impacts which is of course, one of our requirements.

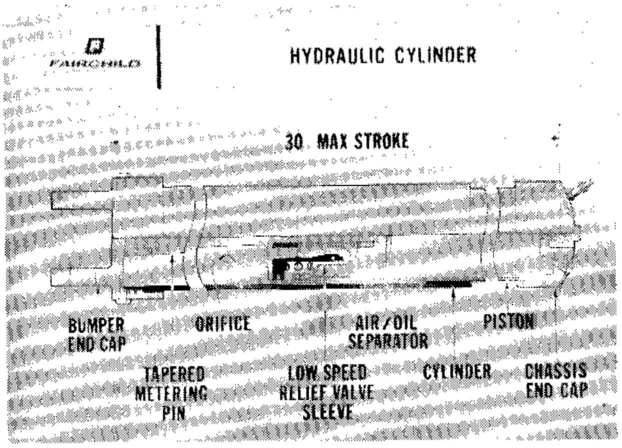
The most severe condition for that front bumper, which I indicated, is pole impact. This shows the

Slide 16



analytical prediction of the loads to which we designed our bumper: the hydraulic loads are only 79,000 lbs. per cylinder at the time you get the worst inertia loading on the bumper. The inertial loads due to the mass of the bumper are 242,000 lbs., for a total load of 400,000 lbs. We have designed the bumper to take that kind of load; we hope the pole can take it.

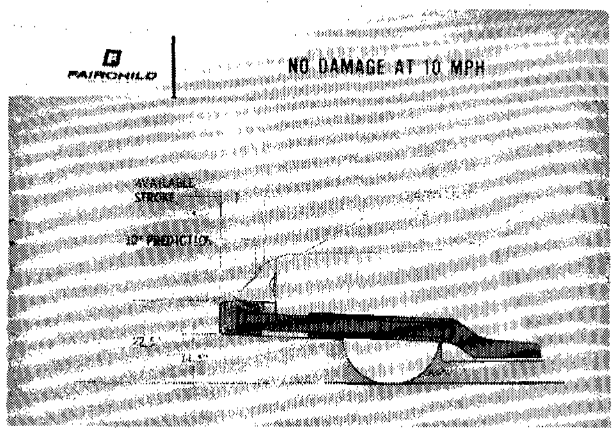
Slide 17



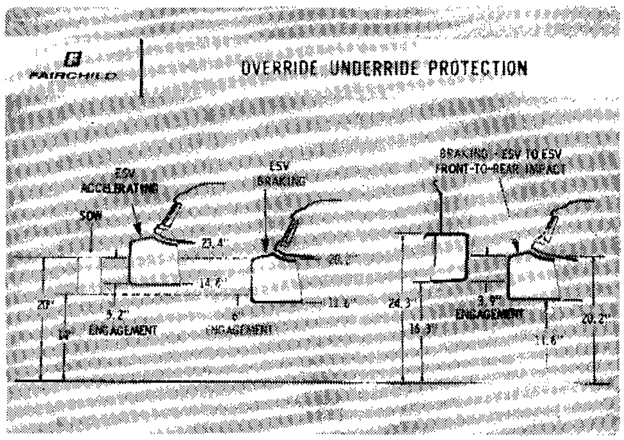
This is a view of the variable orifice hydraulic cylinder. Starting on the left, we have the front bumper end cap, then the gray is the tapered metering pin, the blue is the piston, and the space between the blue and the gray represents the orifice which is a function of stroke. Also shown is the low speed relief valve sleeve assembly which gives us the 10 mph no damage design with returnability.

This slide illustrates the front design where we expect no damage at 10 mph by the addition of the elastomeric nose which is colored green. The bumper stroke we predict on the complete ESV to be about 10", compared to an allowable stroke of 13" before we would get any damage.

Slide 18



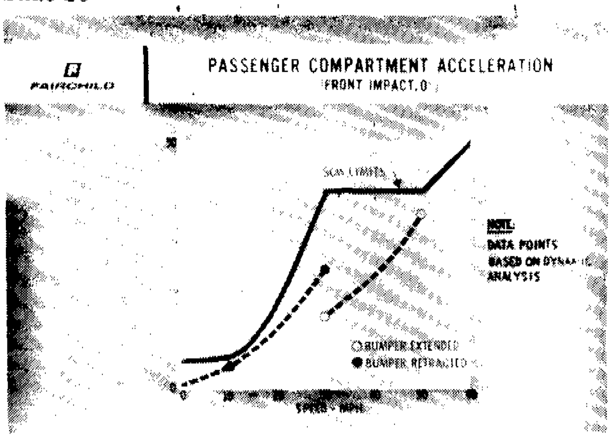
Slide 19



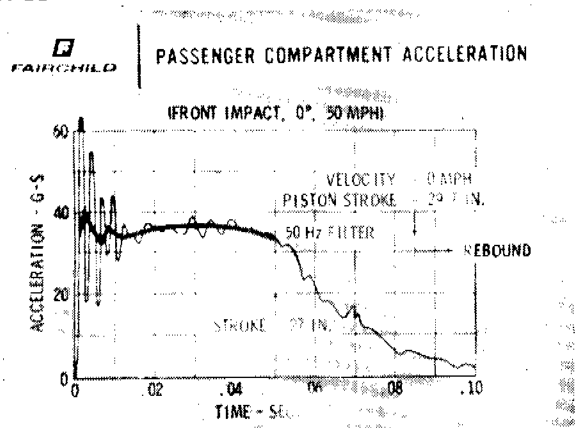
Override/underride protection is a significant criteria in our Statement of Work. If the ESV is accelerating, the first figure on the left shows that the bumper would have a 5.2" engagement with the Statement of Work (SOW) body block. If the ESV is braking, the second figure shows that we would have a 6" engagement with the body block. On the extreme right, we have the case of car-to-car impact with both vehicles braking. The front bumper of one vehicle goes down, the rear bumper of the other vehicle goes up and we have a 3.9" intersection. So we feel we have provided very adequate override/underride protection.

With regard to crashworthiness performance, this curve summarizes performance for zero degree front impact. The vertical scale shows acceleration in g's, the horizontal scale shows speed in mph. The heavy black line is the Statement of Work limits, and the dash lines show our expected performance based on dynamic analysis. The analyses are based on a nonlinear transient analysis computer program that we have used for this and other crash conditions such as angular impact and pole impact, and this is a typical result. The dashed curve on the left represents the retracted bumper position; the dashed curve connecting the open circles is the extended bumper position. As you can see we expect to be well within the specification.

Slide 20



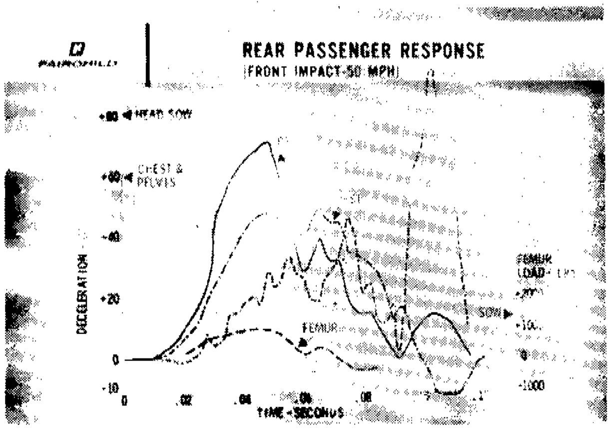
Slide 21



To give you an example of how we got the points on the previous curve, this figure shows how we got the 50 mph data point for front impact. This figure shows acceleration on the vertical scale, versus time on the horizontal scale. The black wiggly curve is the output from our digital computer program which includes all the vibration modes of the structure; the red line is an estimate of what the data would look like if it were filtered with a 50 Hertz filter. Clearly, we are coming in with very close to a square wave for the first 27 inches of stroke. The total stroke is 29.7 inches, and the curve also shows that after a certain time, .085 seconds, we start the rebound. From our experience in the test program we expect a rebound velocity in the order of 3-5 mph in a 50 mph crash.

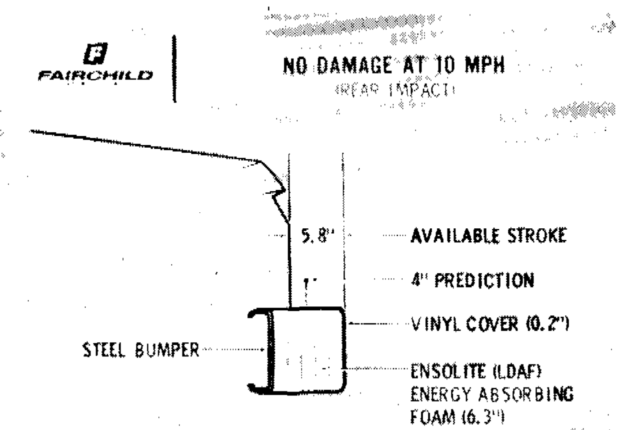
This is a typical passenger response analysis. The vertical scale is deceleration, the horizontal scale is time in seconds. On the right vertical scale we have femur

Slide 22



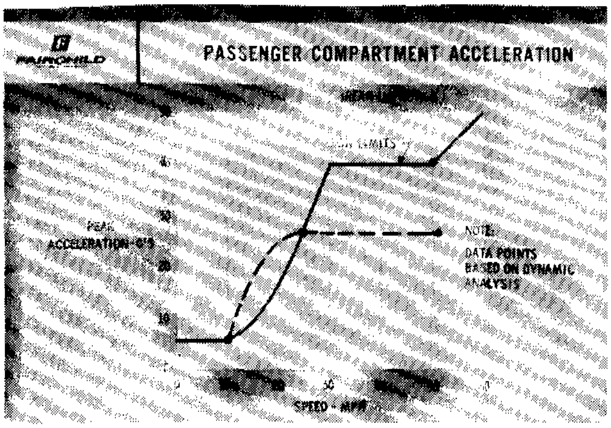
loads. These are the results of a dynamic analysis for the rear passenger which is the most complex position in the car because the airbag hits flexible structure, namely the front seat backs. We see the deceleration curve for the pelvis going up to about 70 g's which is somewhat higher than the SOW limits indicated by the arrows on the right scale: 60 g's for the chest and pelvis and 80 g's for the head. The chest level seems to be below the 60 g level. The head g's at the end of the time period suddenly take a sharp spike up. This is probably a problem with the dynamic model of the occupant we used because the head bottoms out on the chest. We don't expect that kind of head performance in the actual tests that are currently being conducted on a body buck at Wayne State University. The femur loads are well within the 1400 pound allowance. These analyses were used to estimate the effect of occupant loads on the structural design.

Slide 23



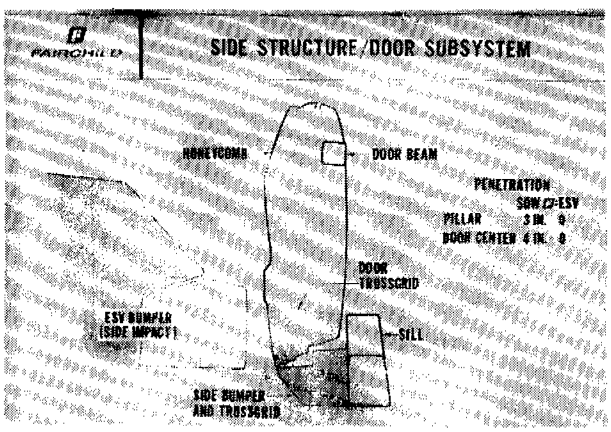
For the rear impact subsystem we have a "no damage at 10 mph" requirement. Our system in the rear is a 6.3" depth of Ensolite energy absorbing foam which will deflect about 4 inches during the 10 mph impact by the J972 moving barrier, and there will be no damage. The torsion hinge assembly will not yield because the loads are low.

Slide 24



Here is a curve showing acceleration on the vertical scale vs. speed on the horizontal scale for the rear impact subsystem. The heavy black line indicates the Statement of Work performance requirements; the dashed line is our predicted performance. You will notice that in the speed range of 30-50 mph our system design is much better than the SOW requirements; however, in the lower speed 10-20 mph region we may slightly exceed the allowable limits. We feel that the trade-off in getting the lower g's at the high speeds more than outweighs the slight deviation at the lower speeds.

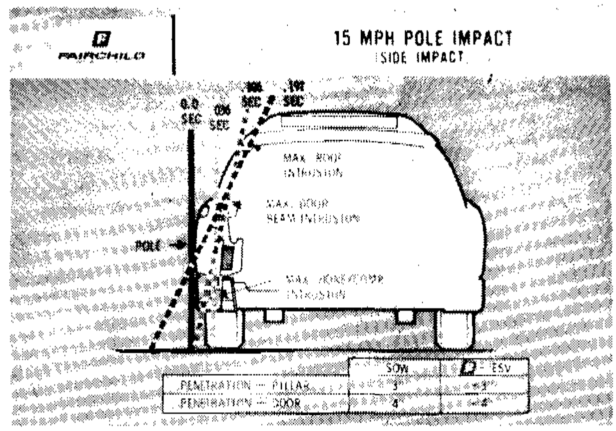
Slide 25



Looking at the side structure, we have a cross section of the door. At the bottom of the door we see the main sill. In front of it is Trussgrid which is like an aluminum honeycomb but is less sensitive to impact direction. For a car-to-car crash we have shown the front bumper level of the striking ESV. We expect that we can take a 30 mph impact when the bumper is retracted and at least a 35 mph impact if the bumper of our car is extended. Essentially, we will have no penetration under these conditions in a car-to-car impact.

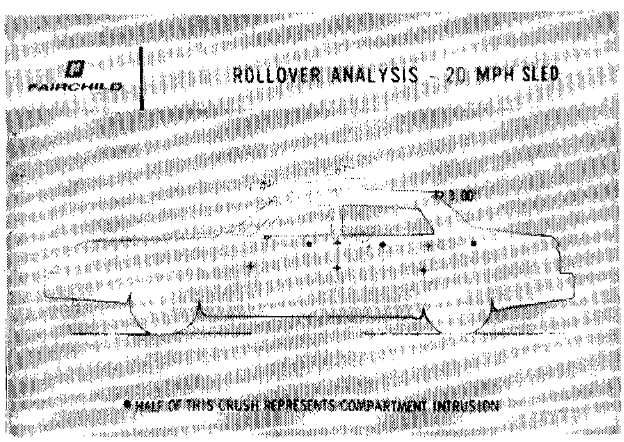
Also shown in the door is the upper door beam which has honeycomb in front of it. This is not specifically required for car-to-car impact but is required for pole impact, which is described on the next slide.

Slide 26



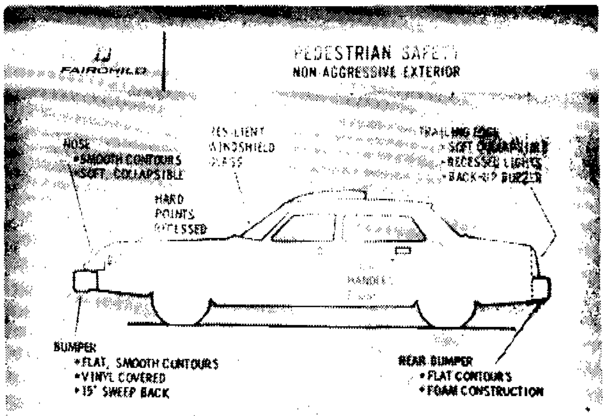
When the car hits the pole, it is the car that is going to roll. For convenience we have shown the relative position by rotating the pole. What happens is that in a 15 mph side pole impact the car will initially strike the pole at the lower sill. This induces a rolling motion and if we didn't have that door beam in the upper part of the door you would get large penetration at that particular level. This figure shows the successive penetration of the car into the pole, and the red line (.197 sec.) shows the maximum penetration at the roof line. Based on these analyses we expect that penetration will be limited to 3 inches at the pillar and 4 inches at the door.

Slide 27



For rollover we conducted analyses for a 20 mph sled test. That sled test is the Mercedes type of test, where the vehicle is mounted at 23° and run down a sled and caused to roll. We feel this 20 mph speed will be sufficient to roll the car twice. Based on the dynamic analyses we have shown some of the deformations that we expect on the side of the car, the maximum deformation being 4.33 inches. However, only half of that number is actual penetration; the rest is crush of the outside of the car.

Slide 28



Primary consideration, of course, has been given to occupant injury reduction as per our Statement of Work; however, we have given consideration to the pedestrian problem. You'll note that the collapsible nose section on the front is soft and is not a pedestrian hazard. We have also swept the front bumper rearward 15° on the outboard ends which helps to deflect the pedestrian out of the path of the car. The bumper is fairly smooth and we think it is the best design we could get within the other restrictions on the vehicle.

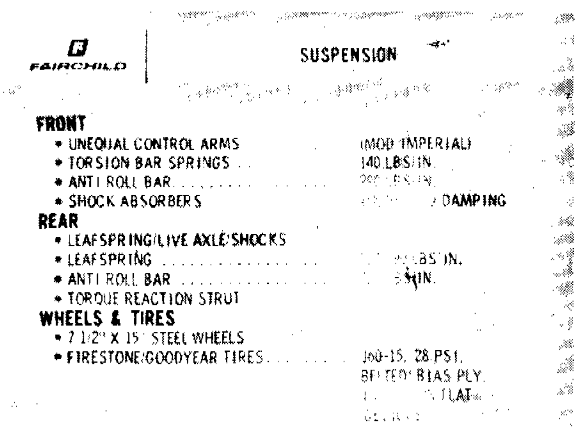
On the rear of the car we have, of course, a flat contour and our Ensolite foam material has a very soft impact surface, so we think we don't have any problems there. We also have added a warning buzzer to warn pedestrians. On the side we have a smooth shape and even the door handles are recessed.

That is the end of the crashworthiness part of the session; Mr. Wait will now continue with the Accident Avoidance characteristics.

Mr. W. Wait:

Thank you Sol. Before engaging in any discussion on the Accident Avoidance criteria of the car, I think it's proper to discuss a little bit of the priorities of the program. The primary thrust of the program as Mr. Davis has stated, was directed towards the improvement of crashworthiness. As such, the vehicle configuration and the performance of the other subsystems of the car, were to be traded, if there were to be any trades, in the terms of improving the crashworthiness. As such the configuration of the car was dictated in this fashion. Further, the handling requirements of the vehicle do not represent any breakthrough or state-of-the-art developments. They represent a good present automobile, and this is what we feel we've done with this car developed an automobile that will have good handling and be fun to drive. How did we get there? First of all we utilized two chassis mules; one was a 1970 Plymouth which was modified by installation of ballast, suspension components, and wheels and tires. The second was a Chrysler Imperial equipped with anti-lock brake system, and ESV wheels and tires and ballasted to the ESV weight and distribution.

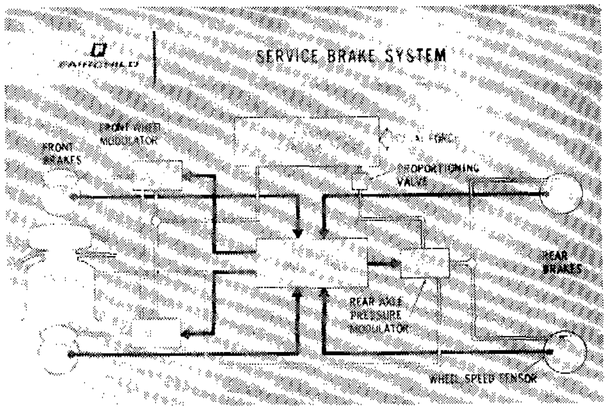
Slide 29



Now, if we may, let's consider first the chassis structure. What does this consist of? In order to fit the front energy management system in, a torsion bar front suspension system was the most logical arrangement; therefore we did use the torsion bar with unequal control arms, which were modified Imperial components, a front anti-roll bar and shock absorbers with increased damping. The rear suspension was quite conventional, leaf spring, Hotchkiss live axle, shock absorbers, but again with the addition of an anti-roll bar and a torque reaction strut. Wheels and tire are tire-wise either Firestone or Goodyear; J size, 60 aspect ratio, and 15 inch rim diameter. They're belted bias construction, equipped with inner run flat devices, which precludes the requirement for carrying a spare in the car. They are operated at 28 psi in the normal tire chamber and approximately 15 psi higher than that in the inner tire chamber. Wheels are 15 inch diameter rim, with a 7½ inch rim width.

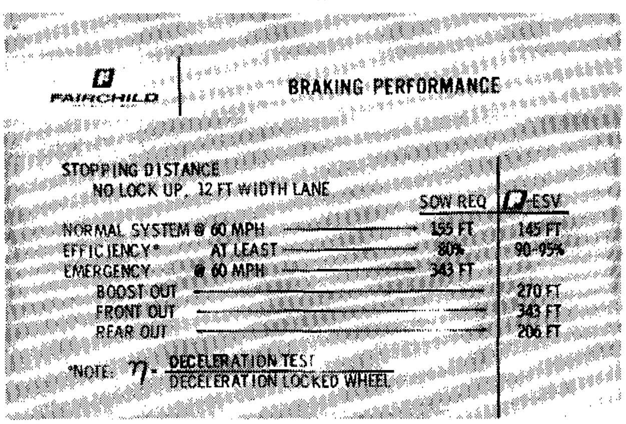
The braking system, again in avoiding the trap which is so easy to fall into, "to reinvent the wheel," we utilized normal components wherever possible, and

Slide 30



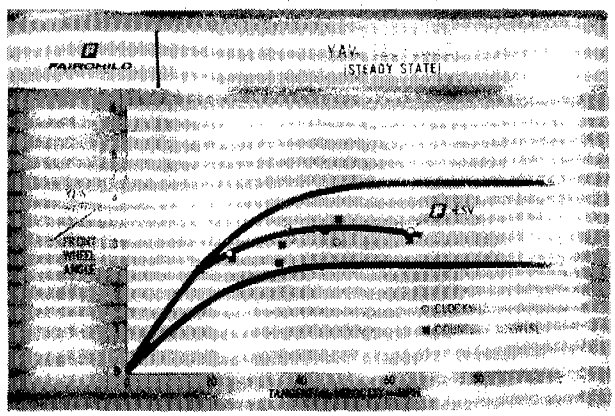
modified when necessary. The brake system is composed of the Imperial foundation brake system, of disc brakes in front, drum brakes in the rear, a dual master cylinder with a front to rear split, a proportioning valve, and a vacuum boost system. This system is modified further by the addition of the Bendix-Chrysler "Sure Brake" system composed of wheel speed generators at each wheel, electronic logic control unit, modulators for each of the two front wheels, and a single modulator which functions to dump pressure to both rear wheels when either rear wheel indicates a skid signal.

Slide 31



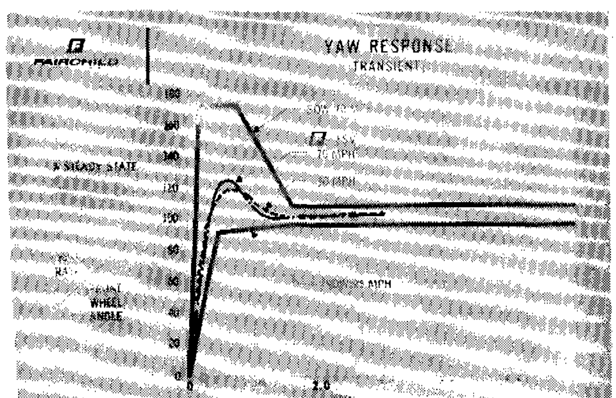
We have obtained the following performance with this system, well within the requirements of the Statement of Work. Stopping distance with normal system operation on dry pavement has averaged in the order of 145 feet against the 155 feet requirement. The best stopping distances achieved have been in the order of 136 feet. The efficiency we have achieved has been approximately 90-95% against 80% requirement defined in terms of the test deceleration noted vs. a locked wheel deceleration. Emergency stopping distances, again from 60 mph, against a requirement of 343 feet have achieved a distance of 270 feet with the boost out, 343 feet with the front brake system inoperative, and 206 feet with the rear brake systems inoperative.

Slide 32



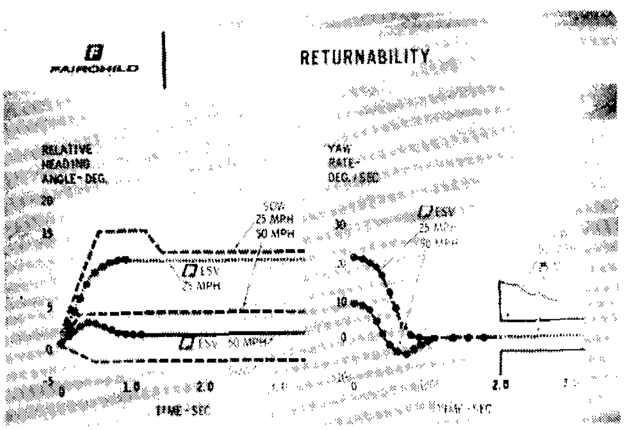
Next area of interest to us will be the steady state yaw response. This chart presents the standardized format of yaw rate, that is, yaw rate divided by front wheel angle, vs. vehicle velocity. The red lines define the allowable envelope and the blue line defines the test data which we obtain. It will be noted that the curve is concave down as required by the Statement of Work. Also to be noted it is well within the allowable envelope.

Slide 33



The transient yaw response is shown in the form of a time history. Again standardized yaw rate, yaw rate divided by front wheel angle, however, in this case it is presented in terms of a percentage of a steady state value. That steady state value being the standardized yaw rate required to generate a lateral acceleration of .4 g's. The green lines indicate the allowable envelope, the upper representing the 70 mph limit and the lower speed limit. The two curves shown, 50 and 70 mph, will be noted to lie within the allowable envelope.

Slide 34



The returnability is determined by establishing a lateral acceleration at various speeds of .4 g's and releasing the wheel. This also is shown in the form of a time history, however in this case it is shown as a relative heading of the vehicle response and the yaw rate of the vehicle response. The upper dotted line represents the maximum allowable deviation in the heading when released from 20 mph, the lower or middle dotted line represents the higher speed or 50 mph limit. Two curves with the data points illustrate the vehicle response. Again well within the allowable envelope.

The curve on the right presents the same data in terms of vehicle yaw rate. The upper and lower envelope representing boundaries which cannot be exceeded, and the dotted line through the middle representing a total damping at 25 mph.

Slide 35

FAIRCHILD | LATERAL ACCELERATION

100 FT RADIUS, MANUAL CONTROL,
DRY SURFACE, DESIGN TIRE PRESS.

SOW .65 g

ESV .73 g

The maximum lateral acceleration as defined in our Statement of Work called for several configurations of tire pressure and surface condition. However, we utilized this parameter as a tool to develop our overall cornering power, and devoted our energies almost entirely to the dry, design pressure area. We felt that if we obtained sufficient margin in this area we would have no difficulty in meeting the off design and low friction coefficient requirements. As you can see, we were able to generate a lateral acceleration well in excess of the requirements and this has given us the confidence that there will be no problem in meeting any of the off design conditions.

Slide 36

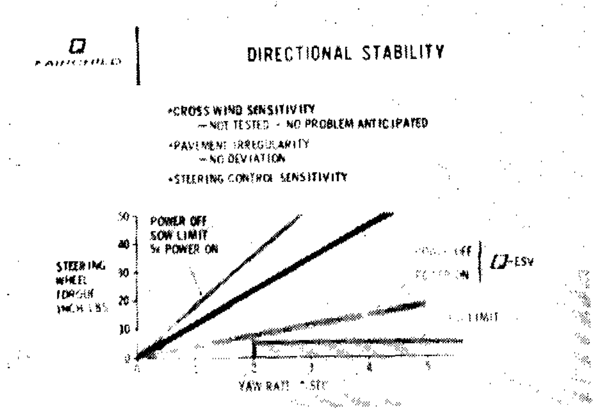
FAIRCHILD | HANDLING

CONTROL AT BREAKAWAY
REGAIN PATH IN LESS THAN 4 SEC

RADIUS	TIME	
	SOW	ESV
100 FT	4 SEC	2.35 SEC
225 FT	4 SEC	-
417 FT	-	2.45 SEC

Control at breakaway test is conducted by driving on various radii at maximum attainable lateral acceleration, then increasing the speed until the radius is increased by 10 feet, at which time the throttle is closed and the vehicle returned to the original path. Statement of Work requirement allows 4 seconds to return to the original path. We have been able to achieve this in under 2½ seconds on both the 100 foot radius and a 417 foot radius circle. No problem is anticipated in this area either.

Slide 37

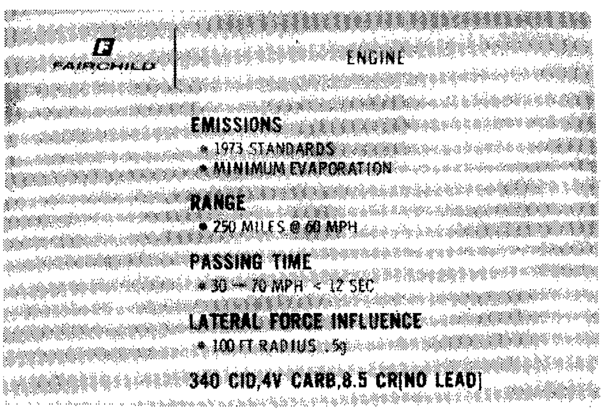


Directional stability is broken into three basic components. First the vehicle sensitivity to cross winds. This was not investigated with the chassis mule as we did not feel it was a true aerodynamic representation of our final car. Further, most modern American automobiles do not suffer from this to any great degree, therefore this was not investigated.

The pavement irregularity on the other hand, was anticipated to be somewhat of a problem; the very low aspect ratio tires used were anticipated to have a pull or nibble tendency when crossing pavement irregularity such as trolley tracks or any of the pavement separators at various angles. However, much to everyone's surprise the vehicle was completely unresponsive to any of these disturbances.

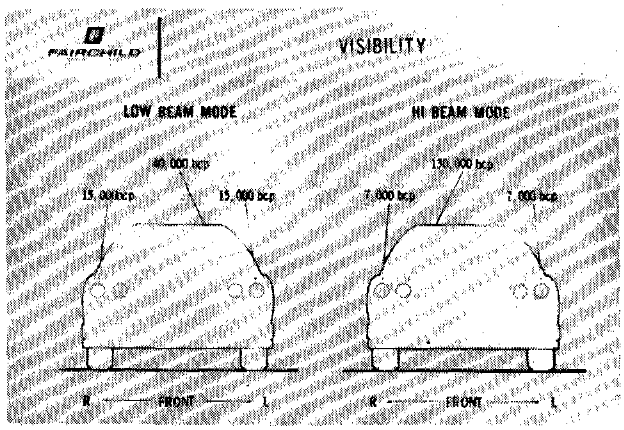
The final area involves that of steering control sensitivity, and a Statement of Work requirement that for a 2° per second yaw rate, a wheel force of no less than 5 inch-pounds of torque is required. The blue line represents the vehicle performance in the chassis mule, resulting in 7 inch-pound torque requirement, somewhat in excess of 5 inch-pound requirement. The "power off" requirement, when the steering boost is inoperative, is that the force shall not be more than 5 times the "power on." This provided us with an allowable torque "power off" at 2° per second yaw rate of 35 inch-pounds. The black line represents the vehicle performance in this area, again well within the allowable performance.

Slide 38



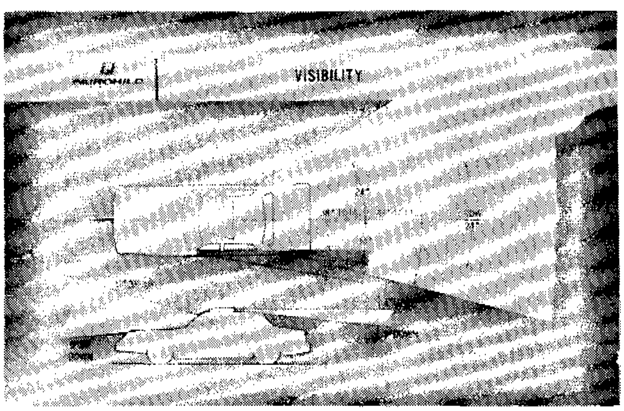
The engine must meet the 1973 emission standards and have a minimum fuel evaporation from the fuel system. The engines which we will utilize have been run and successfully demonstrated to meet these emission standards and the fuel system is equipped with the various check valves, filters and ingestion systems to eliminate all practical fuel fume evaporation. The range requirement of 250 miles at 60 mph is believed attainable although not tested at this point in time, but the fuel capacity, rear axle ratio, automatic transmission which we are utilizing should result in satisfying this requirement. Passing time requirement 30-70 mph in less than 12 seconds is also believed attainable with the drive line components and engine performance which we are utilizing. Lateral force influence, that the vehicle will not suffer a power fluctuation when subjected to a half g laterally has been demonstrated satisfactorily. The engine is a Chrysler 340 cubic inch displacement V-8, equipped with a four barrel carburetor, 8½ to 1 compression ratio, operable on low lead or no lead fuels.

Slide 39



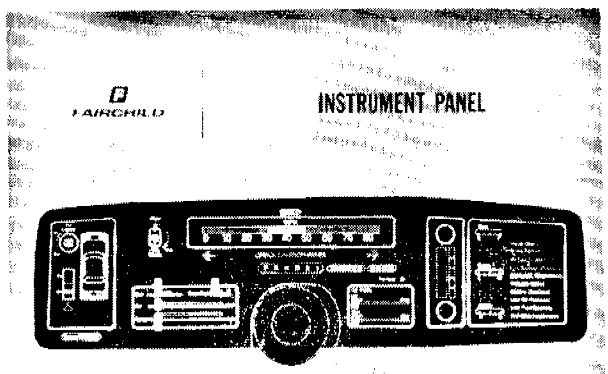
The visibility area will be discussed next. The head lighting utilizes a GE 3 light, sealed beam system. In low beam mode of operation, the two outer lights are operated at 15,000 beam candle power, while the left hand inboard light is operated at 40,000 beam candle power. In high beam mode, the two outboard lights are reduced to 7,000 beam candle power, and the right hand inboard light is illuminated at 130,000 beam candle power.

Slide 40



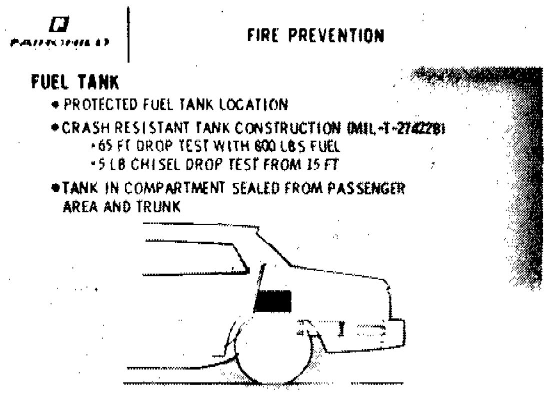
The driver's visibility will be discussed next. The Statement of Work requirements called out a 24° included angle of visibility to the rear; utilizing the periscope we are able to achieve a 49° included angle to the rear, 32° to the right, 17° to the left. Utilizing the same rearview mirror, which is adjustable by the driver to look directly out of the rear window and not through the periscope, the yellow area of visibility is realized here as a 38° included angle. The question of if we could get this visibility with just the rear view mirror why bother with the periscope. The prime reason for this was to achieve the down angle visibility which is effectively blocked off when utilizing the normal rearview mirror through the rear view window by the seat head rests. The forward visibility upward angle has been achieved quite handily, however we have not met the downward angle at the driver's position in spite of the very large envelope of driver seat movement. We have chosen to take exception to this limitation in view of our yoke rollover protection and in view of the priorities of the program in terms of crash injury reduction we felt that rollover protection should take precedent over the visibility requirement.

Slide 41



The instrument panel represents some unconventional or aerospace techniques and some normal automotive methods. The center of the panel represents normal driver information system, utilizing a speedometer, odometer, heater control, fresh air controls, turn signals and passing beam, warning light and windshield wiper operation switches, all these are the normal conventional system. On the left side we have the lighting panel. In addition to the normal push/pull switch to activate the headlights and parking lights on and off, the twist to control the intensity of illumination of the instrument panel, a plan view of the car is provided with indications of the status of each of the lights on the car provided by fiber optics; when a light is illuminated it will appear as an illuminated light on the plan view car. The emergency warning flasher operation is next to the plan view car. If we move to the right hand side the radio is quite conventional and the normal driver advisory instruments in terms of fuel remaining, coolant temperature and generator status for the electrical system. However, the extreme right portion of the car is where we utilized what is referred to in fighter aircraft as a "peek and panic" or a master caution panel. Directly under the speedometer you will note the words, "Check Caution Panel." These are illuminated, your attention is directed to the extreme right hand side where one of the legends of several items underneath the caution panel will be illuminated. The red ones are those which require stopping the car, and immediate attention, such as a door is open, a brake system malfunction. The yellow items represent service items, which require service at the earliest convenience, like low oil pressure, high coolant temperature; things of this sort.

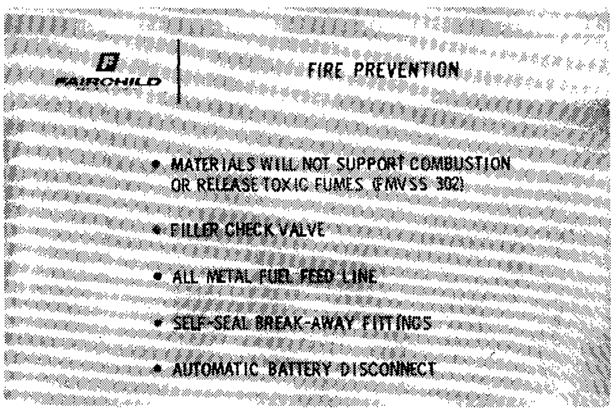
Slide 42



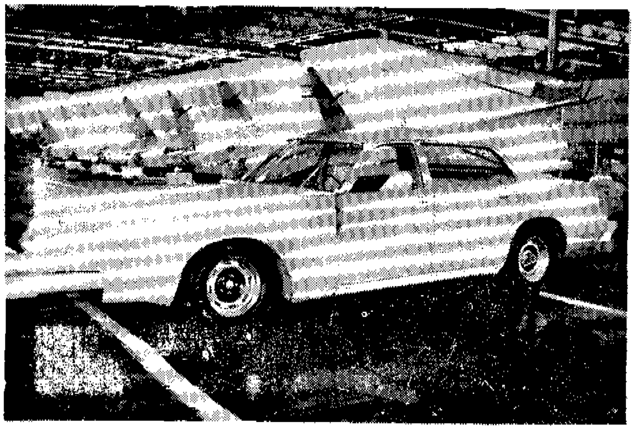
In terms of fire protection, we have looked at several areas. The primary area is the fuel tank, being the largest source of fire within the car. It is located in a position where we believe it is well protected from impact, being well in from the rear of the extremity of the automobile, and between the two rear wheels. The tank is made in accordance with a Department of Defense Specification required for combat helicopter fuel tanks. When these tanks are used for helicopters, utilizing this fabrication technique, they must be capable of being dropped without rupturing from 65 feet containing 800 pounds of fuel. They must also be capable of withstanding the impact of a 5 pound chisel when dropped from 15 feet. In addition the tank compartment is sealed from the front passenger compartment and from the rear trunk compartment of the car.

The other areas of fire protection which we have addressed have been the satisfaction of the Motor Vehicle Safety Standard 302. We have a check valve in the fuel system to protect any spillage of fuel in the event of overturn of the car, the fuel feed line is all metal and equipped with breakaway fittings, which seal when broken, at the chassis engine interface and an automatic battery disconnect has been provided.

Slide 43



Slide 44



Next question that might be asked is where do we stand now? This is the car, as we took it off our final assembly fixtures, just before we came over here. At this point in time it is about to be shipped for final chassis tuning tests, and it will be delivered to Secretary Volpe on December 25. Thank you.

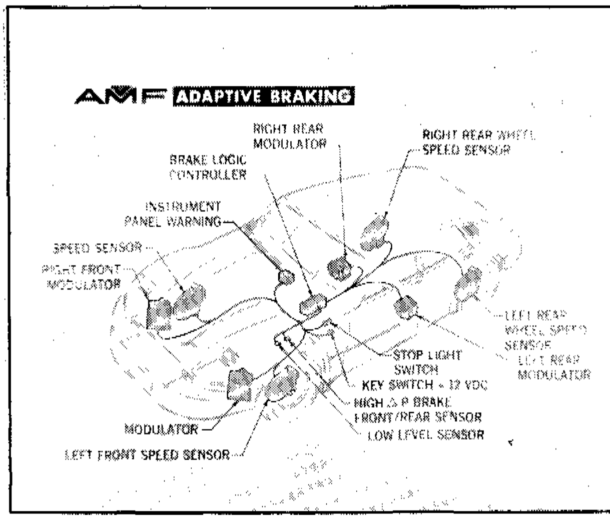
AMF INCORPORATED

Mr. Alan H. Roth
Director

Members of the conference, AMF will provide to you a brief description of the general features of the automobile in the form of a short slide and motion picture presentation. I will then conclude my part of the presentation with a status report as to the construction of our vehicle. Then I will turn the microphone over to Mr. Wingenbach who will discuss the crashworthiness features of the vehicle, and show your our most recent test results, in the various energy management and structural systems.

AMF, as you may know, is a leading producer of leisure time and industrial products. We are known for our AMF pinspotter bowling equipment, our Head skis and Tyrolian bindings, Voit basketballs, undersea equipment, Harley-Davidson motorcycles, Ben Hogan golf clubs; and also, our very special machines which form and tie the pretzels which go so well with the beer over here. The Advanced Systems Laboratory in Santa Barbara has been involved with many of the U.S. aerospace programs. While we don't build automobile vehicles, we have developed special one- or two-of-a-kind vehicles for the space program. Things such as the Saturn Missile Transporter, large rocket stage transporters, and many of the mechanisms and systems in the Crawler for the Apollo program. We've been a contractor to DOT for the past four and a half years.

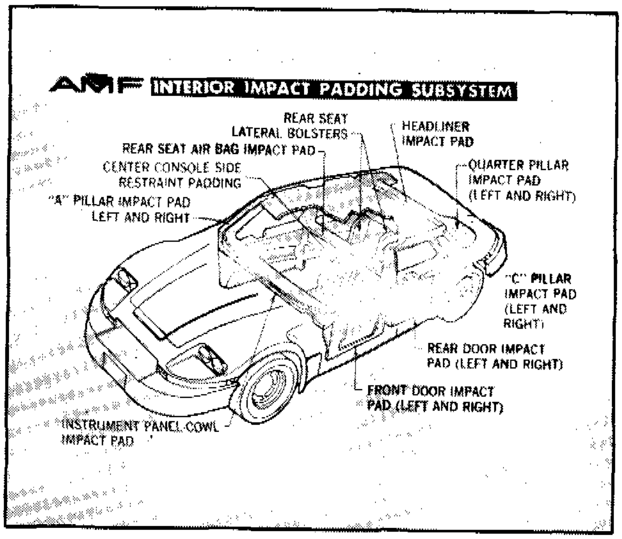
Slide 1



The first slide shows the vehicle's adaptive braking system. Bendix Research Labs is supporting AMF in this area and providing the adaptive braking system. This particular slide shows the location of the modulators and speed sensors for the adaptive system. A sensor on each wheel sends a signal to an electrical control unit in the trunk which controls the actuation of three modulators, one each for the front wheels and one for the two back wheels together. The control unit causes the modulators to release the brake pressure to the wheel that is about to lock up. In the adaptive brake system, hydraulic pressure is controlled so that the wheels never do lock up; and therefore, steering control is never lost during braking actions. The system is inactive under 10 miles per hour.

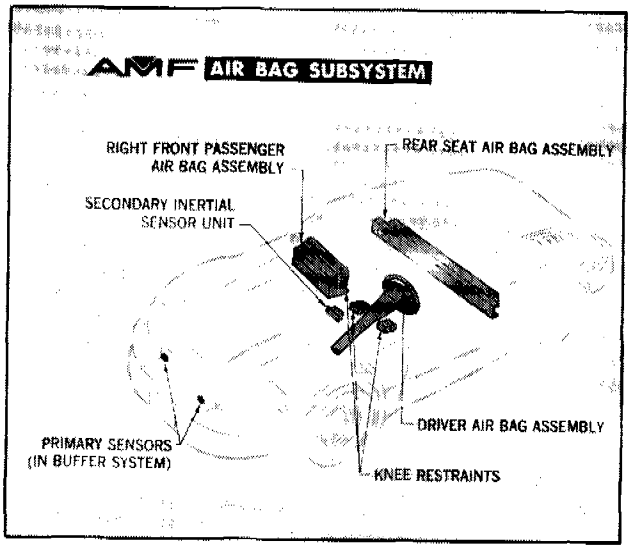
The interior impact padding subsystems are shown on the next slide. The padding itself is made of a polyure-

Slide 2



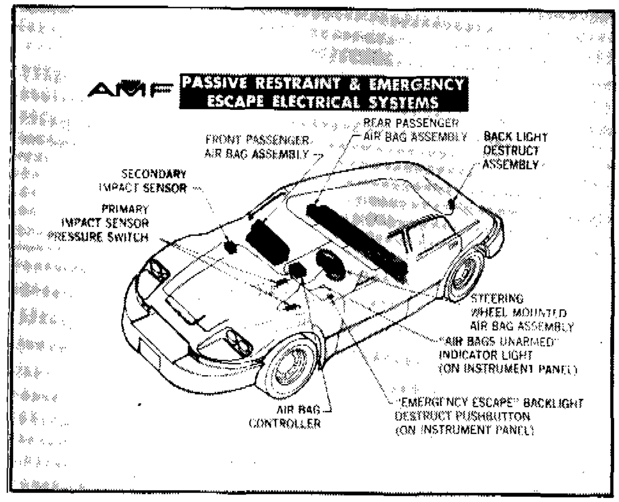
thane foam, which is sculpted and glued in place in the passenger compartment. The interior is fire-retardant and fire-resistant. The foam padding protects the unrestrained occupant in collisions up to 20 mph.

Slide 3



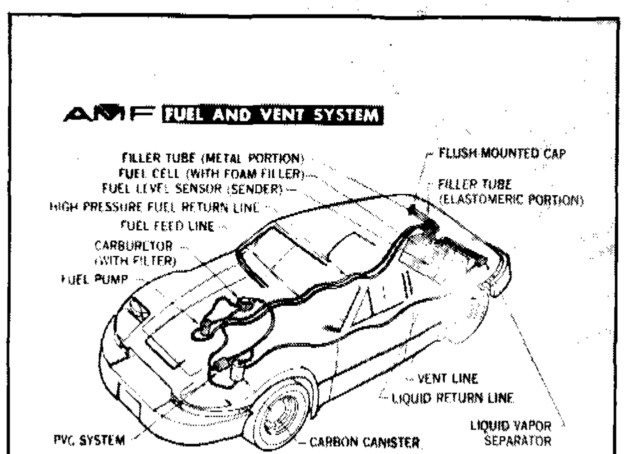
The next slide shows the location of the airbag subsystems. The rear airbag compartment contains the three individual airbags for the rear passengers, and is located approximately chest-high in the rear of the front seat. There are two separate systems in the front: a right front occupant and a steering wheel system. The airbags are being provided by the Eaton Corporation Safety Systems Division in Troy, Michigan. The airbag systems are actuated using squibs and a high-energy cooled gas generator system.

Slide 4



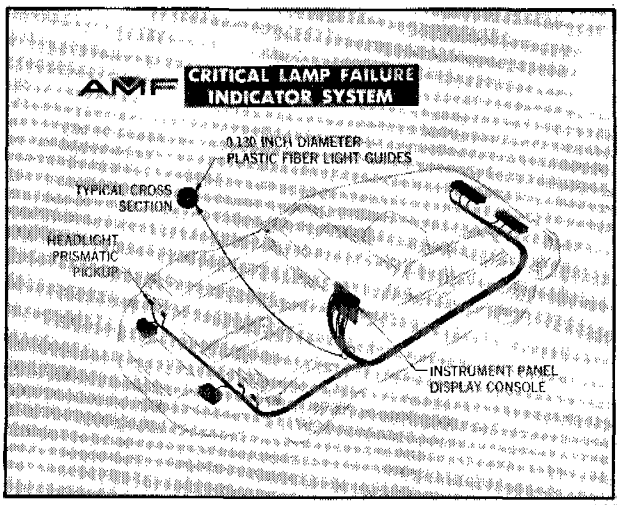
The next slide shows the passive restraint electrical system; showing the location of the pressure sensors for the airbag systems, located in the front energy management system buffers, and the location of the back-up inertial sensor, which is called the secondary impact sensor. Only 4 milliseconds are required for response time by the pressure transducers mounted in the front buffers. Total actuation time is 30 milliseconds.

Slide 5



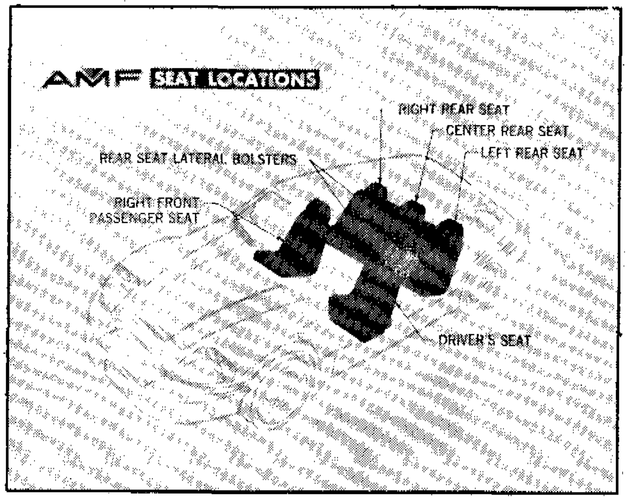
The fuel system depicted on the next slide utilizes a flame-proof fuel tank or fuel cell which is provided by Don Allen. G-sensitive electrical system disconnects add to the fire preventative characteristics of the vehicle. For impacts above 14 g's, the electrical system is disconnected from the battery and grounded.

Slide 6



The lighting systems include flashing turn indicator lights, both front and side markers. In the rear, there are three individual lamps on each side mounted at bumper height; stop lights, rear taillights and turn lamps and the backup lamps. Glazing for the front windshield is laminated safety glass as it is in the rear doors. Front doors utilize tempered glass. The rear backlight is tempered glass which shatters when the airbag actuates, to relieve pressure in the passenger compartment.

Slide 7



The next slide shows the passenger seats, two in front, three in rear. There is a console, separating the front passenger from the driver for restraint purposes. The seat structure is made of special high-strength steel frames with foam padding over rubber strip supports. The seats can withstand over 40 g's.

The bumpers provide the "no vehicle damage" protection for low-speed collisions at 10 mph or under. The front bumper will stroke 9 inches at 10 mph and slowly return to its normal position after impact. The normal bumper stroke is 30 inches in the front and 15 inches in the rear. The system is a velocity-sensitive one utilizing a variable orifice principle. The hydraulic cylinders are 4 inches in diameter and are made of high-strength alloy steel. The bumpers themselves weigh about 100 pounds each and are made from high-strength aluminum alloy forgings. There is a torsional linkage from the bumper to the cylinders to allow for oblique impacts and the differential stroking which results. The system has a hydraulic crossover feature which allows for both cylinders to share the load. Bumper wing tips. fastened by splines are made to yield or deform under certain loads, thereby absorbing some of the load.

In the following film, the exterior styling model shows the original concept of the vehicle. It has a wheel base of 121 inches and overall length of 220 inches. In the final version, the front and rear bumpers are less massive, and all exterior panels are made out of fiberglass. The interior buck shown here was a design tool used to try out and to improve the interior seating arrangements; also the placing of the critical items, such as the tilt and telescope steering wheel; the driver's seat, the airbags and a rearview periscope system. The driver's name is Lynne, if anyone is interested, and she lives in Santa Barbara. This interior buck was also used for other studies of visibility for the driver, and for the location of the instrument dials and driver controls; the placement of the padding and other protection for the occupants. An extensive program was conducted by AMF to develop the required riding, handling and braking characteristics. A special vehicle was constructed having the same front end shape as the prototype, with provisions for changing weights and moments to simulate various loading conditions. The ESV suspension system selected was a torsion bar front and leaf-spring semi-floating axle rear. Aluminum wheels and J60-15 tires of advanced design were selected. During a five-month program, we tested various types of tires. We recorded and analyzed vehicle performance under steady state transient yaw conditions; demonstrated immunity to overturning; and made preliminary measures of braking performance. The slalom type of overturning immunity tests are very impressive, both as a spectator and as a driver. All the requirements tested for were either met or exceeded. For example, the pylon course was run at velocities well in excess of the 45 mph specified, 50-55 mph in several instances. The instrumentation which you are looking at, used in measuring the handling performance, was developed, installed, and operated by AMF personnel. An additional structure of the inside of the passenger compartment was built for use in dynamic testing of the interior protective systems. This testing simulated three types of car impacts: frontal, lateral, and rear. It was done by Cornell Aeronautical Laboratory on a dynamic sled. Dummies of various sizes, covering the range of the 5th percentile female to the 95th percentile male were placed in various seating positions for the tests. The series you are seeing here was related to the requirement for providing protection for the unrestrained occupants, that is, without seatbelts, without harnesses, no airbags or other devices. The design goal was to limit occupant decelerations to 60 g's for frontal vehicle velocity and 20 g's for the same lateral velocity change. To accomplish this, we used polyurethane foam extensively on exterior surfaces, from 2-3 inches thick on the pillars, and 3-4 inches thick on the doors and other areas.

This is our full-scale mock-up, and is what our vehicle will look like when we deliver it to DOT. The vehicle is all fiberglass, the doors include aluminum honeycomb for impact protection and intrusion resistance. The doors include triple hinge, triple pin and clevis door hardware. The vehicle frame is made of T-1 high-strength steel which totally encloses the passenger compartment in a space frame configuration. The periscope system provides a wider and clearer field of view to the driver.

Photographs

This set of photographs was taken in Detroit, at the Pioneer Engineering & Manufacturing Company, where two prototypes are being assembled. The fiberglass skins have been assembled, the engine and drive line was in, the wheels were being put on, the doors had been installed and were check fitted, and the front windows roll up and down. The bumper system was in the process of being installed. This was fabricated in Santa Barbara, and is the second-generation bumper system, which is made out of aluminum, and as such, has reduced 300 pounds from the vehicle weight. Fiberglass was used, not

Figure 1

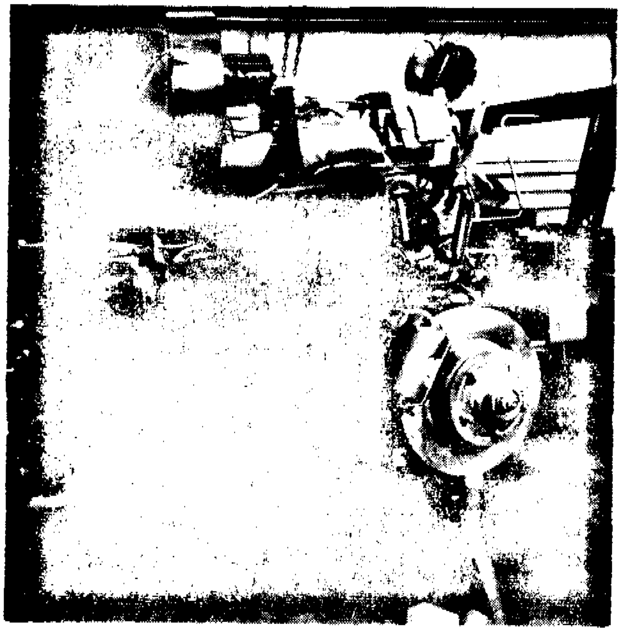


Figure 2

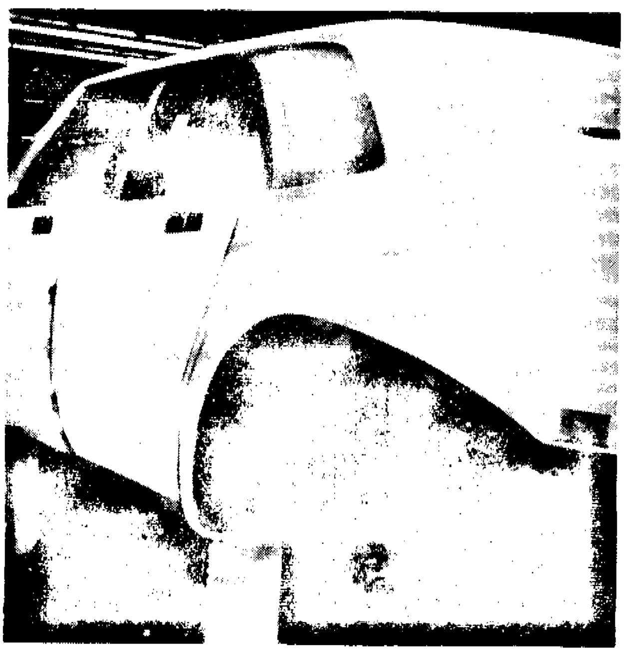


Figure 3

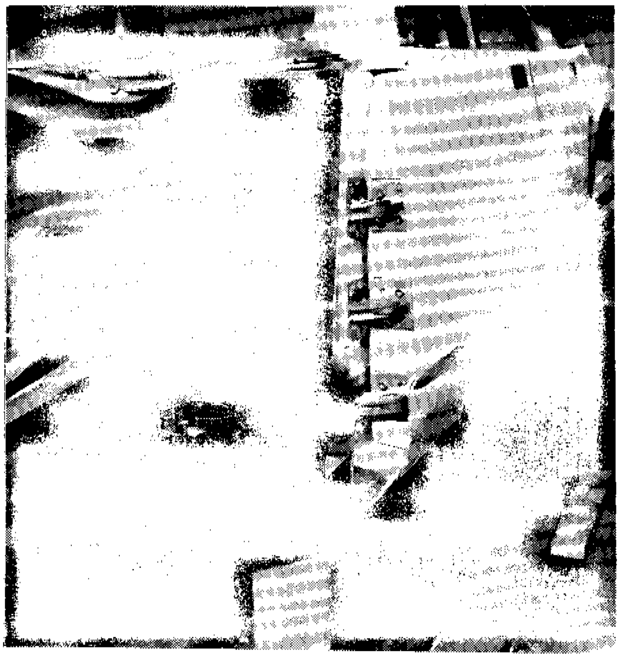


Figure 4

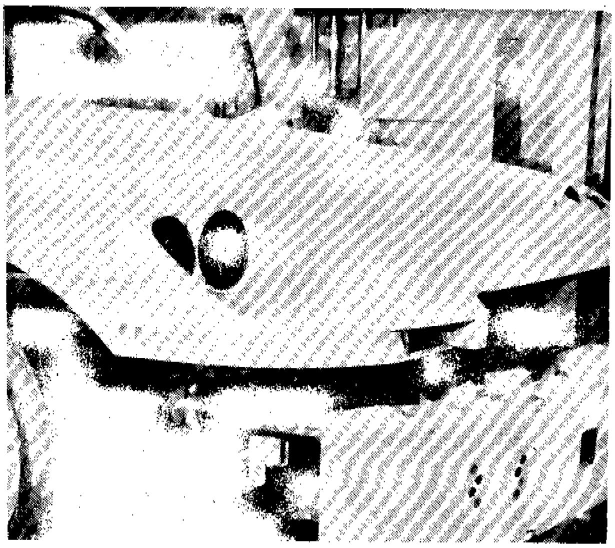


Figure 5

for weight saving advantage, but as an expedient, and also for minimization of cost in design and fabrication.

The vehicle is powered by a standard 350 cubic inch Chevrolet engine which will meet the emission requirements for 1973. The transmission is the Chevrolet Turbo Hydromatic type. We eliminated all our interferences in the engine compartment through the use of a front-end configuration buck, and wooden mock-up, which provided confidence for us that when we put all the pieces together, they would all fit. We expect that the vehicle

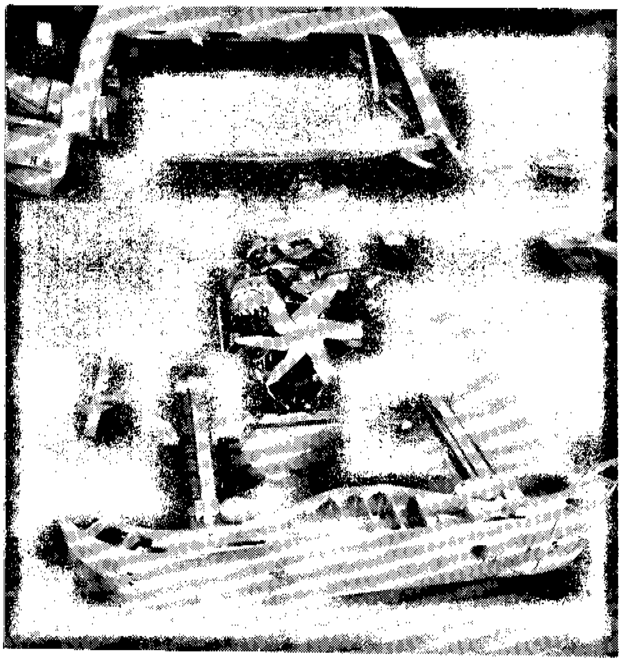


Figure 6

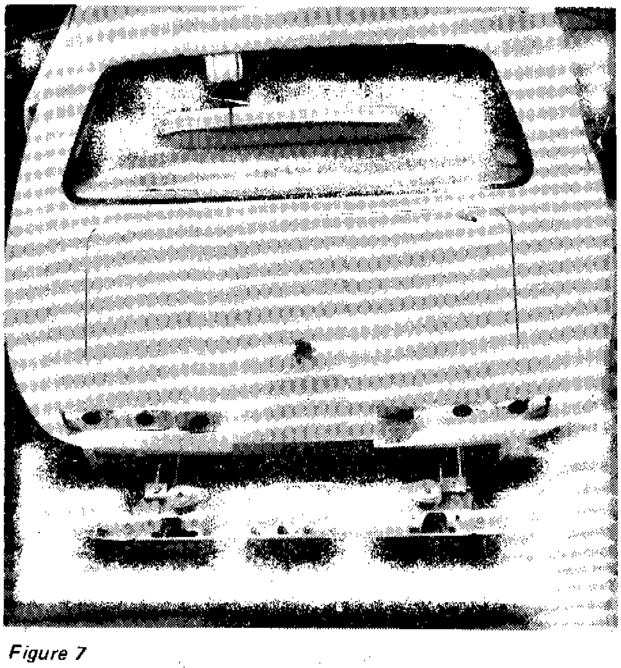


Figure 7

will be delivered to Bendix for some final shake down testing in the ride handling area in December.

Now, I would like to turn the floor over to Mr. Bill Wingenbach, who will go into detail on the crashworthiness systems, and also show you the results of our development tests in those areas.

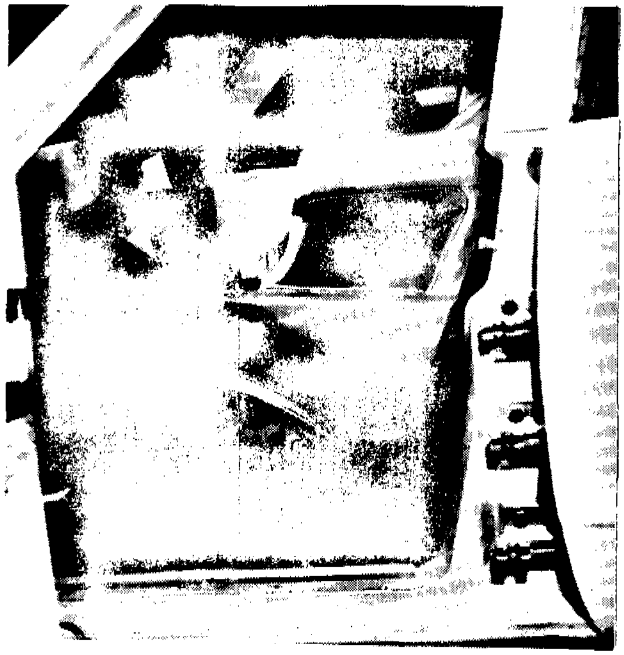


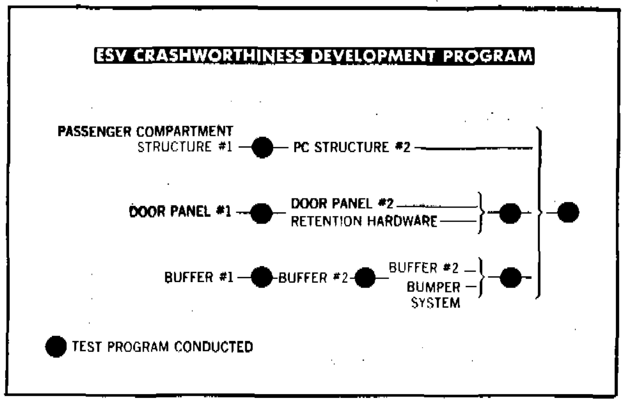
Figure 8

Figure 9

Mr. William J. Wingenbach

Ladies and gentlemen. First, I think I would like to define crashworthiness. My definition of crashworthiness is the ability of a vehicle to sustain the defined impact conditions while maintaining the survivable occupant's space. Survivability means control of both intrusion and acceleration.

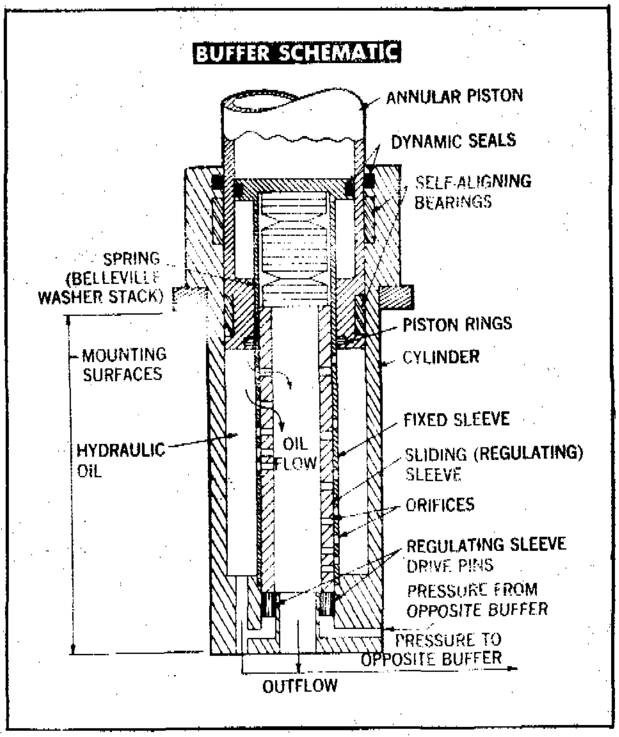
Slide 1



My first slide defines the logic which was used in the crashworthiness development program. We began by defining three principal components of the structural system. These were: the passenger compartment structure, that part of the structure which forms a space around the occupants; the door panel, which is a key element in absorbing the side impact energy; and the hydraulic buffers, which are the key elements in absorbing front and rear impact energy. We performed two complete engineering cycles on these three components. The engineering cycle consisted of synthesis, analysis, design, fabrication, test, and evaluation. During the second cycle for each component, we added auxiliary components to aid in their development and to expand the system so that its behavior would be similar to the behavior of the prototype ESV. I will go through and discuss these components, the problems and solutions. I might point out that we did prepare papers on both the intrusion resistant side structure and the front and rear energy management systems, and they will be available to you. I am assuming that you understand the requirements on all of these systems by this time, and I will not refer to them. If you do not know what the requirements are, they are given in the papers.

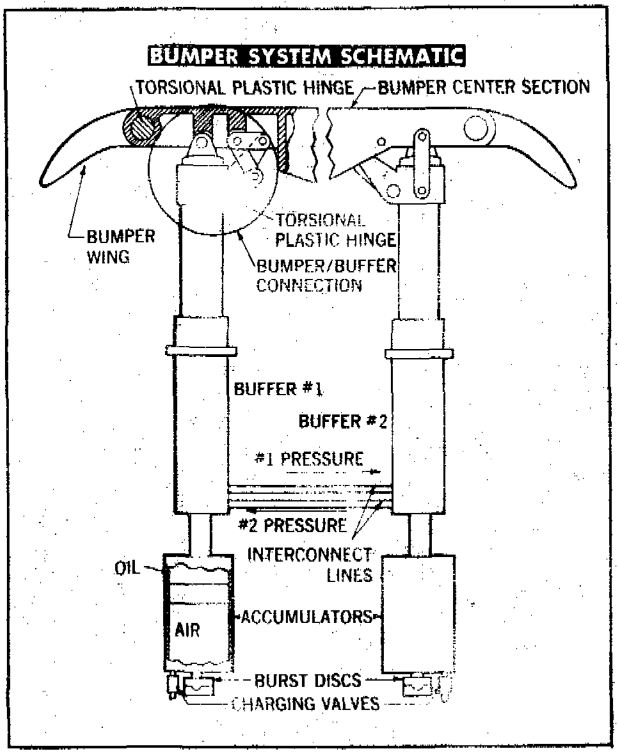
This slide is a schematic of the hydraulic buffing unit that we use. It is a complete hydraulic energy absorbing system. By that I mean, we absorb all of the energy front and rear with the hydraulic buffing units. There is a pair of hydraulic buffing units front and rear. The complete energy management systems front and rear are similar with the exception of the stroke of the buffing units. The front buffing unit strokes 30 inches, and the rear 14 inches, which reflects the difference in energy

Slide 2



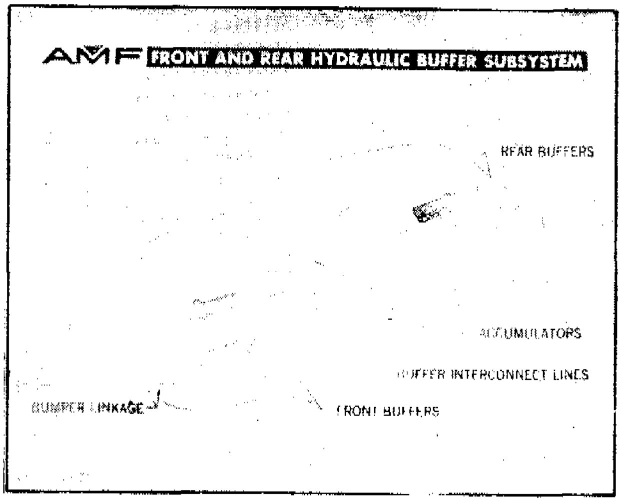
absorbing requirements on these two systems. The principal parts of the hydraulic buffer are the piston, the cylinder, a fixed sleeve, and a regulating sleeve. During impact, the piston strokes downward, forcing oil out of this chamber and through the orifice holes and on out the system. You can see as the piston strokes downward, it progressively covers up these holes, so that the orifice area decreases with stroke. The sizing and spacing of the holes are such as to give something close to a rectangular deceleration pulse. To this point, we have a more or less conventional variable orifice buffing unit which produces a force and consequently an acceleration which is constant with stroke, and a length of stroke which is a fixed dimension. The force varies to the square of impact velocity. This system will not, of course, meet ESV requirements, but it is the basic starting point. Beyond that, we have the regulating sleeve. Oil pressure from the chamber behind the piston is forced down through this passage, in behind the regulating sleeve, and through a series of pins which are around the circumference of the regulating sleeve, driving it upward a distance which is dependent on the hydraulic pressure, and which is also dependent upon impact velocity. The regulating sleeve at certain positions uncovers a new set of orifices and at the same time, covers up this set of orifices so that we now have again a variable orifice system, but of a different pattern. There are, in fact, three separate and distinct patterns in the front, and two in the rear at which the regulating sleeve may line up. The effect is to convert from the constant stroke velocity squared system to a system which is linear both in force and stroke with impact velocity. This is a system which does meet the specified ESV requirements. I might point out a design detail of the pins which actuate by the pressure within this buffer and the other half are regulated by pressure in the opposing buffer.

Slide 3



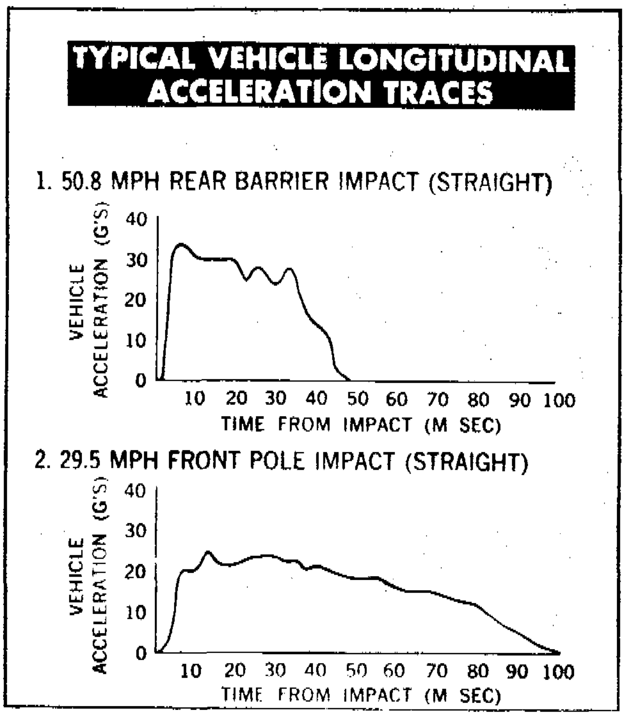
This slide is a schematic of the entire buffer system consisting of the bumper, the various connections, the pair of buffing units, and the hydraulic connections. The effect of various kinds of impact is a varying behavior of this system. I'll discuss the most critical, which is the case of the pole impact directly over one of the buffing units. One way to solve the problem is to make completely rigid joints, between the bumper and the buffing units. This would make the system independent of the point of application of the impact, but would result in very high moments at these joints. These very high moments would result in an extremely heavy bumper and piston, both of which are moving parts which would give the system very high inertia. The problem is essentially unsolvable with the rigid joint. An alternative is to make a loose or pin joint. This would allow the system to have differential motion between the pistons, but the misalignment between the pistons would be quite severe, and would introduce high transverse loads between the pistons due to differential stroking of the buffing units. They would bind up and not work reliably, so the problem is essentially unsolvable by a completely free joint at the connection of the bumpers and the pistons. Our solution is to use a controlled moment between the piston and bumpers. That is, a system that has a constant moment at the joint as one piston strokes with respect to the other, so we do allow a differential stroking, but in a very controlled manner. Part of the control is exerted at this point. This is a torsion link which, as the buffing units stroke relative to each other, applies a constant moment to both the pistons and the bumper. Another control of moment is at this point. If the point of impact of the barrier or of the pole with the bumper is outboard of the piston, it will contact the wing. If the moment is too high, this particular link yields, allowing the point of impact to move back inward until it is at a level which the system can sustain. There are a number of problems which develop by using a system such as this. One is the control of moment; another is the control of the side forces which develop between the two pistons as a result of the change in length of the bumper with respect to the fixed transverse distance between the two. We solve these problems with an additional linkage which is not shown in this slide, but it is shown clearly in the paper. This linkage allows the hypotenuse of the bumper to grow with stroke resulting in a fixed transverse distance between the two points of attachment, and eliminates any transverse force which might develop through differential stroking. One of the more difficult problems is control of the longitudinal force developed by the buffers under various impact conditions. We can see that if impact is at the center of the bumper, both pistons stroke at the same velocity and both have the same force. This will produce a given acceleration of the vehicle. If, however, the impact point is directly over one buffer, it will have essentially the same velocity as before, but now it would be desirable to produce twice the force as before in order to maintain the same acceleration and energy absorption. We accomplish that goal through these lines which are oil passages, interconnecting the two buffers. The signal going to the regulating sleeve is an average force or pressure between the two buffing units. In other words, if a point of impact is directly at a buffer, it will generate twice the buffing force that it would if the point of impact was at the center of the system. The piston which is opposite the point of impact will essentially generate no force under such an impact condition. The total system using this arrangement has approximately the same energy absorbing capacity independent of the point of application of the impact.

Slide 4



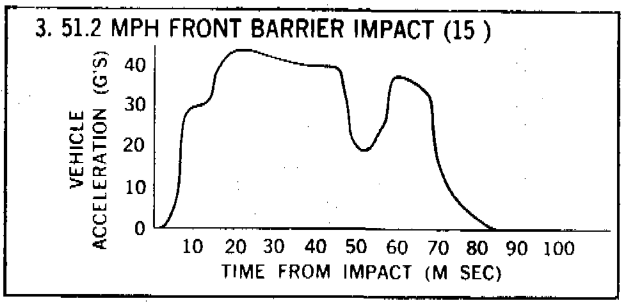
This slide shows the complete front and rear energy absorbing systems installed in the vehicle. These are the accumulators, which keep a preload on the buffing units during their no-use condition and restore them back to their original position after the impact. The rear system has only one accumulator, but both have the feature of return to normal position after impact.

Slide 5



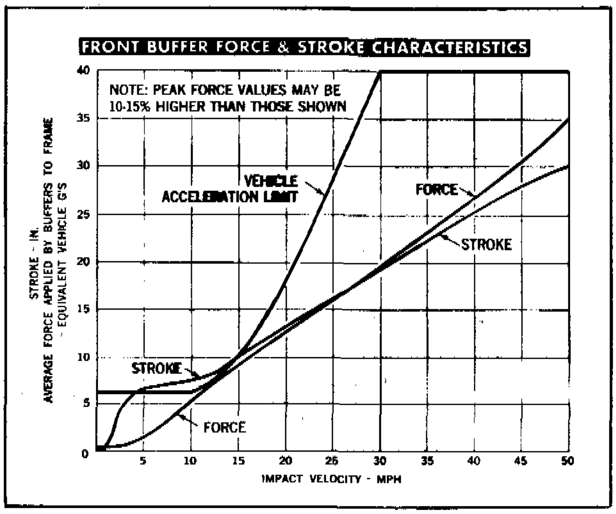
This slide shows typical performance of the unit during test. These are observed acceleration forces as a function of time during test at varying velocities. These are development tests, and do not show performance of

Slide 5 Continued



the final delivered system. We expect prototype performance to be better, although these results are generally considered to be acceptable. They are close to rectangular pulses, and are within the specifications in all cases, except this particular one: There was a component failure, and we got a peak acceleration of slightly in excess of 40 g's. This was at the most adverse impact condition. In fact, it was at a velocity of 52 mph rather than 50, and at the 15° oblique type condition. But behavior was still generally acceptable.

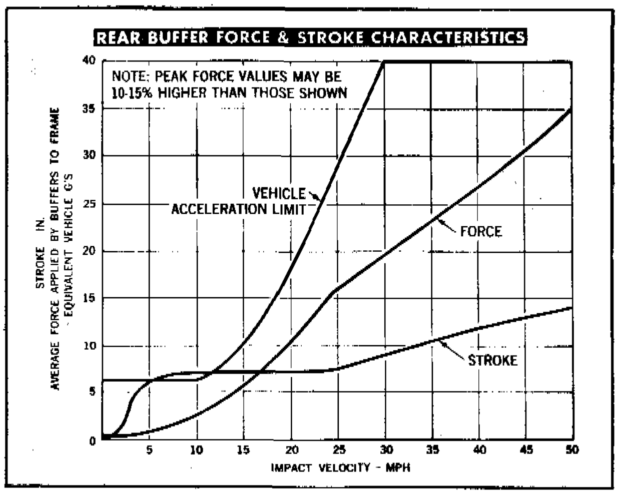
Slide 6



These graphs show behavior of the front and rear systems in terms of acceleration as a function of impact velocity. You can observe that both systems are well below the requirements for a straight-on impact. This is to assure ourselves that we stay below the specified acceleration under all oblique loading conditions.

These two curves show the stroke of the buffing unit as a function of impact velocity. I might point out that in our design, a stroke of 9 inches front or rear is permitted without damage. You can see from this that we would be able to sustain an impact in the front system of approximately 15 mph without incurring damage; and in the rear system, we could sustain an impact of 25 mph without sustaining damage.

Slide 7

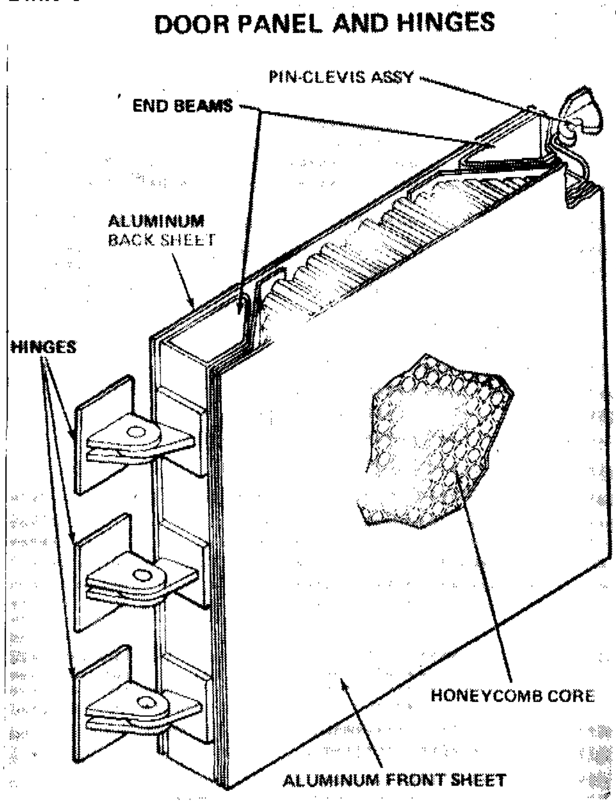


I would now like to show you films of some of these developmental tests in front and rear bumper systems.

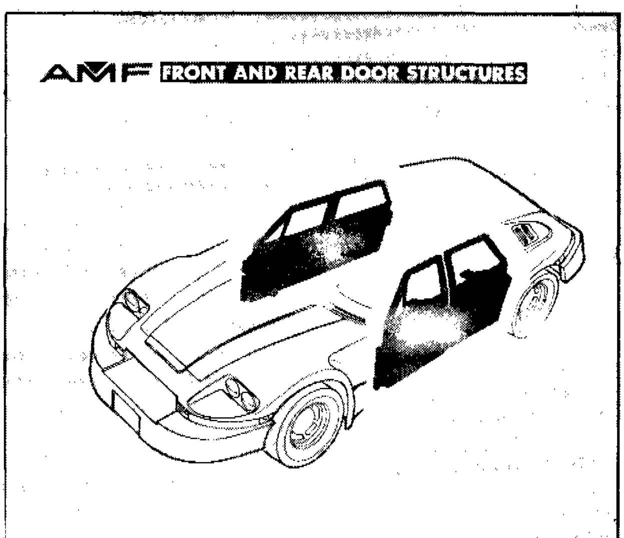
The first test is a rear system impacting at 50 mph. The next test is at 20 mph and 45°. See the wings and some of the connections that we used in the development system. You can see the differential stroking of the buffing units. There are a few minor component failures that you may observe as we go along here, but these will not reoccur in prototype testing. This is a 30 mph, 45° test, which is the most severe impact condition for the rear system. Here is a 30 mph pole impact of the front system. You can see the longer stroke of this system. The front system has a maximum of 30 inch stroke versus a maximum of 14 inches for the rear system. The bumpers that are shown here are heavy weight systems that were used during the development testing program and are not the prototype bumpers. We have not yet tested the prototype bumper systems. This shows a 40 mph, 15° impact on the front system. Notice the differential stroking. This is the linkage which allows the differential stroking without binding the pistons. Next is the most critical design condition for the front buffing unit, the 50 mph, 15° condition. This is both front and rear systems impacting at 75 mph.

Now I will discuss the next component, the door panel. This panel is fabricated of aluminum honeycomb, with aluminum front and rear sheets, aluminum vertical beams, fore and aft, and high-strength steel hinges and pin clevis assemblies. The operating principle of this system is that the panel acts like a beam under initial contact. It behaves elastically for a while, and then starts to go into plastic beam action; following a period of plastic beam action, the honeycomb starts to crush, allowing stroke of the outside sheet without further stretching of the rear sheet. Finally, the honeycomb is completely crushed, and both the outer and inner sheets stretch as a membrane. In order to make this happen, both the hinges and pin clevis assemblies have to hold their position longitudinally, that is, they cannot stroke inward towards the panel as it is being deflected transversely. The energy absorption occurs both in crush of the honeycomb, and principally, in stretching of the face sheets.

Slide 8

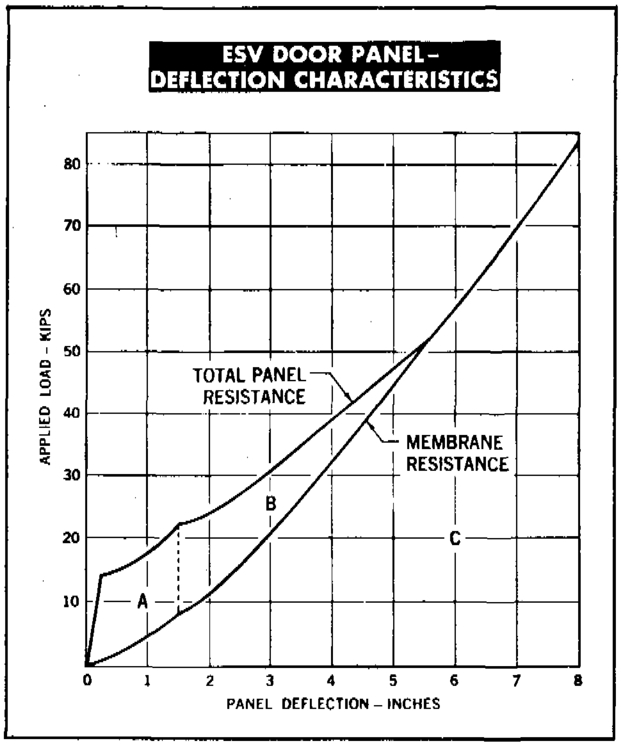


Slide 9



This slide shows the complete door configuration as it is installed in the vehicle. The front and rear doors are similar in principle, although slightly different shape. The front door also has a movable window, while the rear door system has a fixed one. The system uses a conventional latch to resist load from the inside out. It is an American Motors type of latch.

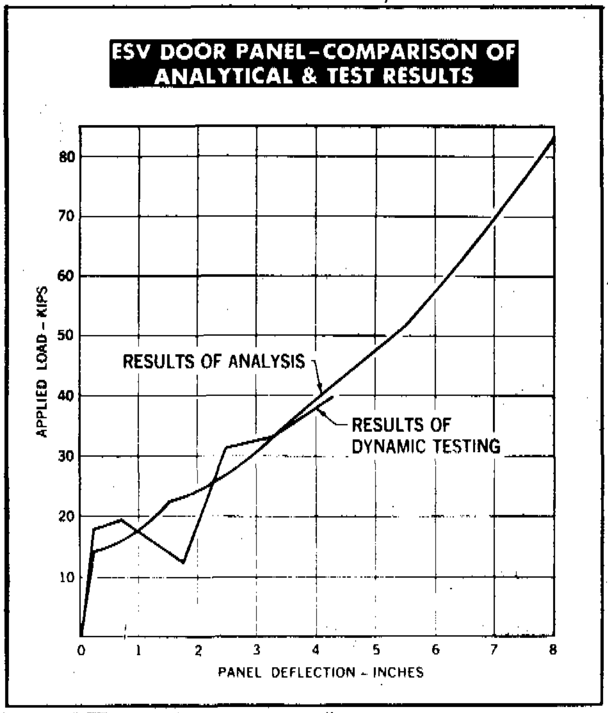
Slide 10



This slide shows the analytically predicted behavior of the door panel. The top curve shows the complete load deflection characteristic of the panel, while the lower curve shows only the membrane action of the front and rear sheets. The region of the area under that curve marked "A" indicates the amount of energy which is absorbed by beam action of the panel. The region marked "B" represents the energy absorption of the honeycomb during crush, while the region marked "C" represents the energy absorbed by membrane stretching of front and rear sheets.

This slide shows the comparison of analytical and experimental behavior of the door panel. The experimental behavior is superimposed over the analytical data. Test loading was not as high as we had hoped since we experienced a failure of a weld in the hinge at this point. We considered this to be a manufacturing defi-

Slide 11



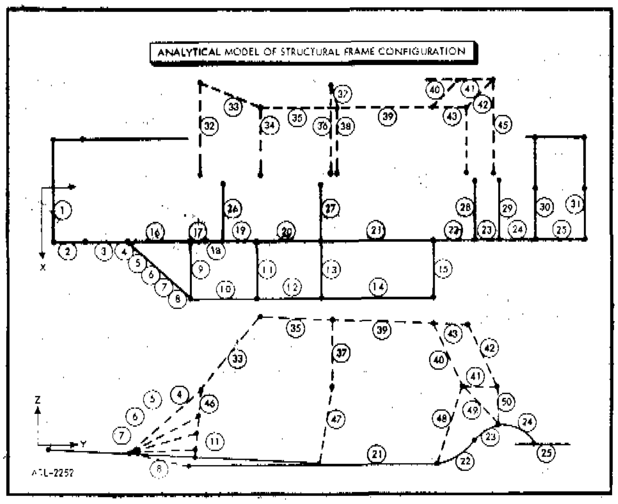
ciency which would not be repeated; and therefore, we considered this behavior as essentially satisfactory. We then installed a similar panel on a structural vehicle and subjected it to a dynamic test.

I would now like to show you a film of this test. This is a dynamic test, although it is not at 15 mph. During the stroke, you can observe the different behavioral modes as they progress. We did not get complete crushing of the core due to the hinge releasing the panel prematurely, but crushing was at about the stage it was supposed to be for the applied load.

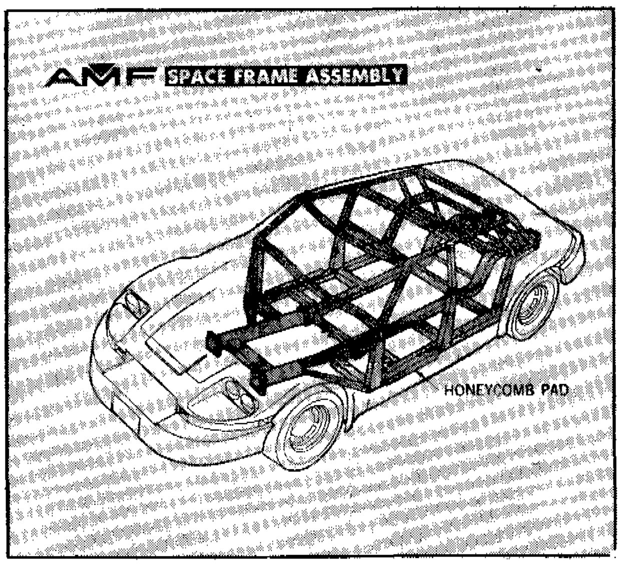
The next component that I would like to discuss is the passenger compartment structural frame. The frame serves as a mount for the front and rear energy systems and the side structures as well as providing occupant protection during rollover. It consists of main frame elements which run the length of the vehicle, perimeter frame elements which are most active during side impacts, substantial A, B, and C posts, and A, B, and C pillars, roof rails and cross members, frame cross members and some longitudinal load-carrying members which pick up the load from the hinges and transmit it back to the frame. I might mention something about the magnitudes of those loads. During the worst condition, which is pole impact condition at 15 mph, the total transverse load that we experience is something in excess of 100,000 lbs. The longitudinal load which is developed as a result of the membrane action is around 130,000 lbs. This is distributed to these three hinges. We need these longitudinal members to transmit some of that load back to the frame in order for the "A" post to survive.

Slide 12

This slide is a schematic of the math model of that particular frame.



Slide 13



This is a slide showing a complete structural vehicle containing both the structure which we just discussed with the honeycomb door panels installed. Material in the structure is all T-1 steel, which has about 100,000 psi yield strength. It is an all welded structure. You can see a protrusion below the front door. This is another honeycomb sandwich pad which is installed into the frame at the front door to help in the pole impact. It is intended to absorb a significant amount of energy during that particular impact condition, and is relatively much stiffer than the honeycomb core used in the door panels.

I would now like to show you a film of a test of this particular vehicle. The first test will be the 30 mph impact by an ESV front bumper system. Since there are a number of views of this test, we can get a good look at the behavior of the various structural elements. The maximum dynamic intrusion measured on this test was something slightly under 2 inches as compared to the allowable 3 inches. There is little damage to the vehicle as a consequence of this particular test. The estimated load for this impact condition is approximately 150,000 pounds between the bumper and the side structure. Behavior was a little stiff, and we softened the system since that test. This is the pole impact test into the center of the front door, at 15 mph. Again, there are a number of different camera views, so that you can get a good look at the complete structural behavior. The peak stroke of the vehicle relative to the pole was something slightly over 7 inches which resulted in an intrusion of the interior hardpoint into the passenger compartment of about 3¼ inches as compared to the allowable 4 inches of intrusion. Peak acceleration at the vehicle center of gravity was measured at 20 g. Observe the behavior of both the panel honeycomb sandwich and the frame honeycomb sandwich. Both are completely crushed, and have done the job assigned to them. Total load generated under this impact at the pole was about 105,000 pounds peak load. Final test on this structural vehicle, as we will see, is a 2-foot drop test on to the A post. Dynamic intrusion into the compartment was measured at 1¼ inches.

GENERAL MOTORS CORPORATION

Mr. William Larson
Mr. John Rosenkrands

Introduction

The Experimental Safety Vehicle that has been conceived by General Motors is shown in Figure 1. This is a totally new running car. We wish to describe its design. The goal was to operate within the restraints of contract specifications to provide a vehicle with a familiar configuration, that is aesthetically appropriate to the seventies and with the road feel of a medium size American car. Practicability and feasibility were not our concern.

The challenge was dummy survival, in terms of our contract, under the extreme conditions of a 50 mph barrier impact test. Here we are dealing with nearly a half million pound-feet of energy and it is difficult to conceive of survival under such conditions. However, in terms of our contract with the U.S. Department of Transportation, this is what we are progressing toward – as shown in one of the first 50 mph barrier tests of the ESV built by General Motors (Figure 2). This is equivalent to a 100 mph impact into another car. Of course, survival of dummies may be an entirely different matter than human survival – and we don't have too many volunteers to check this out.

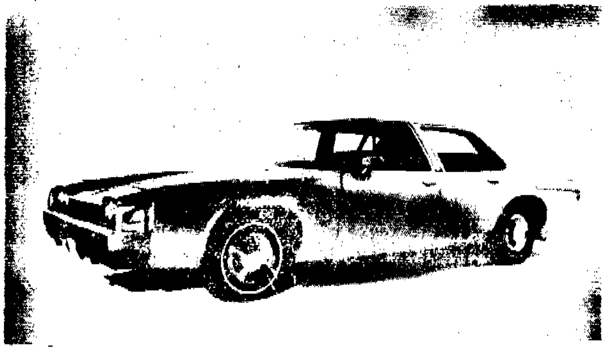


Figure 1

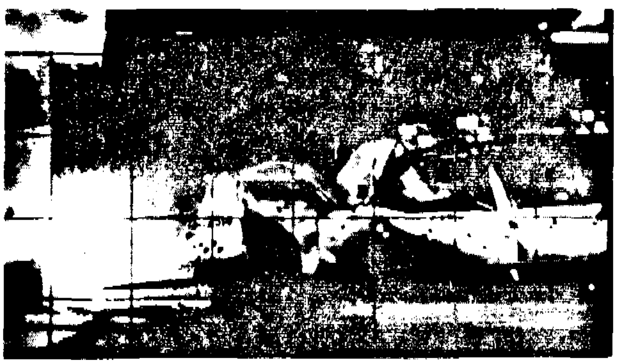


Figure 2

As we go through the design, there are a few factors that need to be remembered – factors that frankly temper the quality of our success. First, this ESV has been designed for the very specific crash test situations of our contract. We don't know the relationship of test performance to actual crashes in traffic. Second, our car has been tested by and built for a particular breed of anthropomorphic test devices which sit passively with perfect posture, calmly waiting for impact. This forces us to conclude that we are really not going to be able to determine from this particular program whether or not ESV specifications answer the question of human survival in real world accident situations.

Before getting into details of the design, we wish to outline the nature of our presentation. We will describe our approach to this assignment, introduce you to the overall configuration and provide some of our observations of the program based on our initial test results and progress (Figure 3).

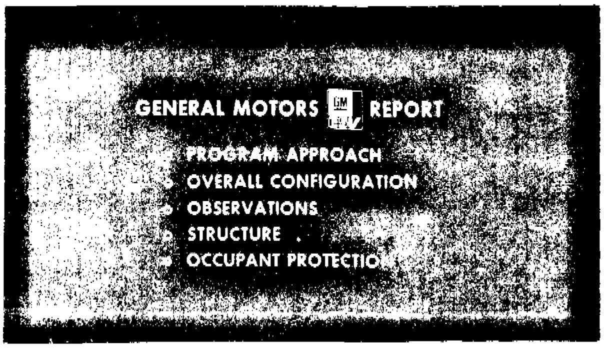


Figure 3

Within General Motors, the coordination of forward safety and emission control programs is the responsibility of the Environmental Activities Staff. For this reason, our Experimental Safety Vehicle Group is part of this larger activity (Figure 4).

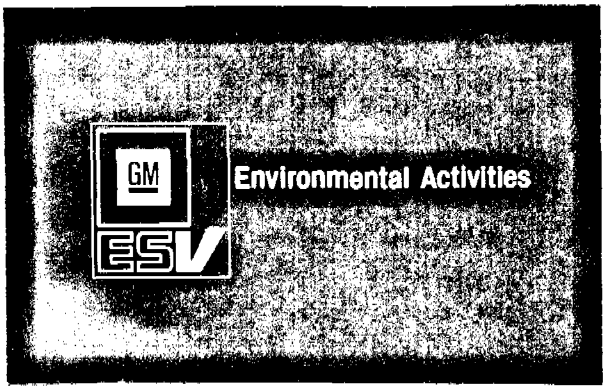


Figure 4

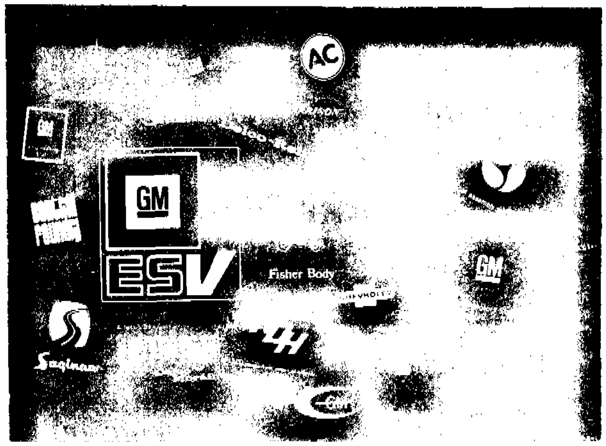


Figure 5

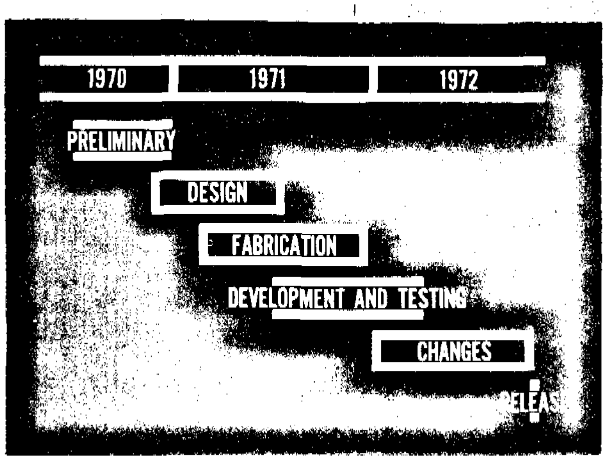


Figure 6

As one of the three original ESV contractors, General Motors organized its ESV program in July, 1970. Personnel from twelve different divisions and staffs were assembled within a flexible organization. We have had complete responsibility for design, testing, fabrication, quality assurance and styling. However, because these functions do not all operate in parallel, manpower has been adjusted to meet the needs of the moment. At the design peak last spring, we had about 150 men in the group. Significant contributions to this program have been made by 23 General Motors units serving as subcontractors and advisers on various facets of design, development, testing and fabrication (Figure 5).

Figure 6 illustrates the overall timetable and the various phases of the program. Following the preliminary design phase and completion of styling during the first six months, personnel were added for detailed design, tooling and fabrication. We are currently in the development and test phase which is basic to the GM program and the principal difference from others. This includes the development and durability testing which we consider is required of any new model, as well as evaluation of many crashworthiness requirements, using complete vehicles. This will enable us to make any necessary design changes prior to final release of the two prototypes to our government in 1972.

Configuration

The ESV built by GM is a 5-passenger, 4-door family sedan. It has a wheelbase of 124 inches, an overall length of 219 inches, a 64-inch tread, an overall width of 79.6 inches and height of 58 inches. The maximum dimensions allowed by our contract were needed to achieve the required performance. This preprototype weighs approximately 4,700 pounds – and keeping weight at this level has been one of our most significant challenges because our contract is for a 4,000-pound car (Figure 7).

The powertrain consists of a 362 cubic inch displacement V-8 engine, a 3-speed torque converter type automatic transmission, a drive shaft with two universal joints, and a live rear axle (Figure 8).

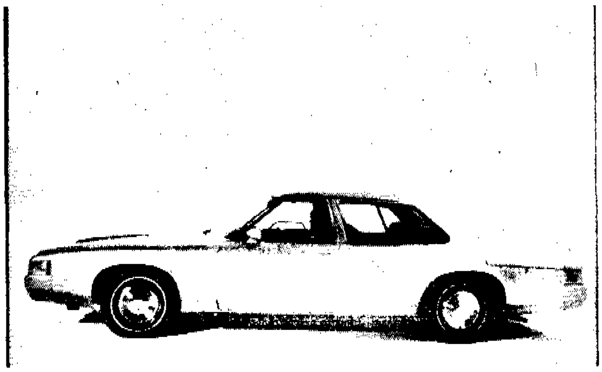


Figure 7

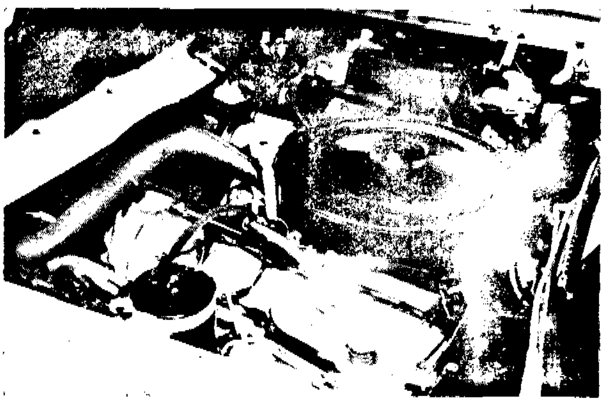


Figure 8

The engine is a modified production unit with an experimentally tooled aluminum cylinder block, heads and intake manifold. This saves about 180 pounds over conventional cast iron. With an 8.1 to 1 compression ratio, designed to run on nonleaded 91 octane fuel, the engine develops 185 net horsepower at 4000 rpm. Engine accessories are mounted on brackets designed to permit the lower profile hood required to meet the specified 8-degree down vision angle (Figure 9).

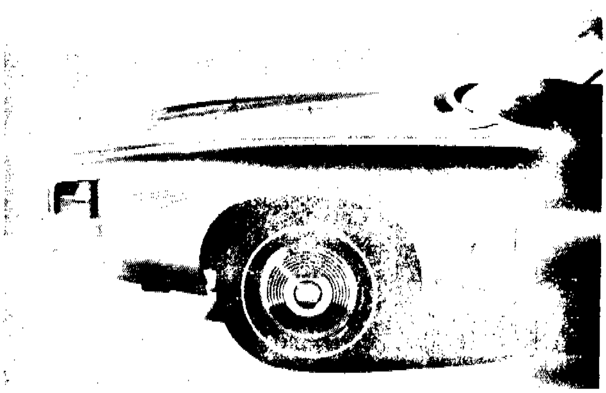


Figure 9

Emission controls are designed to meet 1973 U.S. Federal requirements for hydrocarbon, carbon monoxide and oxides of nitrogen control. They include a positive crankcase vent system and the General Motors Air Injection Reactor. A transmission controlled spark advance, an evaporation control canister and an exhaust - gas recirculation system are also used. The sealed 23-gallon fuel tank is provided with special fuel line provisions to prevent spillage in any vehicle attitude (Figure 10).

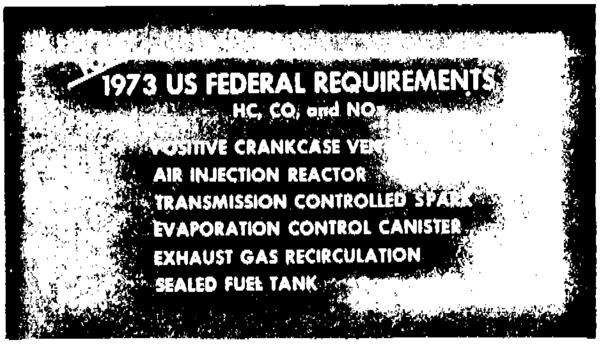


Figure 10

Both brake and steering systems feature hydraulic power assist to reduce driver effort (Figure 11). An

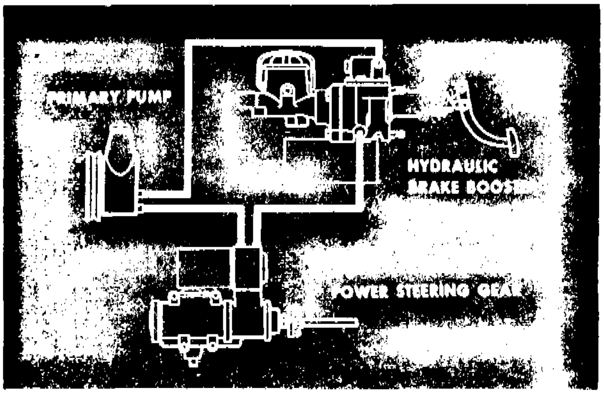


Figure 11

engine-driven pump supplies high pressure oil for this purpose. However, both the power steering gear and the brake booster have built-in back-up pumps which are electrically operated to maintain hydraulic pressure in the event of a failure in the engine-driven pump or connecting hoses (Figure 12).

The brake system employs dual piston brakes at each wheel (Figure 13). Two separate, dual master cylinders are used, one for the front and one for the rear brake circuits (Figure 14). The two pistons at each wheel are connected to different master cylinders, eliminating the effect of a single line failure (Figure 15). Should such a failure occur, original system effectiveness is retained with only a slight increase in pedal effort. Both load proportioning and wheel-lock control devices at each wheel are incorporated in the system.

Figure 12

Figure 13

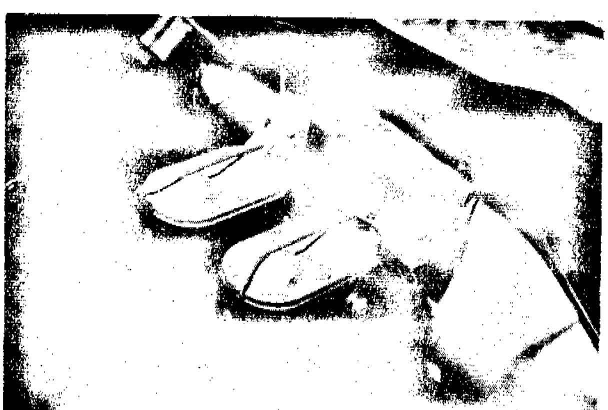


Figure 14

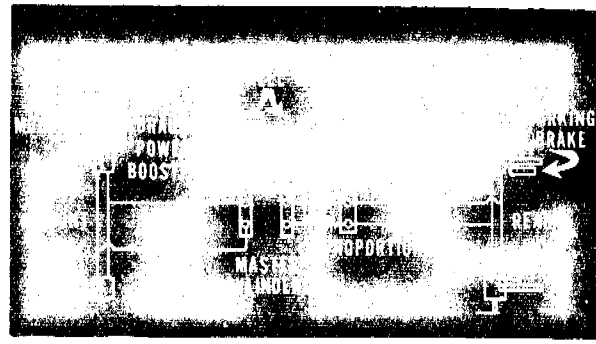


Figure 15

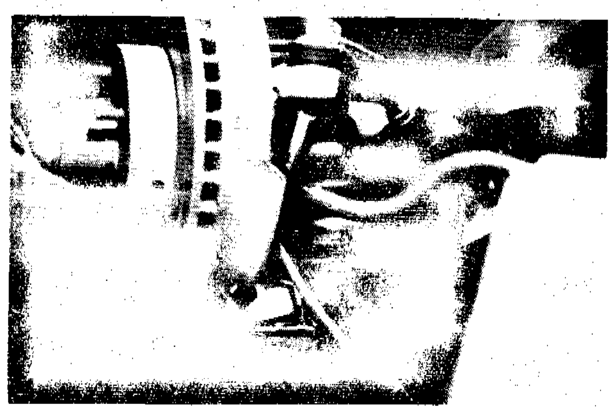


Figure 16

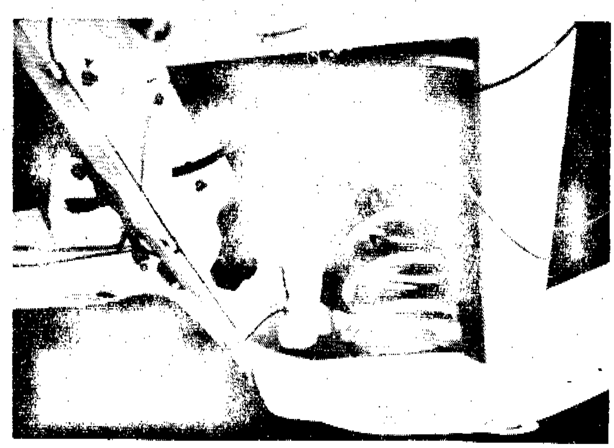


Figure 17

The front and rear suspension systems of the car are basically standard U.S. production configurations, but the geometry of each has been revised to meet the handling and steering requirements. A stabilizer is used in front (Figure 16). At the rear, coil and pneumatic springs operate in parallel (Figure 17). The pneumatic springs also serve as part of an automatic leveling system to maintain rear height. To meet other handling requirements, a variable ratio steering gear with ratios from 16.0 to 12.4 has been selected (Figure 18). The tires are specially fabricated HR70-15s (Figure 19).

Because driver eye position is such an important factor to visibility, a single pivot seat design has been

Figure 18

Figure 19

selected. This eliminates fore and aft seat adjustment. Movable pedals are, therefore, required to make up for the difference between 5th and 95th percentile drivers. The result of this arrangement is a smaller eye ellipse and appropriate vision arcs without having to resort to unfamiliar architecture in the upper portion of the vehicle body (Figure 20).

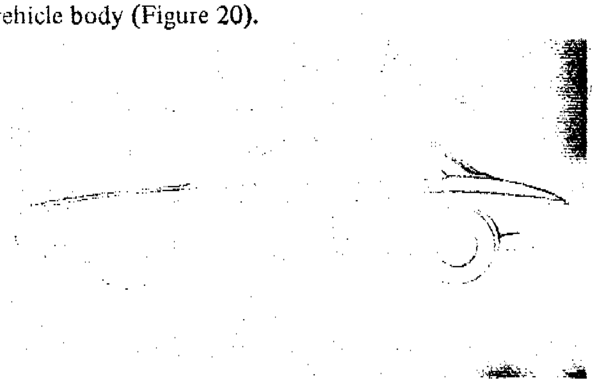


Figure 20

The car has about 10 percent more glass than a typical current production sedan. The forward portion of the roof is cantilevered from the center pillars, eliminating the need for pillars at either side of the windshield. The results are improved driver visibility and less likelihood of unrestrained occupants hitting a structural pillar (Figure 21).

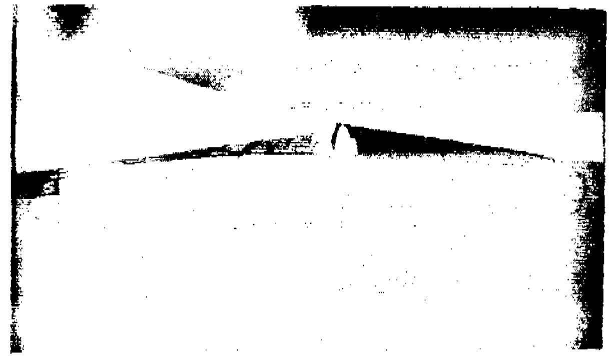


Figure 21

In the rear seat area, we have a full width, 3-passenger bench seat, except that the center section moves forward when not in use to provide a lateral restraint surface for outboard passengers (Figure 22). By simply pushing the spring-loaded center seat back to normal (Figure 23), the cushion is latched in place and seat dividers are automatically extended to provide lateral restraint for the third occupant (Figure 24). This is an extremely tight squeeze, however, for three above average size occupants.

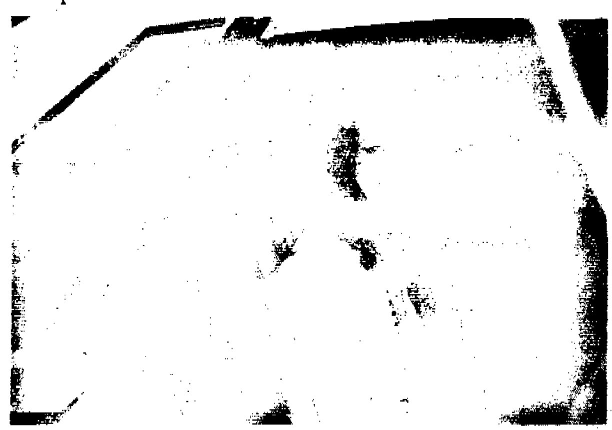


Figure 22

Four sealed beam headlamps have shock resistant mounts (Figure 25). Amber front parking and turn signal lamps are mounted below the headlamps in the bumper. Corner lamps, as well as combination turn signals and side marker lights, are mounted on the wrap-around portion of the front bumper (Figure 26).

We have a distinctive rear signal system. The tail lamp arrangement includes high level mounted auxiliary stop and turn signals. These incorporate a dual intensity feature. In daylight the brightness of the upper lamps is high so that the intended signal may be clearly seen. This

Figure 23

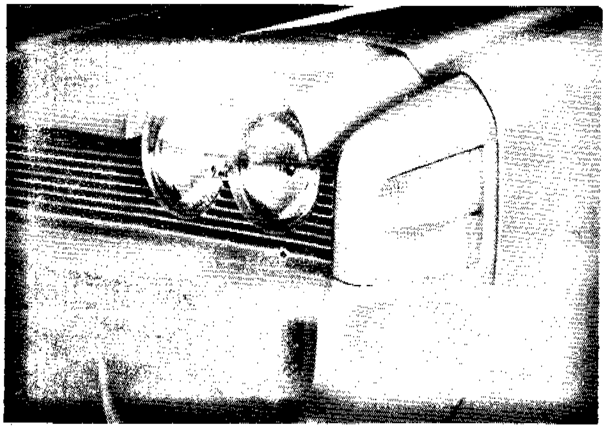


Figure 26

Figure 24

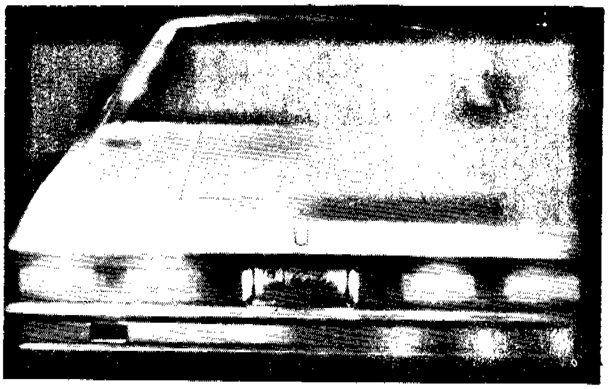


Figure 27

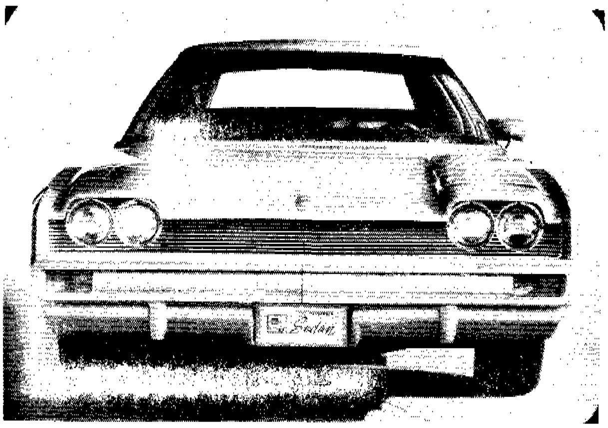


Figure 25

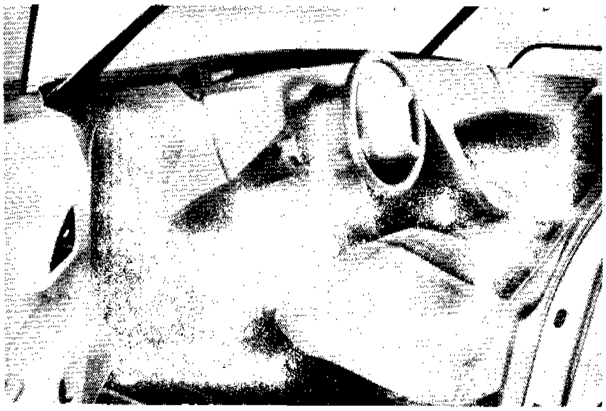


Figure 28

level is too bright for night driving and therefore the intensity is reduced whenever the headlamps are turned on. This effectively reduces glare (Figure 27).

Driver controls are in conventional locations (Figure 28). A high mounting position for the enlarged rear view mirror is provided along with a triple sun visor arrangement. This meets the specifications for rear vision as well as unobstructed upward viewing through 17 degrees (Figure 29). Instrumentation is unique. A message center concept is employed in which the driver views only critical, need-to-know information in a "primary" message center located in his forward viewing area above the steering wheel rim (Figure 30). Other more detailed information regarding vehicle conditions or malfunctions

Figure 29

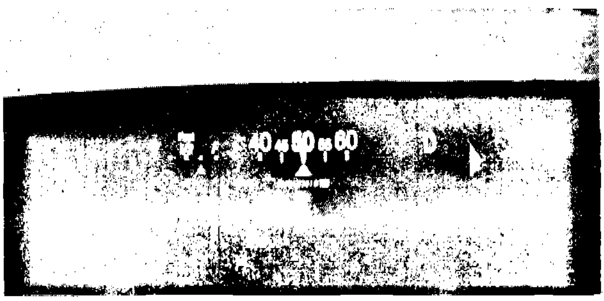


Figure 30

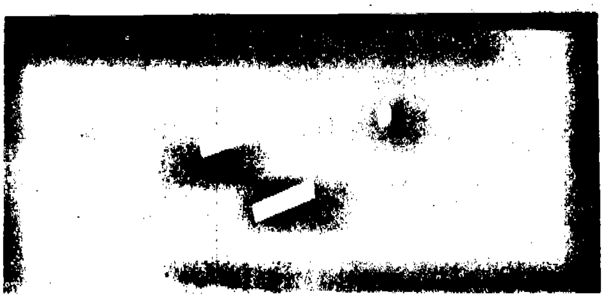


Figure 31

appears in a "secondary" cluster located in the center console where it is visible at a glance but not in his primary field of view (Figure 31).

Turning now to the important areas of crashworthiness and occupant protection, our performance requirements have been derived essentially from 17 crash conditions representing our interpretation of the ESV specifications. These may be divided into low and high speed impacts, because the performance levels measured on the anthropomorphic test devices are specified in this manner.

The 10 mph rear (Figure 32) and front tests (Figure 33) are to produce no damage to the vehicle and deceleration is not to exceed 6 g's. The 20 mph test is to be conducted without deployment of any form of

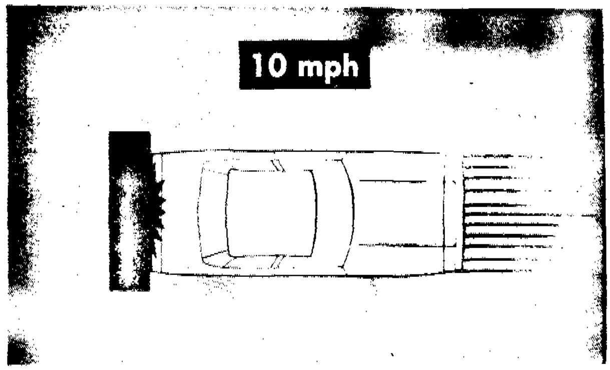


Figure 32

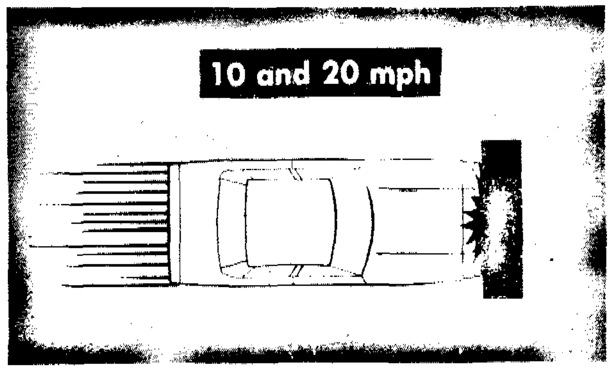


Figure 33

restraint system. In these tests, head, chest and pelvic g's on any of the five test dummies are not to exceed 60 except that pulses up to 100 are allowed for less than 3 milliseconds. Femur loads are not to exceed 1400 pounds. We do not intend to editorialize on the validity of these figures in terms of saving lives – except to say that the subject is still open to question.

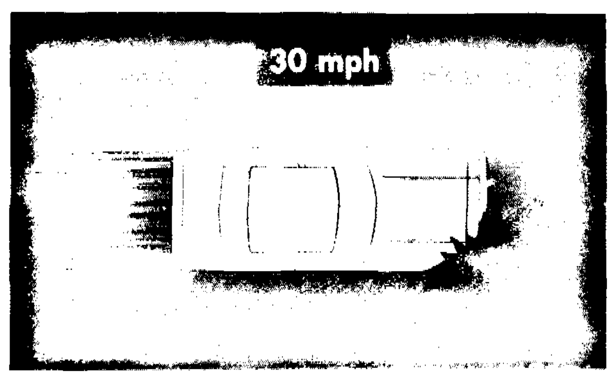


Figure 34

Higher speed tests include 30 mph front and rear corner impacts (Figure 34) and a 15 mph side impact into a pole (Figure 35). At 50 mph a succession of barrier and pole impacts are included. In these, dummy performance

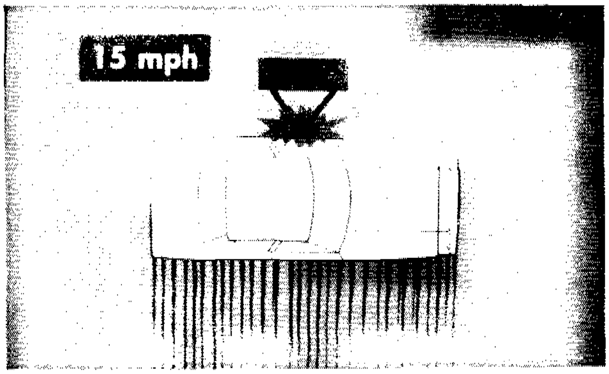


Figure 35

is the same as for the first tests, except that the head is permitted 80 g's for up to 3 milliseconds with no limit on peak deceleration (Figure 36). Another category of tests includes 75 mph car-to-car crashes – front and rear (Figure 37); a 2-foot inverted drop (Figure 38); and some form of double roll-over (Figure 39).

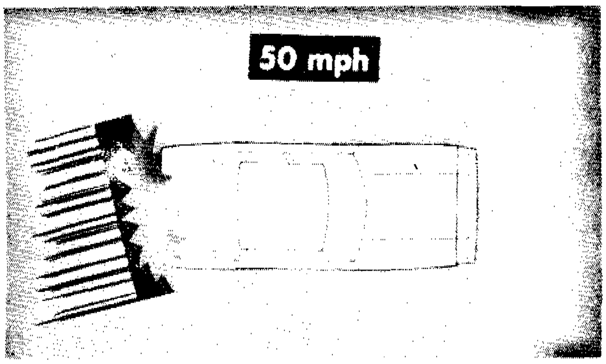


Figure 36

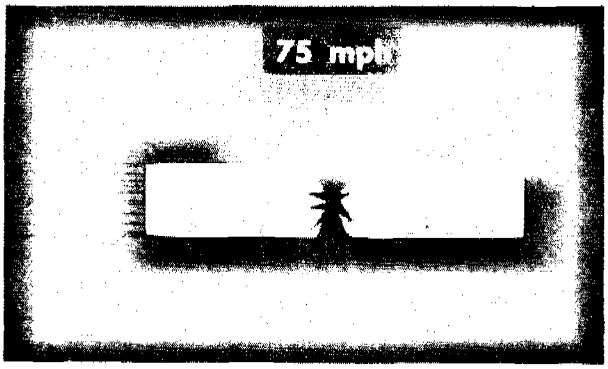


Figure 37

These requirements have led to a very substantial frame and body structure for the ESV. Aluminum panels were chosen for much of the body to achieve high

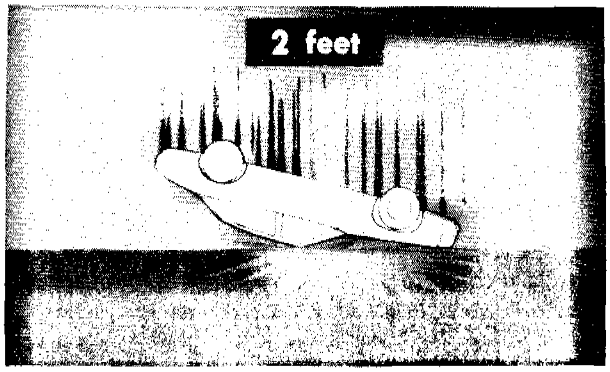


Figure 38

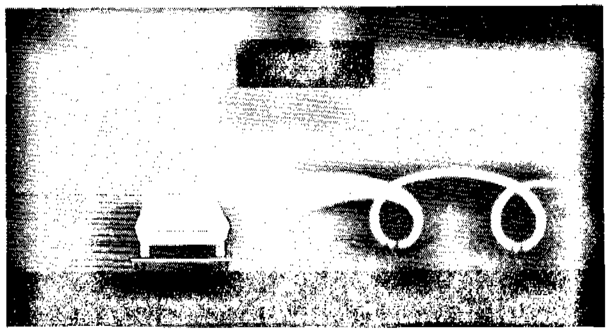


Figure 39

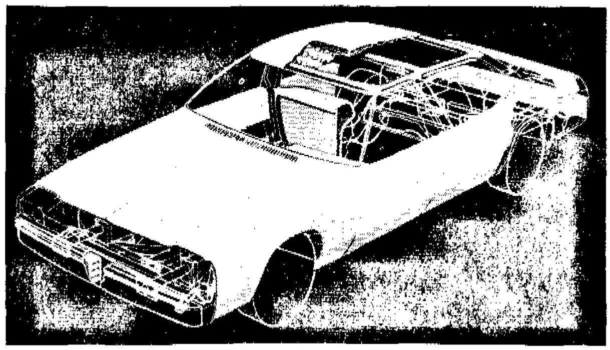


Figure 40

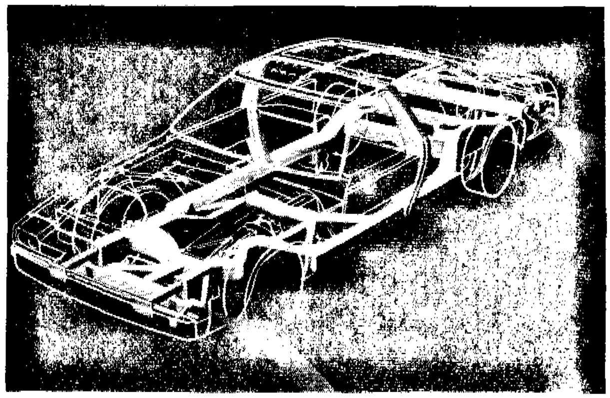


Figure 41

strength and maintain reasonable weight (Figure 40). In addition, aluminum is used in the bumper and door beams. Also to save weight, higher strength vanadium alloy steel is employed in the frame and body side pillars (Figure 41).

The frame has a full box section with both cross and diagonal bracing to accommodate corner impacts. The ends of the frame side rails house 3-inch diameter hydraulic cylinders with metered orifices. Three-inch diameter torque tubes are housed within the frame cross members, front and rear. These torque tubes connect to the hydraulic cylinders through a dual lever linkage to coordinate the travel of the energy absorbing bumper system in angle impacts.

Bumpers have a 9-inch stroke in 10 mph barrier impacts required by the contract (Figure 42). The bumpers are covered by molded urethane with the front system telescoping inside the body sheet metal and the rear urethane hinged to the rear deck (Figure 43). The amount of space required for the bumper and its travel significantly reduces available trunk space. Access to the 12 cubic foot trunk is from the sides through two hinged deck lid panels. Spare tire removal is somewhat easier in this design (Figure 44).

The air conditioned ESV has fixed side glass to reduce the chance of ejection during roll-over. However, there are small power-operated access sections in the front glass. For roll-over protection, the ESV has high strength roof supports in the center pillars. Sloping the pillar forward reduces the amount of unsupported roof structure over the front seat area and moves this massive member away from the path of some of the rear occupants who might otherwise strike it in certain contract crash situations (Figure 45).

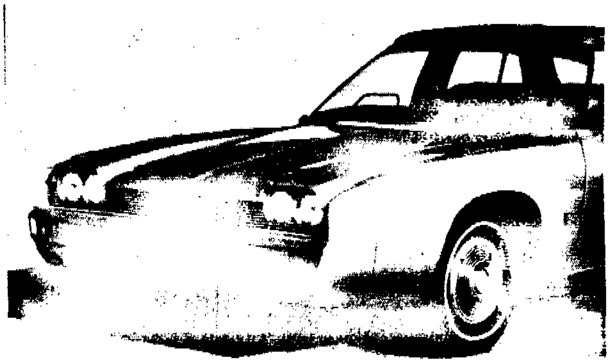


Figure 42

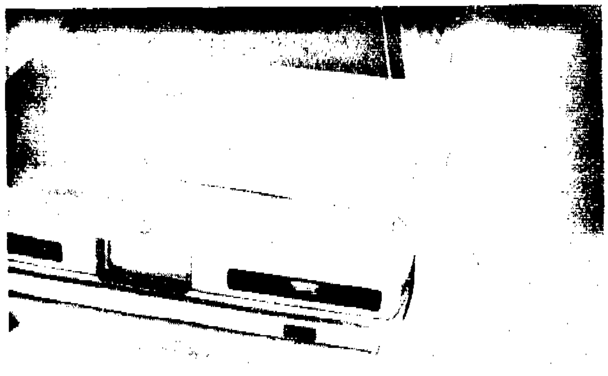


Figure 43

Figure 44

Figure 45

The interior of the ESV has what we refer to as a "30/50 occupant protection system." The interior is designed to provide protection in 30 mph barrier impacts for unbelted dummy occupants – without deploying special safety devices. To achieve our 30 mph barrier performance, considerable padding is required. In front of the rear seat passengers, there is a cross-car structure which we call the "credenza" (Figure 46). Once the occupants are in position, their free motion is effectively minimized. Getting into this position, however, is an art and a science that requires practice to achieve skill (Figure 47).

Figure 46

Figure 47

Protection (in contract terms) in 50 mph barrier impacts is accomplished by means of air cushions without belts or other devices that the occupant must actuate. The air cushions are deployed from the credenza in the rear, and from the steering wheel, driver knee area and the front passenger instrument panel (Figure 48). Movable knee panels are used to absorb upper leg impact energy (Figure 49). Air cushions in the system are actuated at barrier impact speeds over 30 mph by deceleration sensors mounted in the bumpers.

Following are some of the most significant differences between this car and contemporary models in the same size class. We should stress, however, that many of these features would have very significant costs.

- The braking system – a double brake circuit complete with automatic wheel lock controls and proportioning, as well as an emergency power source for the four-wheel disc brakes (Figure 50).
- Elimination of the windshield pillar – this has provided panoramic vision and a new approach to hardtop styling (Figure 51).
- The aluminum body results in significant weight savings without loss of structural integrity – without its use the car would be prohibitively heavy (Figure 52).
- Message center instrumentation provides detailed information and reduces driver distractions (Figure 53).
- 10 mph barrier impact bumper units, front and rear,

Figure 48

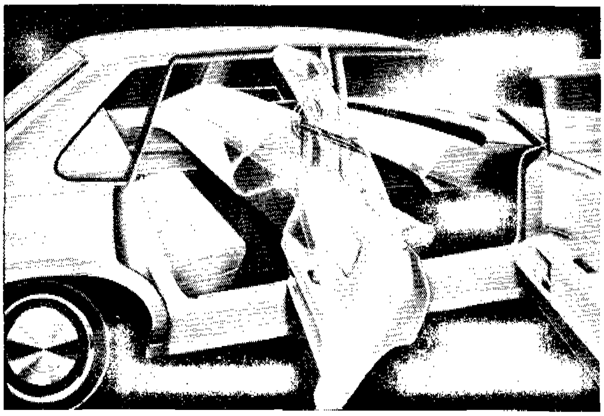


Figure 49

Figure 50

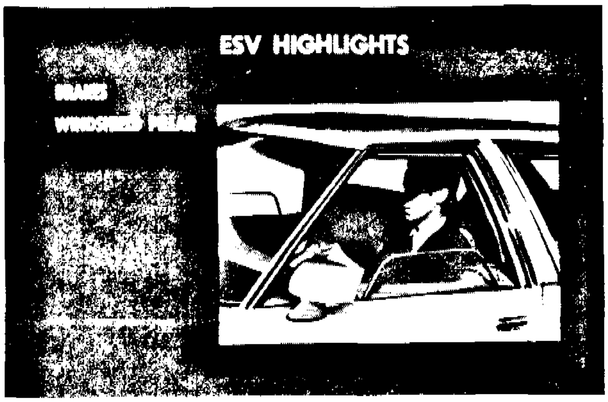


Figure 51

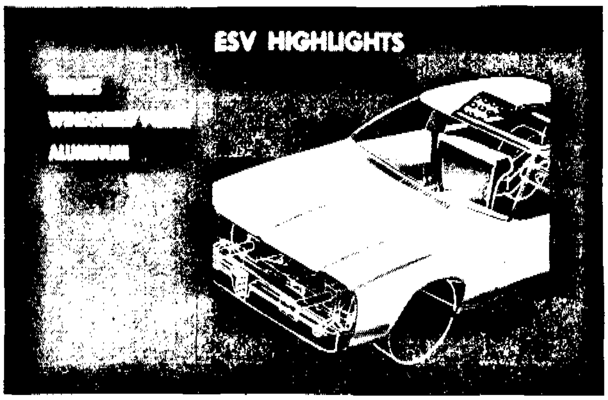


Figure 52

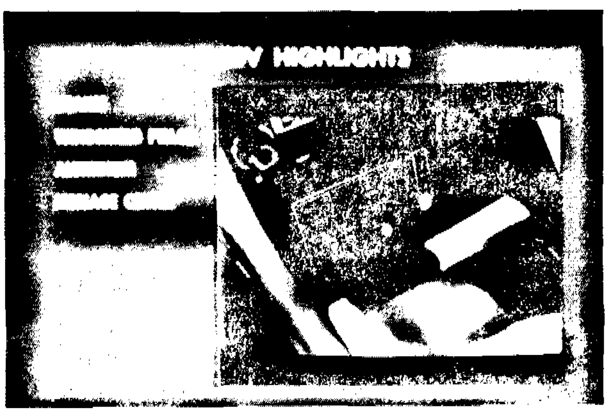


Figure 53

eliminate body damage in car-to-car crashes up to 20 mph (Figure 54).

- The side opening rear deck affords a new concept in curb-side loading (Figure 55).
- Fixed side glass is intended to keep occupants within the safer confines of the passenger compartment in a wide array of accidents (Figure 56).

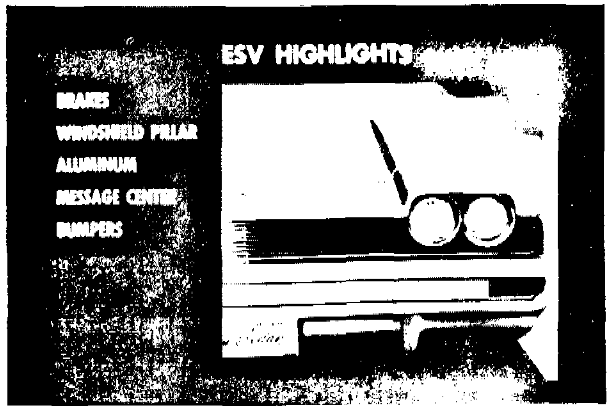


Figure 54

- High level rear signals – the dual levels of brightness provide for improved day optometrics and night visibility without glare (Figure 57).
- And last, the all-enveloping interior and occupant protection system (Figure 58).

We have considered design of the occupant protection system to be the most important and challenging portion of this assignment.

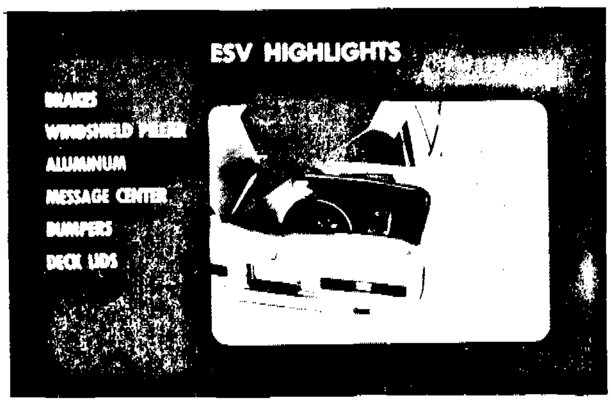


Figure 55

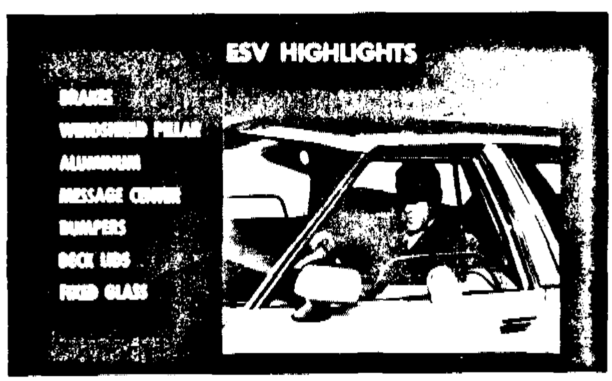


Figure 56

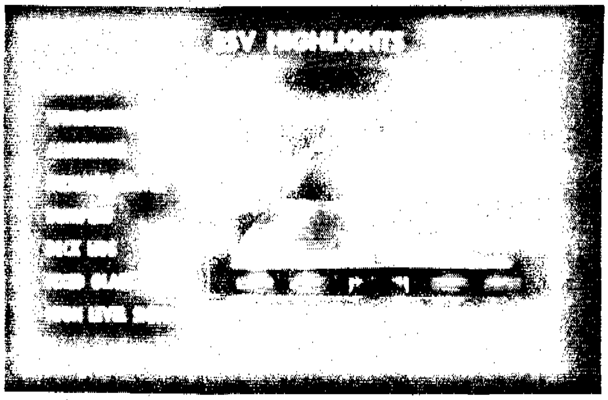


Figure 57

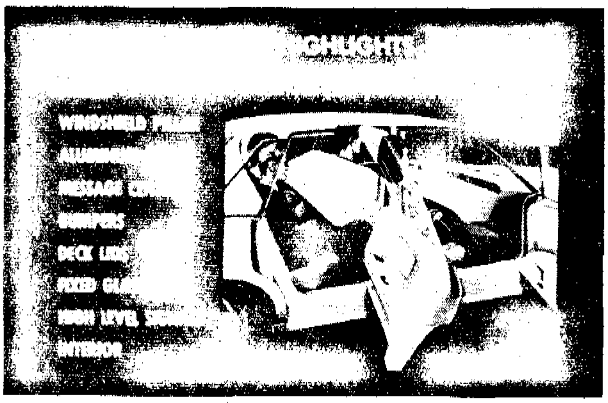


Figure 58

Structure And Occupant Systems

The engineering analysis involved defining vehicle structure and occupant kinematics parameters. In making this analysis we used all available simulation techniques. But first we had to make a number of assumptions and arbitrary decisions. Many different designs could be imagined, all possibly fulfilling the requirements of our ESV contract. We chose to make the configuration rather conventional. One reason was that some background experience was available. Furthermore, a more conventional approach could provide a basis for better comparisons.

To provide the maximum space for added structure, a seating arrangement equivalent to current intermediate size cars was used, combined with overall dimensions very close to full-size production sedans. This, incidentally, was also the exterior envelope defined in the contract.

While trade-offs between various requirements were acceptable, we decided that the specifications for a two-level occupant protection system provided the greatest challenge. The first level specified survivability in terms of the contract at a 20 mph barrier impact with no restraint other than the interior surfaces. We decided to try for 30 mph without restraint to make a more significant contribution to the state-of-the-art in occupant protection (Figure 59). The second level of protection involves a 50 mph barrier impact with a fully passive restraint system.

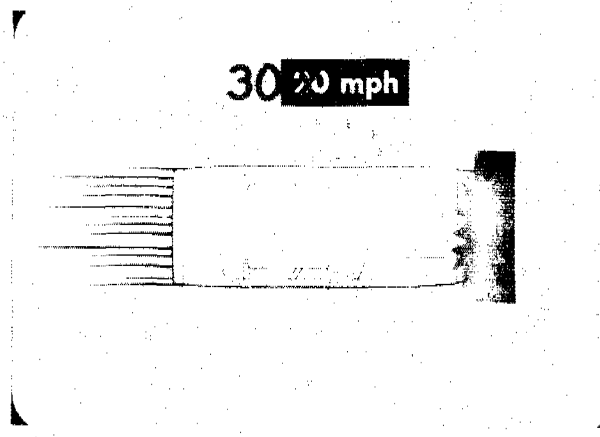


Figure 59

A lot of study went into the question of whether or not to design for changes in vehicle pitch during impact. It was apparent that certain manipulations of vehicle pitch could produce lower g levels on the vehicle (Figure 60). It was also quite obvious that by controlling occupant kinematics we could do a better protection job. Such control can best be maintained when vehicle pitch change is kept to a minimum (Figure 61).

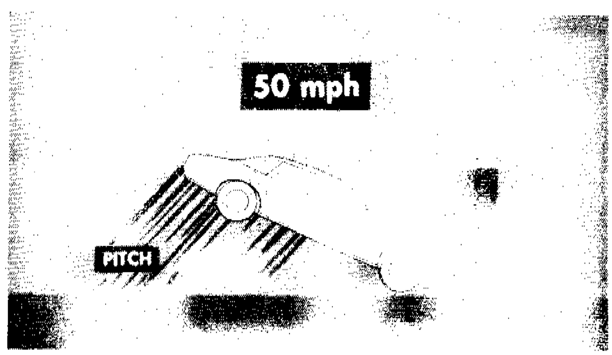


Figure 60

Therefore, we decided to design the structure for this performance by carrying two-thirds of the impact force through the frame and one-third through the front sheet metal and hood to the doors. This permitted much of the development work to be conducted on impact sleds without requiring pitch compensation.

The contract specification curve is well known (Figure 62). We designed the bumper system for 6 g's in

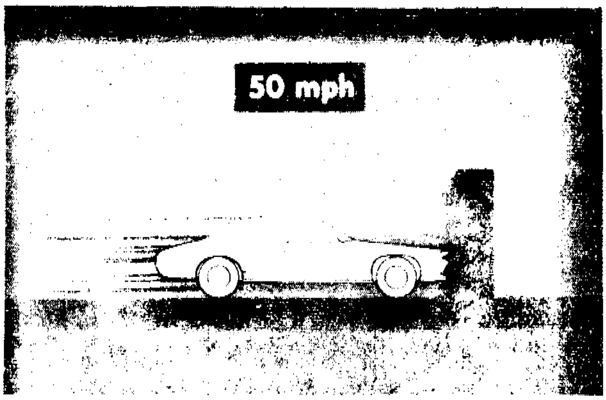


Figure 61

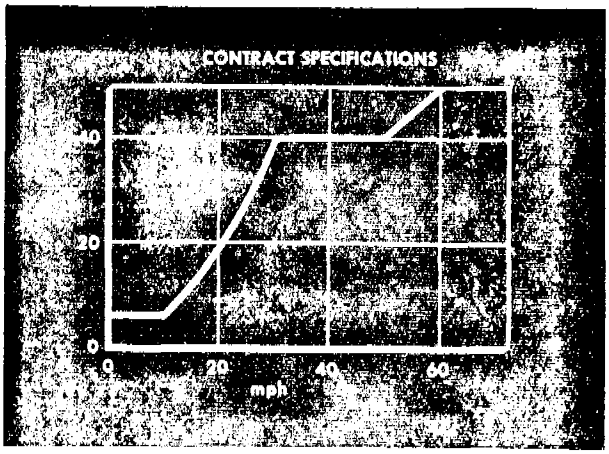


Figure 62

a 10 mph barrier impact. As the trace for the bumper system shows, the desired resistance is obtained up to approximately 15 mph, after which deformation of the structure occurs (Figure 63). The deflection-time curve

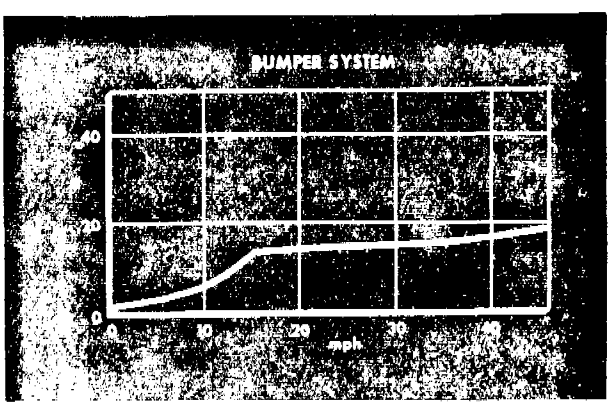


Figure 63

in Figure 64 illustrates the characteristics of the structure. We designed the vehicle structure and component dynamics to produce nearly a square wave deceleration.

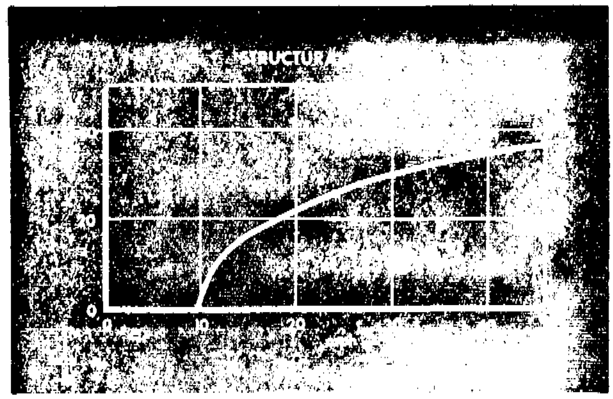


Figure 64

Superimposing these performance characteristics provided us with the overall curve shown in Figure 65.

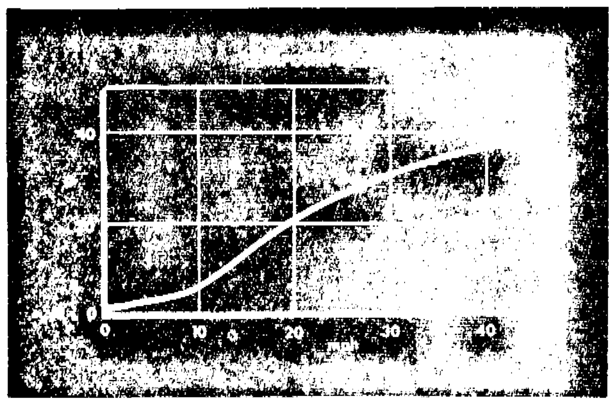


Figure 65

Figure 66 shows the actual performance of the front end of the vehicle in a barrier impact, including the effect of the bumper. It could also be plotted against crush distance instead of time, and similar curves are obviously available for other velocities, such as the one in Figure 67 which shows the behavior at 30 mph.

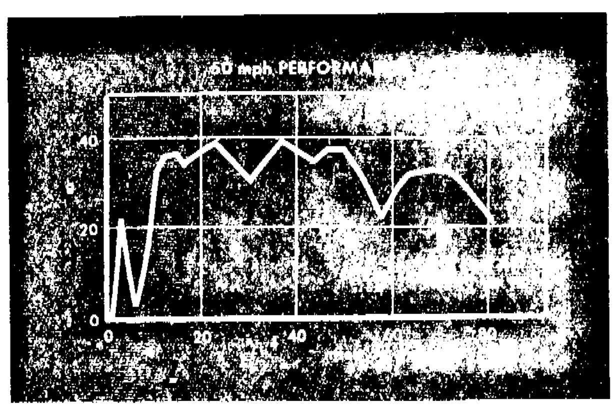


Figure 66

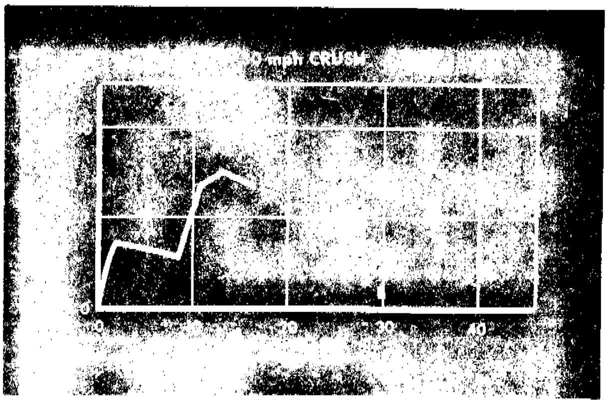


Figure 67

The structure was designed as a statically indeterminate bridge or truss work. Each element was analyzed individually for its behavior beyond the elastic limit (Figure 68). Calculations were verified through slow speed crush tests such as the frame which is being crushed by a ram illustrated at the top of Figure 69. This kind of preliminary testing is valid because we have found that the collapse mode at slow speed is identical to the mode at high speed for all structures normally used in frames and bodies.

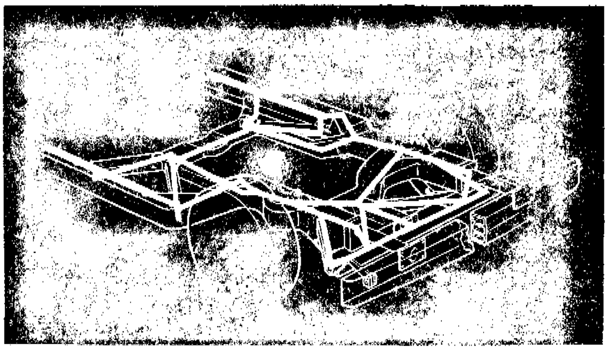


Figure 68

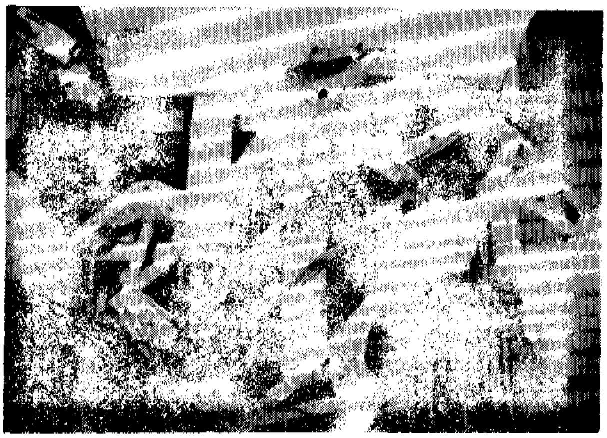


Figure 69

Turning now to our primary goal, occupant protection, the main reason for specifying a certain maximum vehicle deceleration is the relationship to occupant "ride-down" with the vehicle during impact (Figure 70).

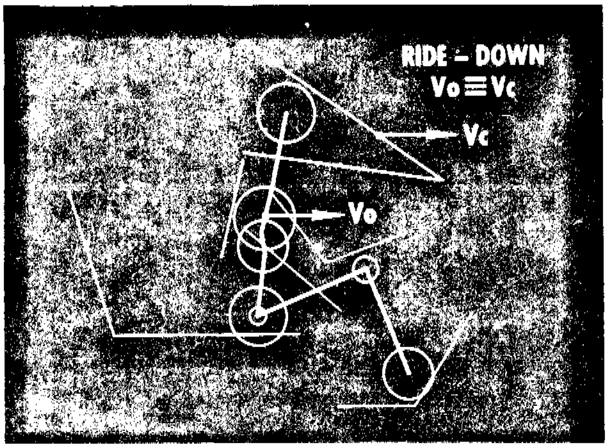


Figure 70

In Figure 71 the solid line indicates the decreasing vehicle velocity during the impact. The dotted line

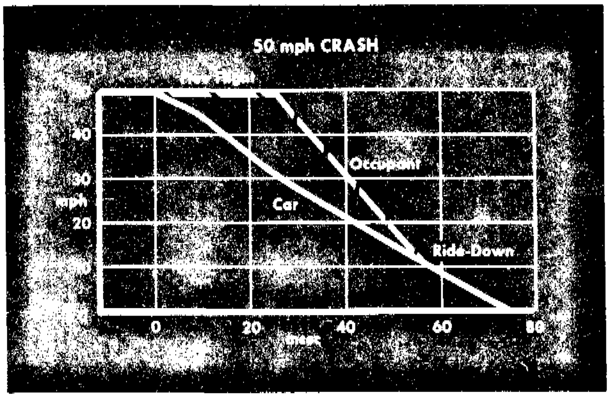


Figure 71

indicates the occupant's actual velocity. This shows the free flight distance or occupant spacing as well as the pure ride-down time or distance. In between, there is the restraining effect of the crush of the interior. There is always some rebound or spring-back of the vehicle and a certain amount of overlap between the interior crush and the ride-down. However, if we for a moment simplify the problem by disregarding occupant kinematics and assume a structure which produces close to a square wave deceleration, we can get a feeling for the potential ride-down which may be obtained at a given impact velocity. The three parameters which determine this potential are: (1) the structural characteristics of the vehicle as represented by the force-deflection curve, (2) the occupant spacing or the so-called free flight distance, and (3) the crush behavior of the interior, including the total deflection or penetration possible (Figure 72).

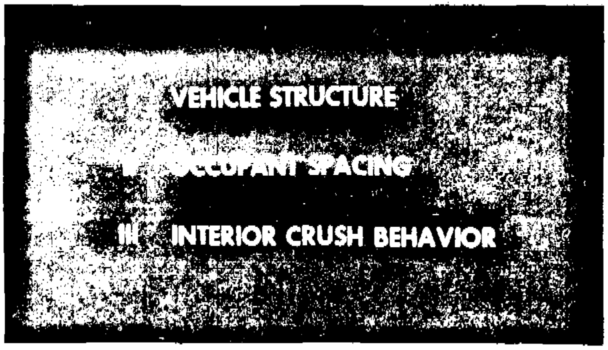


Figure 72

Add now the complexity of occupant kinematics. For the moment, we will consider only one specific dummy. It is quite apparent that the various parts of the dummy have different spacings (Figure 73). The degree to which ride-down is utilized varies accordingly. For this reason, control of the occupant kinematics becomes the most important single factor in designing for occupant protection. A precise definition of the dummy, including the dynamic properties and interactions of the various components, is absolutely necessary to insure the prescribed reactions.

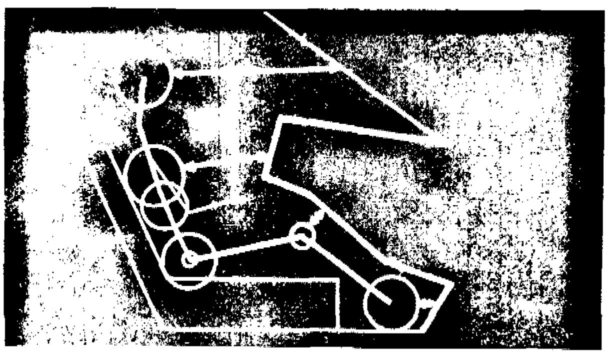


Figure 73

Our solution for 30 mph was to separate, physically, the interior surfaces which support the feet, knees, chest and head (Figure 74). The force-deflection characteristics of the surfaces could then be tailored to provide the desired kinematics. Of course, there are problems concerning the mixture of dummies, ranging from the 5th percentile female to the 95th percentile male – probably enough for another technical paper (Figure 75). We can mention, however, that the necessary deflection of some of the panels is more than double the amount required for a single size dummy design. There is

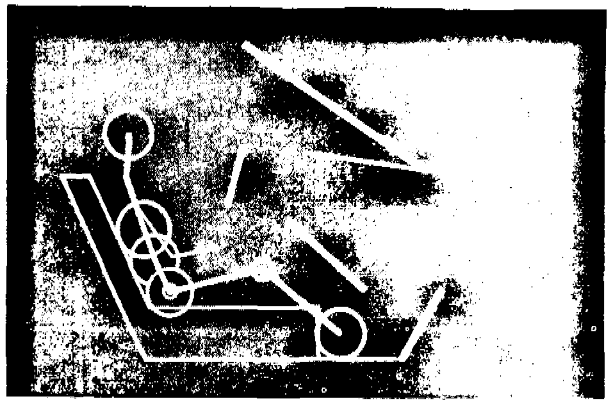


Figure 74

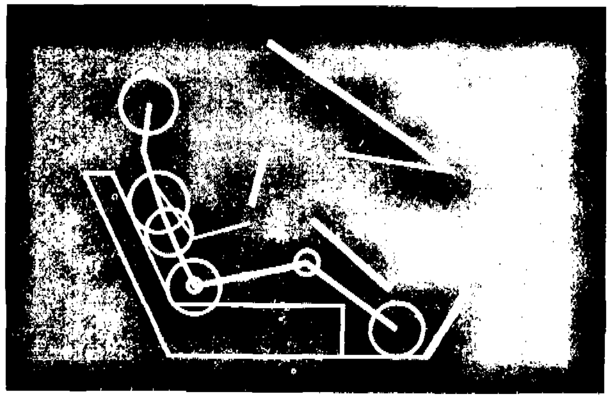


Figure 75

also the very significant question of the ability of these, or any known dummies, to model or reflect human behavior with fidelity.

Having first resolved the problems related to the 30 mph impact, we chose to make use of the air cushion concept for the high speed impacts. Such a system is simple enough in theory in that it provides for two very important functions: (1) it will reduce the free flight distance, increasing the distance over which deceleration forces are applied, provided full deployment can be accomplished quickly enough; and (2) it acts somewhat like a very low rate spring and shock absorber between the body shell and the occupant. This compensates for the effects of fluctuations in the g-t curve from the vehicle front structure.

Figure 76 indicates what is necessary to restrain the driver properly. It includes an air cushion mounted on top of the energy absorbing steering column and another air cushion which acts in unison with the energy absorbing knee panel.

The computer has been of great use in the study of occupant kinematics. In Figure 77, taken from a film sequence of the front seat passenger in a 50 mph impact, time after impact is indicated in the upper left hand

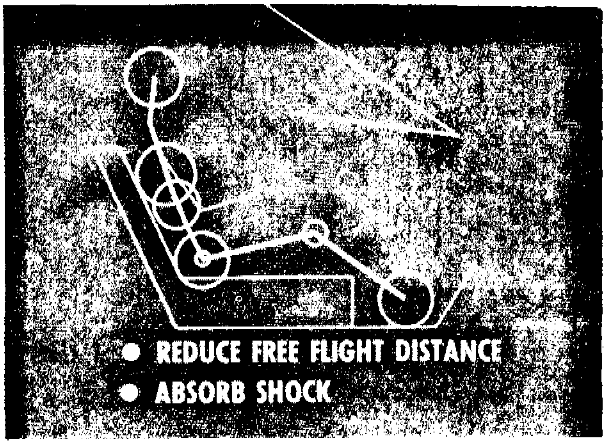


Figure 76

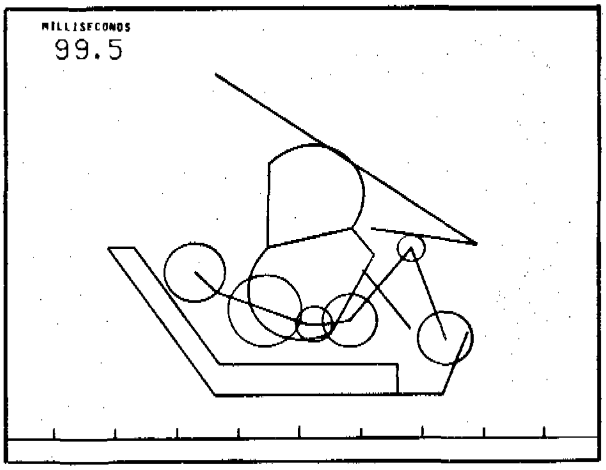


Figure 77

corner. This illustration is of an early design in which knee panel support was not sufficient. The result was submarining and an incorrect rebound trajectory.

In Figure 78 a rear seat occupant, again at 50 mph, has reprogrammed impact surfaces and air cushions. The

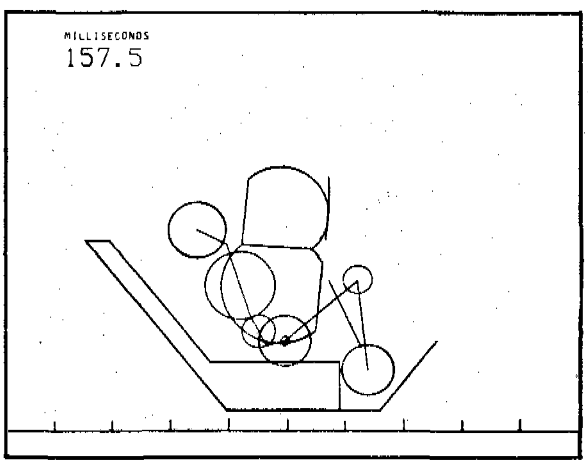


Figure 78

system is generally tailored to provide the appropriate energy absorbing characteristics and the trajectory is maintained so that the dummy can make full use of the system. He is stopped in the air cushion and is rebounded in an erect position. This has proven to be a very useful tool in studying the effects of changing design parameters without having to resort to time consuming and costly fabrication programs.

The air cushion must be in place before the occupant has moved significantly, and collapse must begin soon enough to insure a low rebound velocity.

In a 50 mph impact, you can't waste much time. We found that a deceleration sensor mounted directly on the bumper as shown in Figure 79 would produce the signal for triggering within 5 to 7 milliseconds. This was sufficient to get the air cushions fully extended within about 25 milliseconds.

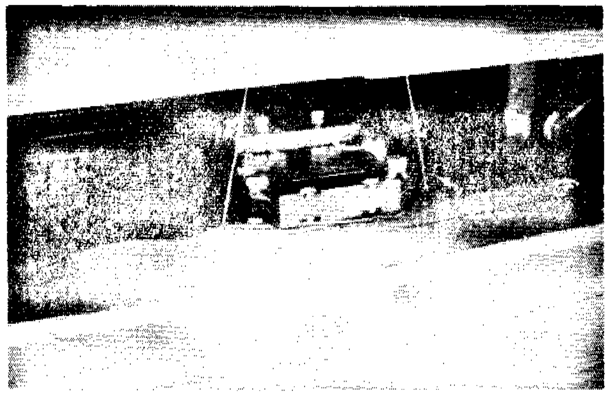


Figure 79

Summarizing the considerations for the design of the interior, I want to emphasize that positive control of the kinematics of the occupant is essential (Figure 80). If this is not done, it becomes impossible to provide the proper characteristics of the impact surfaces for the head, shoulders, chest, buttocks, knees and feet.

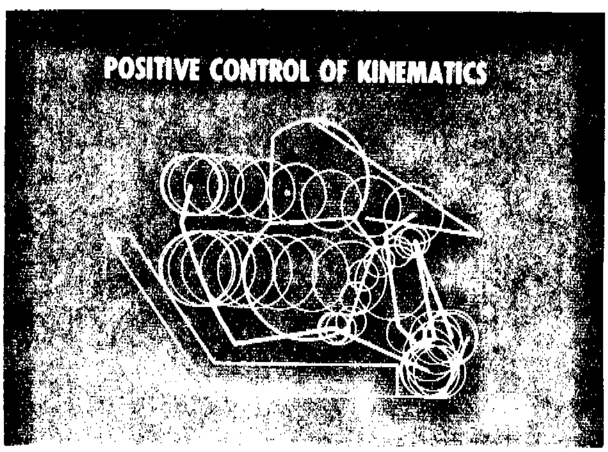


Figure 80

Secondly, as in the before and after cartoon (Figure 81), impact surfaces need to be designed with a minimum spring-back. This also applies to air cushions.

Third, the resisting force of the impact surface must be designed for the lightest weight occupant. In addition there must be tailored resisting forces and unobstructed deflection space for the wider and heavier 95th percentile passenger (Figure 82).

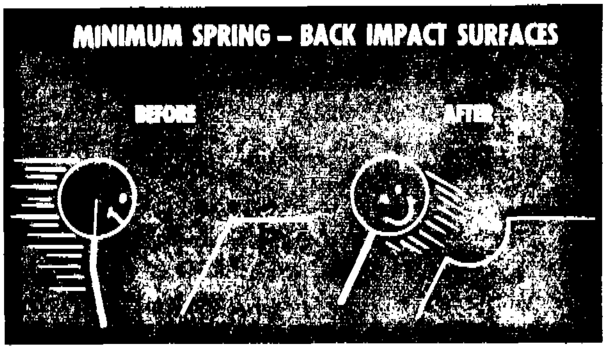


Figure 81

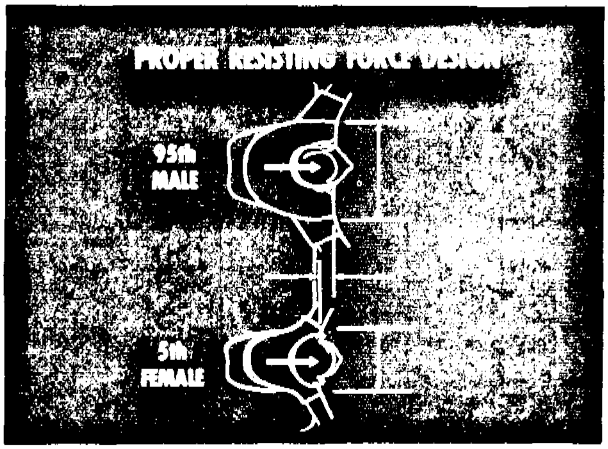


Figure 82

And fourth, there must be a "no protrusion zone" in which no massive objects can be allowed. There must be space into which the instrument panel may displace during the impact (Figure 83). And we should not forget that we have only studied the idealized situation where all the dummies are placed in their proper seating positions before the crash.

An important part of the development of the design has been testing on our impact sled (Figure 84). The theory for this sled testing is very simple: while a barrier crash begins with a high speed and ends at rest, our sled begins at rest and is accelerated to a high speed (Figure 85). However, the reactions of the occupants will be identical, provided the same acceleration versus time is obtained.

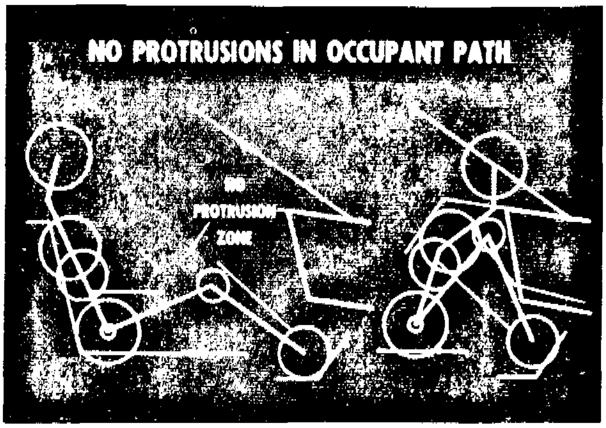


Figure 83

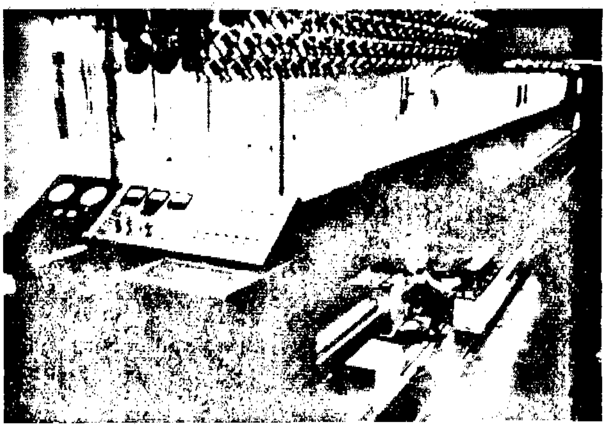


Figure 84

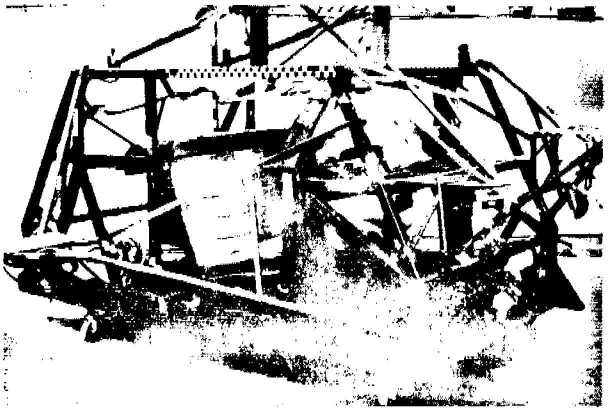


Figure 85

We have made extensive use of our sleds and here are some examples. Figure 86 is from a high speed movie of an early front seat passenger test with a pre-deployed cushion. The submarining problem is apparent. In Figure 87 we have a dynamic deployment and improved tailoring of resistance forces in the system. The occupant

Figure 86

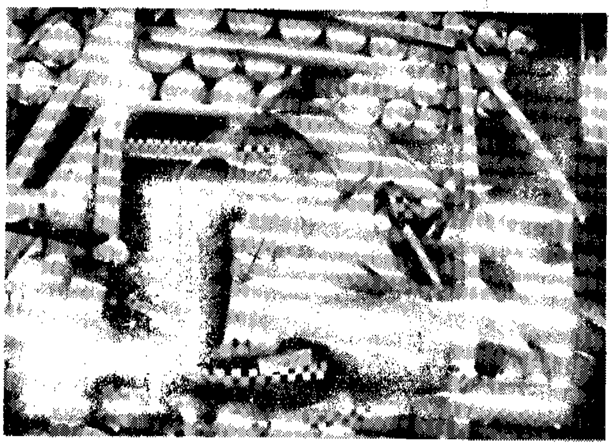


Figure 87

stays erect and has generally good kinematics. It is costly and time consuming to run enough tests of each configuration to insure repeatability. To get a feel for the statistical significance of measured data, a series of nine sled shots were run, three each with three different dummies, and all with identical interiors.

The plot of the driver head deceleration (Figure 88) illustrates some of the results. The mean value for Dummy "C" was 50 percent greater than for Dummy

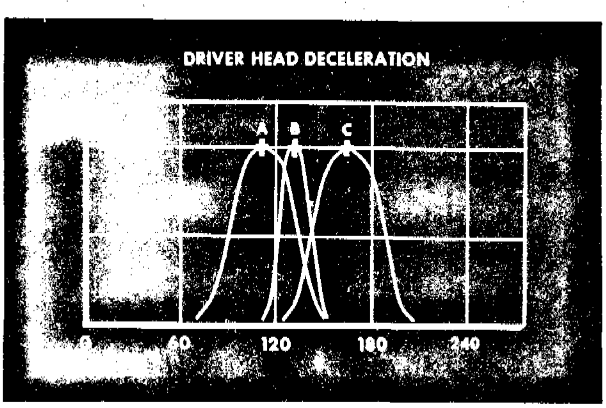


Figure 88

"A," which shows that comparable results can only be expected when everyone uses the same type of dummy.

The spread of data must also be considered in the selection of anthropomorphic test devices. In this test, Dummy "B" showed the best bunching of data, and this happens to be the one we are using, the GM hybrid unit.

I want to stress, however, that this dummy design is not the answer to all fidelity problems. It merely represents the most recent dummy that was available for use in our program. You can appreciate that we had to choose a design early and then stay with it for the course of the program. The design is based on an Alderson model which has been modified in the head, neck and chest (Figure 89).

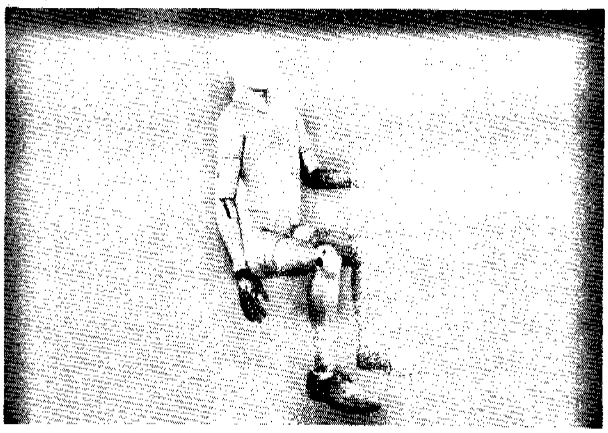


Figure 89

The original head is replaced by a Sierra head which, in turn, has been modified by grinding smooth the parting lines on the skull, removal of the rigid nose, removal of neck below the collar, removal of the ears for ease in targeting, and addition of a spacer for an accelerometer. The neck is replaced by a rubber design and a new mounting plate (Figure 90).

Figure 90

The chest is modified by removing internal braces and padding. The sternum assembly is replaced by a leather sternum with metal stiffeners, while new damping material has been added to each rib (Figure 91).

Figure 91

The head is instrumented with three orthogonally mounted, piezoresistive accelerometers with all major axes passing through the center of gravity of the head. Similar accelerometers, aligned to the c.g. of the shoulders, are mounted in the chest. The pelvic measurement system is in the same format and oriented to the hips. Strain gages are mounted in the femurs, and joints are properly tightened. The finishing touch is Sears Roebuck underwear.

However, it takes more than human underwear to simulate human behavior.

Test Results

Figure 92 shows ESV-1 from the passenger side. The car comes to rest in about 90 milliseconds. The front passenger air bag failed to inflate. The front structure successfully handled all the force for which it was designed. Residual crush is 34 inches.

Next we have a detail of the bumper action. It telescopes properly within the fender skin. There was,

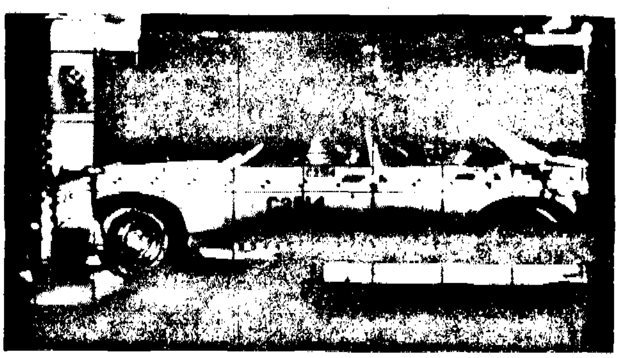


Figure 92

however, a short drop-off in load before the primary impact structure began to absorb energy (Figure 93).

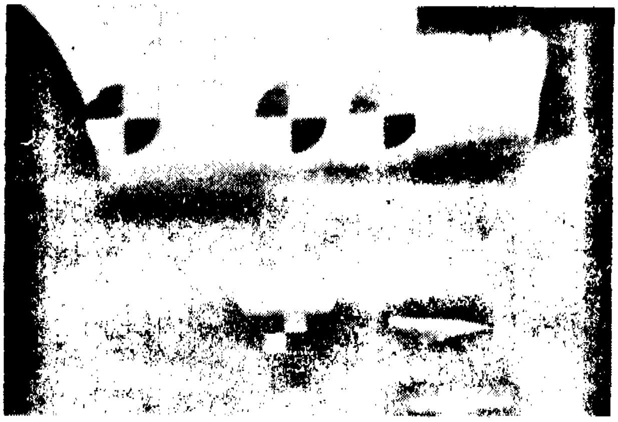


Figure 93

Looking in on the driver, his steering wheel air cushion starts to deploy after five milliseconds and is in position for his impact. The instrument panel displaced rearward more than anticipated and the knee cushions failed to deploy (Figure 94).

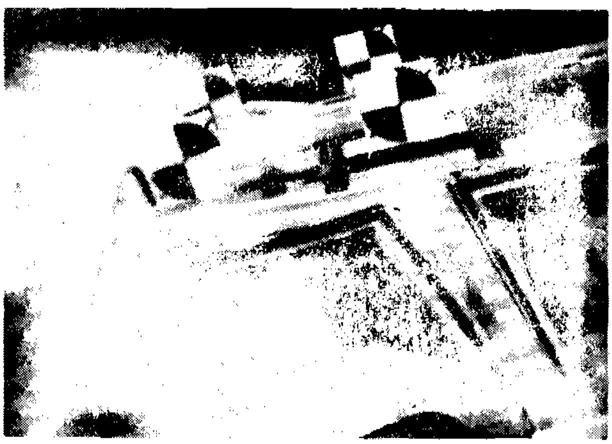


Figure 94

In ESV-2 the front seat passenger had a hard impact due to instrument panel motion. This time his air cushions were properly deployed but were not helped by the door motion when we experienced a failure of the latch system (Figure 95). Figure 96 shows another view of the proper air cushion deployment and windshield breakage.

The three 50th percentile rear seat occupants of ESV-1 essentially survived the crash. They were effectively stopped in the cushion without deflecting the credenza as much as we expected. As a result they rebounded too fast and all struck the rebound surface above the rear seat back at high g levels (Figure 97). In ESV-2 we again had good kinematics and modifications made to the energy absorbing mounts of the credenza provided the action we expected (Figure 98).

The quarter view of ESV-1 in Figure 99 illustrates the cooperative action of the body and frame. Pitch action, and its effect on the occupants, is apparent. In ESV-2 we modified the load path through the doors, which appears to perform properly here, but there is still pitching motion, which is largely due to the failure of the door latch in the passenger side (Figure 100).

From underneath ESV-1 we observe the desired progressive deformation, but there is too much motion in the torque box area. The drive line remained intact, transmitting force to the rear axle in a proper manner (Figure 101).

We were using 86 channels for data collection, 55 of which were used to monitor dummy reactions. In the table of Figure 102, results from the barrier tests are compared to results from the sled test, where we used identical interiors and g-t curves. The upper line indicates the contract specifications which are: up to 80 g's for no more than 3 milliseconds for the head, while chest and pelvis are permitted only 60 g's for 3 milliseconds with peaks up to 100, and a maximum of 1400 pounds on each femur.

Figure 95

Figure 96

Figure 97

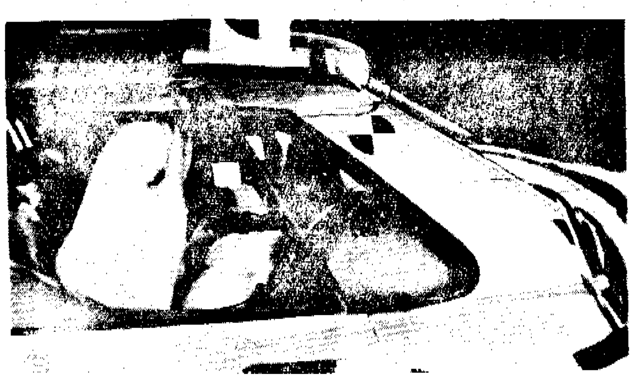


Figure 98

Figure 99

Figure 100

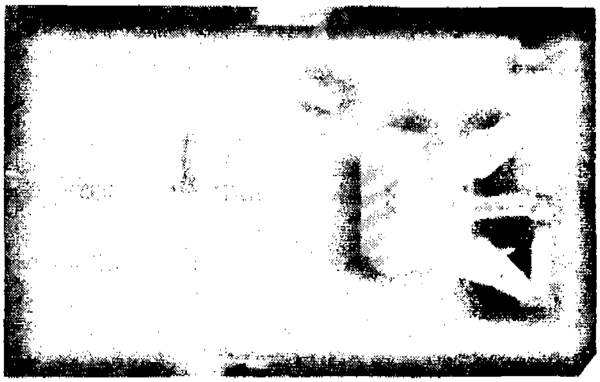


Figure 101

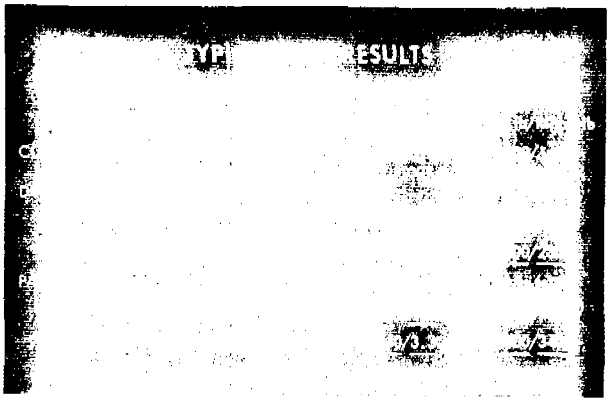


Figure 102

The next two lines are typical measurements for the driver from the sled and barrier respectively. The underlined numbers indicate either peak g level or duration values that were greater than specified. The reason for the large differences can be explained as a result of the pitch change, which we have not yet succeeded in eliminating. As an example, the driver's head was properly supported by the steering wheel air cushion and the deceleration did not even reach the 80 g's, but the instrument panel was forced backwards, taking the steering wheel and knee pads with it, to produce too high forces on the chest and knees.

Similar results were obtained for the front passenger. In the barrier test, the roof came down against his head, which brought the g level above 80 for 9.6 milliseconds, and again the instrument panel deflected rearward to bring the femur loads way out of line.

The numbers in Figure 103 are typical for the outboard passengers in the rear seat. Here the vehicle pitch did much less damage, but resulted in a greater tendency to submarining and an increase in rebound severity. We still have a problem with the knee loads.

Also, the center rear occupant had a problem; in this case the g level on the head stayed above 80 for 6.4 milliseconds during rebound.

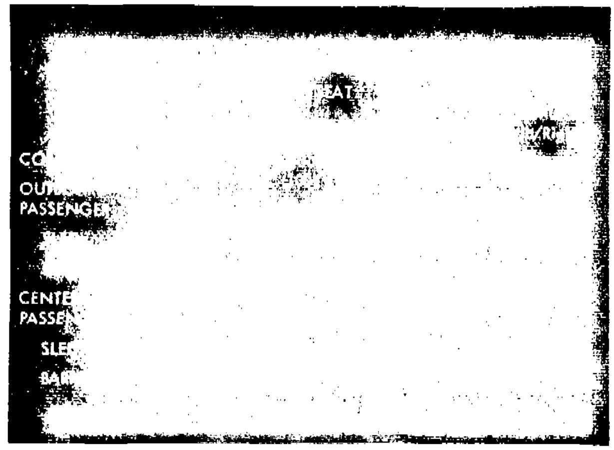


Figure 103

All the dummies were killed, so to speak, although some only slightly.

The impact forces were measured on the barrier face, with the distribution shown in Figure 104. It appears that the design goal of carrying one-third of the force through the sheet metal and two-thirds through the frame, was almost obtained. But it also appears necessary to revise the distribution such that the high level force is increased while the low level force can be reduced.

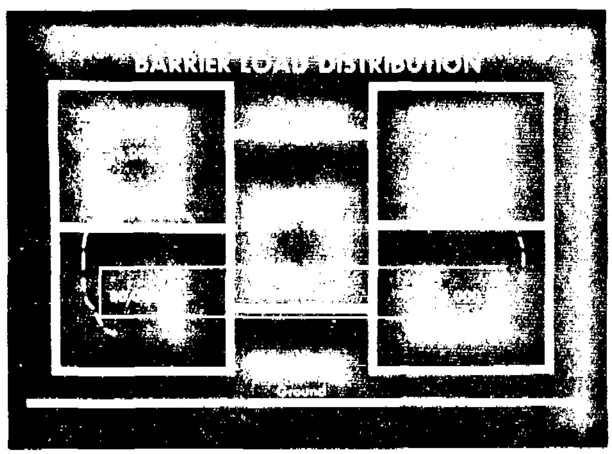


Figure 104

In these barrier tests, the bumper system, frame, engine mounts, drive line and air restraint system performed as expected. Also, there was no fuel spillage.

We have not yet reached the goal completely. But it appears that there is enough evidence that when the structure has been reworked so that proper pitch attitude is maintained, the dummy kinematics will also be controlled sufficiently. This will yield acceptable forces and decelerations in all seating positions.

Conclusions

The ESV program in General Motors is a study in meeting Department of Transportation performance requirements. We have just described slightly over one year's activity in its development, during which time we have designed a basic vehicle concept, reduced it to running hardware and obtained preliminary test results.

Our objective has been to meet or exceed all of the specifications without trade-offs. The emphasis has been on crashworthiness and occupant protection in terms of our contract. Designing for contract accident avoidance involved no new technology.

Our approach represents an effort to accomplish the contract objectives with a newly designed vehicle, conventional in most respects, along the lines of current automotive practice. It is not possible to determine whether or not this approach imposed constraints on the performance of the design. It is obvious, however, that there are many questions of practicability that are not resolved by our program. Such things as interior roominess needs, air cushion hazards, increased weight, and whether or not ESV specifications save lives remain to be resolved.

Because considerable development and testing remain, it is too early to draw any final conclusions. However, it is appropriate at this time to make some observations based on our experiences during the past year:

1. Contract occupant protection objectives have not yet been achieved. However, with design modifications, they are probably achievable.
2. Precise control of occupant kinematics is essential in a totally passive protection system. This is achievable only by development of structural characteristics dictated by requirements of an overall system, including interior components and restraint devices, tailored to accurately program occupant position and velocity during impact.
3. Design for control of kinematics must be restricted to a specific dummy configuration. Designing to accommodate the full size range (5th to 95th percentile) is considerably more complex than for the 50th percentile only.
4. The imposition of structural constraints, such as the specified protective bumpers and intrusion limitations, restricts the ability to optimize structure for occupant protection.
5. The necessary structure can be achieved within the specified exterior dimensions. However, the interior space and entrance and exit accommodations, particularly in the rear, are unacceptable.
6. Structural requirements, if achieved with conventional materials, would result in a vehicle excessively heavy. The resultant use of lightweight materials adds significant cost to the extent that such a vehicle is not marketable.

In reviewing the results of this program, certain qualifications must be kept in mind. Our car is designed for very specific crash test situations. The relationships of our test data to highway crashes is unknown. For example, the correlation between car-to-car and barrier tests, and the subject of the large car to small car crash are not being studied in our program. In fact, it appears that the whole subject of traffic mix may well be the overwhelming factor in consideration of vehicle structures. It doesn't take much imagination, however, to visualize what a large car with substantial structure such as the ESV can do to a small car.

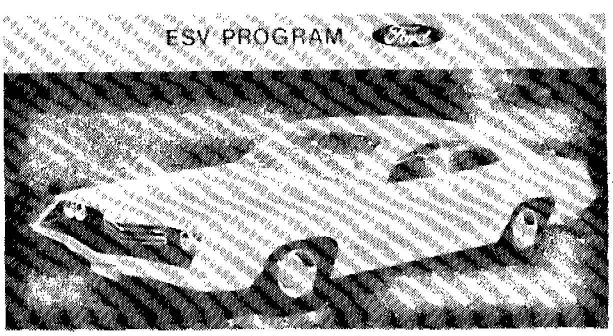
It is important to emphasize that any vehicle designed to occupant protection specifications can only be developed and evaluated with anthropomorphic test devices assuming a normal seating position at the time of impact. It is generally recognized that the fidelity of such devices relative to the human body is questionable at best. Therefore, conclusions regarding human "survival" or injury level are not valid, particularly in light of the limited knowledge of human tolerance factors. It is conceivable that future developments in the fields of dummy construction and bio-mechanics could completely negate test results currently being obtained.

It is apparent that we are not in a position to determine whether or not the specifications have merit in terms of effectively improving the crashworthiness capabilities of marketable cars.

What we now have is a development tool, with which an extensive test program is being conducted. It includes evaluation of crashworthiness in specified crash situations as well as the normal vehicle development activity. Design refinements will be made based on this work.

THE FORD MOTOR COMPANY

Mr. Henry Gregorich
Chief Engineer, Special Vehicles Office



Ladies and Gentlemen:

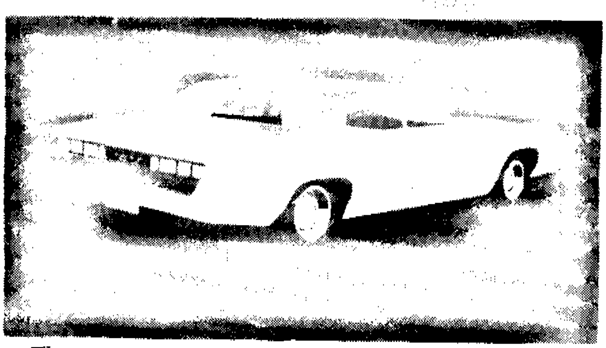
Before we begin the technical part of our presentation, I would like to observe that Ford Motor Company's concern with vehicle safety dates back many years – a fact that is documented by the company's many important product safety innovations.

Our engagement in the current experimental safety vehicle program – the program that we are here today to describe is not a new involvement for Ford, but only a continuation – perhaps on a more formalized basis and with greater public exposure – of activities that for many years have characterized our company's advanced product engineering program.

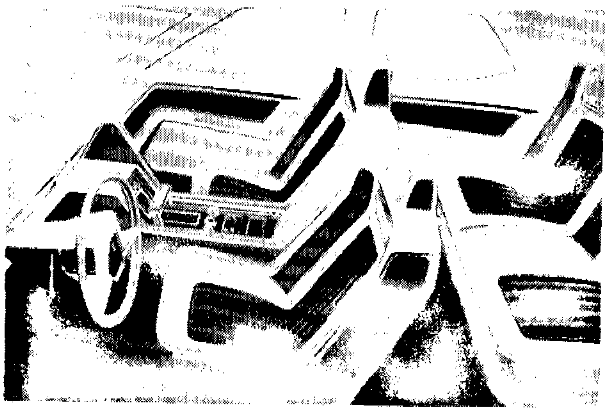
When early in 1970, the United States Department of Transportation sent our requests for bids on the design and construction of experimental safety vehicles in the 4,000 lb. sedan category, Ford responded by submitting a proposal incorporating design features essentially identical to those that will be described in our presentation here. Although our bid was not accepted at that time, the company went ahead with the program as part of our internal advanced product engineering effort. Our major purpose was to meet occupant protection objectives of the levels identified by the Department of Transportation using regular production hardware insofar as possible.

In July of this year, Ford entered into a one dollar contract with the United States government to build and deliver one experimental vehicle prototype to the D.O.T. by the end of 1972. This decision was based on the premise that Ford's participation would make a valuable contribution to the total worldwide ESV effort. The rendering you see before you pictures the Ford car essentially as it will look when completed. It features a longer hood than the current production Ford, but has the same passenger compartment size and basically the same roof configuration.

FORD ESV



The rear view reveals the relatively short trunk, which is a feature we find is necessary in order to remain within the overall length objective of 220 inches.



The interior features include fixed front seats for the driver and front right passenger, separated by a control console, which is an important structural feature of the car. The transmission shift lever and certain other controls are located in the console to provide space in the instrument panel area for restraint devices and associated hardware.

FORD ESV PROGRAM

- FORD APPROACH
- DEPARTURES FROM GOV'T ESV OBJECTIVES
- VEHICLE DESIGN
- SUBSYSTEM TESTS
- VEHICLE CRASH TESTS
- CONCLUSION

Now, with respect to the program we have undertaken – my presentation is divided into six major parts. First, I will explain the approach we are taking to our ESV effort; then point out where we are departing from the original ESV specifications laid down by the DOT. Third, I will describe the vehicle as it stands in its current state of development – particularly with respect to its major systems – and will follow that with a report on the status of subsystem developments. I will then report on the results of vehicle crash tests, using a series of crash test film clips, and will conclude my presentation with some statements with regard to Ford's overall outlook on the ESV program as of the current time.

The approach we are taking to the development of an experimental safety vehicle is to start with a standard production car and modify the design as necessary to meet the objectives of the ESV program. Basic modifica-

FORD APPROACH

OVERALL VEHICLE CONCEPT

MODIFY DESIGN OF CURRENT 4-DOOR SEDAN WITH:

- ENERGY ABSORBING FRAME
- REINFORCED BODY
- FIXED SEATS WITH TRANSVERSE STRUCTURE
- ALL PASSENGER RESTRAINT SYSTEM

tions that we believe will be required are an energy-absorbing frame with front and rear impact bumpers, a reinforced body incorporating restraint systems for all five occupants, and fixed seats with adjustable foot controls for the driver.

FORD APPROACH

CRASH AVOIDANCE:

BRAKING

- FRONT DISC BRAKES WITH SEMI-METALLIC LININGS
- 12" REAR DRUM BRAKES WITH ORGANIC LININGS
- HYDRAULIC POWER BRAKE BOOSTER WITH RATIO CHANGER
- REAR TWO WHEEL SKID CONTROL

In the crash avoidance area, we will meet the DOT objectives for brake system performance by modifying production designs of brake system hardware to accommodate the heavier weight of the vehicle. A new development program will not be required. We will use front disc brakes with semi-metallic linings and twelve inch rear drum brakes with organic linings. These linings on the rear brakes will permit us to meet the desired parking brake operational levels of 90 pounds for hand operation and 125 pounds for the foot.

To meet the requirement for stopping with booster power-off or with partial system failure, we will provide a hydraulic brake booster featuring a ratio change during the power-off mode and will install a 4x2 redundant brake system. A rear two-wheel skid control system will also be included.

We are confident that we can meet the handling performance requirements outlined in the DOT contract. We plan to resort to wider wheels and tires to meet lateral acceleration limits. We also believe it will be

FORD APPROACH

CRASH AVOIDANCE

HANDLING

- INCREASE IN TIRE AND RIM SIZES
- STRENGTHENING AND RETUNING OF SUSPENSIONS

STEERING

- STRONGER STEERING LINKAGE FOR ADDED WEIGHT

necessary to strengthen and retune the front and rear suspensions. Similarly, the steering linkage will have to be beefed-up to carry the added force levels imposed on the system by the added vehicle weight and wider tires.

FORD APPROACH

ADDITIONAL CONSTRAINTS

- DESIGN TO COMPLY WITH:
  - CURRENT FMVSS REQUIREMENTS
  - FORD PRODUCT DURABILITY STANDARDS
  - FORD PRODUCT ACCEPTANCE STANDARDS

As an integral part of the ESV program, the vehicle should and will include all applicable 1972 FMVSS standards.

In addition, in keeping with our approach of production feasibility, the vehicle will be designed and developed to meet our internal product acceptance standards regarding durability, performance, handling, braking, N.V.H. and ride characteristics.

ADVANTAGES OF FORD APPROACH

- **DEVELOP VEHICLES CAPABLE OF MASS PRODUCTION BY PROVEN TECHNIQUES.**

We believe that the Ford approach to the development of an Experimental Safety Vehicle offers several important benefits.

In the first place, developing the car from a production vehicle gives us a better chance of coming up with a final ESV design that can be mass produced – manufactured and assembled by techniques of proven feasibility.

ADVANTAGES — FORD APPROACH

EFFICIENT APPLICATION OF MANPOWER:

- STEP-OFF FROM EXISTING COMPANY SAFETY PROGRAMS:
  - AIR BAGS
  - BUMPERS
  - FUEL TANK INTEGRITY
  - VISIBILITY
  - ROLLOVER

Second, working from a vehicle design that is familiar to our entire product engineering force, and having within that capability the expertise for development of all of the currently available and proposed vehicle safety features for Ford production cars, we are able to exploit these special talents to great advantage in our ESV program. Our engineering groups engaged in the development of air bags, damage resistant bumpers, improved fuel tank integrity, visibility, and rollover, for instance, are available to assist the ESV task force.

ADVANTAGES — FORD APPROACH

- FACILITATES ESTIMATION OF COST ADDITIONS FOR SAFETY IMPROVEMENTS

Furthermore, the Ford approach will facilitate more realistic estimation of the cost additions in our experimental safety vehicle over the base production car which we modify. This could be an important consideration in measuring the success of the ESV program – if success means identifying worthwhile vehicle safety improvements which can be provided at reasonable cost to the car buyer.

Departures From Government ESV Objectives

Now, let me call your attention to the fact that our ESV program involves departures from some of the

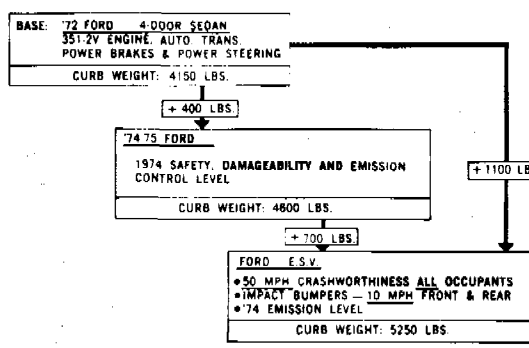
DEPARTURES FROM GOVERNMENT ESV OBJECTIVES

- WEIGHT PROJECTIONS
- VISIBILITY REQUIREMENTS
- INJURY CRITERIA
- INTRUSION LIMITS

objectives laid down by the DOT. Two major differences are in the weight target for the vehicle and in the visibility requirements.

In addition, we have certain reservations in accepting the injury criteria specifications and the definition of intrusion limits and may arrive at determinations other than those advanced by the DOT with respect to the best ways of effectively improving occupant protection.

EXPERIMENTAL WEIGHT INCREASE PROJECTIONS



Since our approach is to step off from a current production vehicle, it is inevitable that we will exceed the ESV weight objective.

The current production Ford sedan that is our base vehicle has a curb weight of 4150 pounds. This is near the 4200 pound upper limit of the ESV weight objective.

Modifying the base vehicle to meet the safety and emissions requirements for 1974 and 1975 automobiles marketed in the United States imposes a weighty penalty on the vehicle of approximately 400 pounds.

Based on our current estimates, an additional weight increase of 700 pounds will be required to reach the 50 mph barrier impact objective of the contract and the 10 mph front and rear no-damage bumper requirements. This adds up to a projected curb weight of 5250 pounds, or 1100 pounds over the base car.

EXPERIMENTAL WEIGHT PROJECTIONS DETAIL: ESV VS. 1972 BASE CAR

BODY REINFORCEMENTS	414
FRAME REINFORCEMENTS	210
RESTRAINT SYSTEM	126
IMPACT BUMPER SYSTEM FRT. & REAR	100
EMISSION SYSTEM '74 LEVEL	90
CHASSIS UPGRADING	80
ENGINE —(400 CID OVER 351)	80
TOTAL ADDITION	1100

A closer examination of the weight addition reveals that body reinforcements and passive restraint systems for all occupants make up approximately one half of the total. Frame reinforcements and general chassis reinforcement account for approximately 25 percent. A larger engine is required to meet the passing performance of 12 seconds from 30 to 70 mph with the increased weight of this vehicle.

Obviously, these projections are based upon our current design knowledge. We are making every effort to hold down these additions as we refine our design.

VISIBILITY REQUIREMENTS

		D.O.T. OBJECTIVES	FORD ESV OBJECTIVES	
FORWARD VISION	UP ANGLE	17°	11.5°	WOULD REQUIRE • 7" ROOF RISE
	DOWN ANGLE	8°	3.2°	• SLOPED-DOWN HOOD
REARWARD VISION	VERTICAL FIELD OF VIEW	8°	4.5°	WOULD REQUIRE • 6" ROOF RISE

The second major departure from the DOT objectives is with respect to visibility. This table compares the ESV objectives with those we have established for our car. Since we are retaining essentially the production roof configuration of our base car, the vision angles forward and rearward are very much the same as current production.

To meet the ESV requirements, the roof would have to be raised 7.0 and 6.0 inches respectively, which could drastically reduce the structural integrity of the roof unless compensating structural changes were made. Our concern is more fundamental, however, in that we question the validity of the requirement.

To establish realistic visibility requirements for safe driving, Ford is engaged in a comprehensive study on this subject. We are periodically reviewing the results of this study with the DOT as an alternative to working toward meeting the visibility requirements in our ESV car.

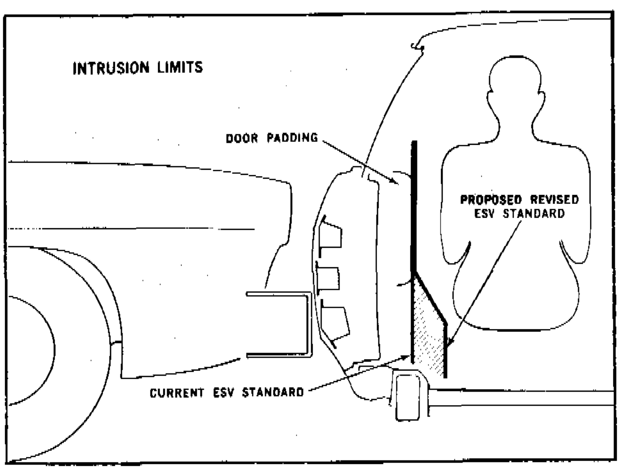
INJURY CRITERIA

	GOVERNMENT E.S.V. POSITION	FORD POSITION
ALL CRASH MODES	CHEST: 60 'G'S MAXIMUM RESULTANT HEAD: 80 'G'S MAXIMUM FOR 3 MILLISECONDS FEMUR 1400 LB. MAXIMUM LOAD	SAME, BUT WITH RESERVATIONS. NOT YET PROVEN AT THIS TIME ARE: SURVIVABILITY AT THESE LOAD LEVELS ATTAINABILITY OF THESE LOAD LEVEL OBJECTIVES
SIDE IMPACT CRASH MODES	SAME AS ABOVE WITH ADDED: 20 G OBJECTIVE FOR OCCUPANT	FURTHER TESTS NEEDED TO ESTABLISH A MORE REALISTIC OBJECTIVE

Injury Criteria

In our ESV program, we are accepting with reservations, the g-level objectives specified in our contract. Our reservations stem from the fact that the tasks involved are monumental, and perhaps impossible, while there is no conclusive evidence that these levels represent human survivability limits or correlate to human response to impact.

With respect to values for human tolerance to side impact, we know of no data reliably establishing acceptable head and chest g-loads. We believe that the 20 g objective for side impact, for example, is not an achievable target within the design parameters specified in the contract, and that further refinement of these specifications is necessary.



With respect to intrusion, rather than setting a three inch limit, we believe that it would be more realistic to define a side envelope around the occupant that would protect against his entrapment under the test impact conditions. Therefore, our program is designed to provide minimum g-levels even if this requires localized intrusion in excess of those specified.

VEHICLE DESIGN

- **DESIGN RATIONALE**
- **ENERGY MANAGEMENT**
- **FRAME**
- **BODY**
- **BUMPER SYSTEM**
- **RESTRAINT SYSTEMS**

Vehicle Design

We will now discuss the design parameters of the Ford ESV. At this point, we would like to stress the fact that our approach has been to put primary emphasis on improved occupant protection. The items affected by this rationale are the energy management between the frame and the body, the frame design, the body front end, the bumper system and the restraint system. A detailed discussion of these items follows.

VEHICLE DESIGN

RATIONALE FOR VEHICLE CONSTRUCTION:

- RETAIN BODY-ON-FRAME CONCEPT
- MAINTAIN FEASIBILITY FOR MASS PRODUCTION
- UTILIZE CONVENTIONAL MATERIALS

Rationale For Vehicle Construction

The design and assembly of this car is basically similar to our full size Ford which is made up of a separate body and a frame.

Also, we have attempted to retain techniques of proven feasibility for mass produced automobiles. Except for the bumper, conventional materials were selected to keep the cost down and maximize the likelihood that we can utilize proven production techniques.

VEHICLE DESIGN

RATIONALE FOR CRASH PERFORMANCE PARAMETERS:

- EFFECTS OF CAR-TO-CAR CRASHES BETWEEN ESV AND
  - OLDER VEHICLES
  - LIGHTER VEHICLES
- EFFECTS OF CRASHES AT SPEEDS LOWER THAN "DESIGN SPEED" OF 50 MPH

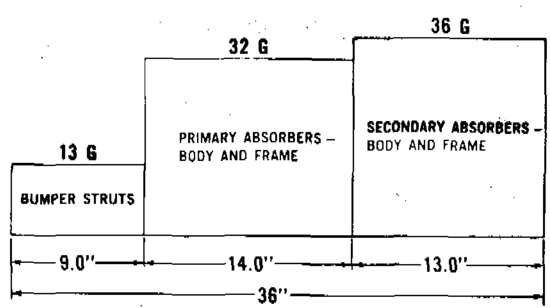
Rationale For Crash Performance Parameters

To design the ESV for improved occupant protection over a wide range of impact speeds, our objective has been to provide some degree of collapse under any crash mode. This approach suggested a front end design that collapses progressively under increasing force levels.

In addition to providing some degree of collapse and, thus, some energy absorption at low speeds, this technique reduces the impact forces imparted to the older and lighter vehicles that might be struck by the ESV.

ENERGY MANAGEMENT

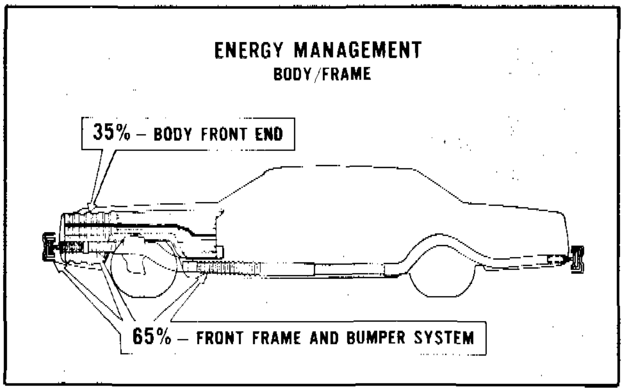
THEORETICAL CRUSH DISTANCE VS PROGRESSIVE G LEVELS AT 50 MPH CRASH



Energy Management

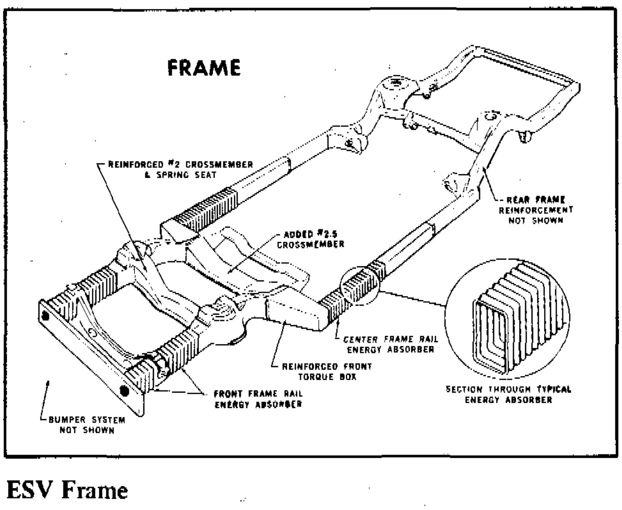
We have taken advantage of the maximum dimensions for overall car and the vehicle wheelbase which are 220 inches and 124 inches respectively. To provide crush distance for front barrier impact, and still satisfy the angle of approach requirement, the front overhang was set at 45 inches. This allows 36 inches of front crush distance with acceptable engine intrusion into the firewall.

The front end is designed to sustain increasingly higher g-levels, from 13 g to 32 g and 36 g. This offers greater predictability of collapse. It also reduces crash loads at lower impact speeds.



The initial front end designs had 90% and 10% for frame and body energy absorptions respectively. This later was revised to 65% frame and 35% body in order to reduce frame frigidity and raise the center of impact resistance line closer to the vehicle center of gravity.

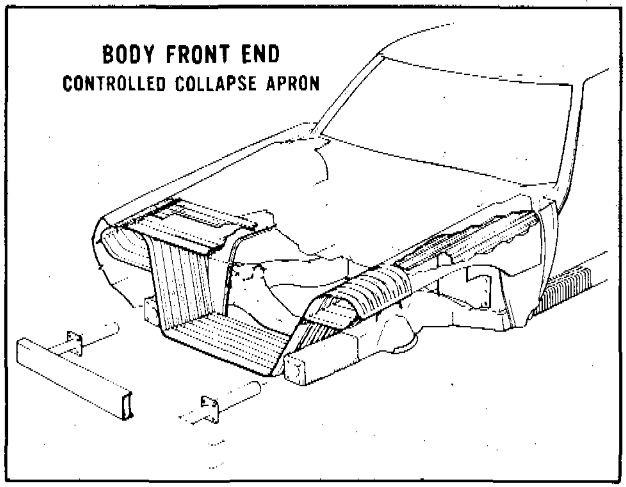
The lower frame force levels result in lower bumper bar loads and improved conditions to cope with pole impact forces while the attendant shifting of the resistance line reduced the tendency of the rear end to kick-up during impact.



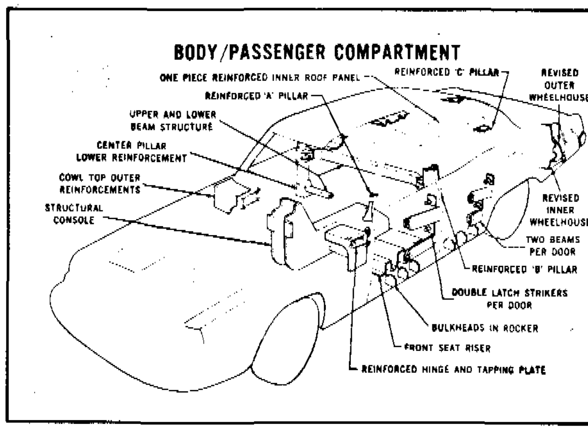
ESV Frame

The general configuration of the ESV frame is similar to the current full-size Ford frame.

The major frame modifications which were implemented to achieve the 65% energy absorption level consist of added convoluted sections ahead of the spring pockets and on the side rails, and adding two cross-members, one ahead of the Number 1 and one at the torque box area (Number 2½). These enhance the lateral rigidity of the front and center frame rails. In addition, the torque box and frame center rail sections were reinforced to withstand the higher level g-forces without bending.



The body front end shown here was designed and developed to absorb 35 percent of the total energy by means of an arrangement, which could best be described as a "controlled collapse apron." It features corrugated sheet metal integrated into the apron. The forward section with transverse corrugations forms a complete hoop after the top section has been bolted on. The bolt-on feature facilitates engine decking. Side structure continues then with longitudinal corrugations toward the firewall for load support.



This slide shows the major structural components of the passenger compartment intended to improve compartment integrity under all crash modes. The basic principle, of course, is to effectively create a "roll-cage" for the compartment to protect the occupants regardless of the crash mode encountered.

The modifications shown here, along with the controlled collapse apron shown in the previous slide, represent the total body changes required to meet the contract objectives for passenger compartment integrity and g loading.

BUMPER FACE BAR PROPOSALS
50 MPH POLE IMPACT DESIGN

	MATERIAL	BUMPER BAR WT.
ORIGINAL CRITERIA - 80,000 LB MAX. FRAME LOAD PER SIDE		
8 × 8, .5	ASTM A500 GRADE B STEEL 46,000 PSI YIELD	300 LB
6.5 DIA., .5	4142-H HEAT TREATED STEEL	160 LB
PRESENT CRITERIA - 40,000 LB MAX. FRAME LOAD PER SIDE		
3.5 × 7, .20	HIGH STRENGTH STEEL 180,000 TO 240,000 PSI YIELD	90 LB

Bumper Face Bar Proposals

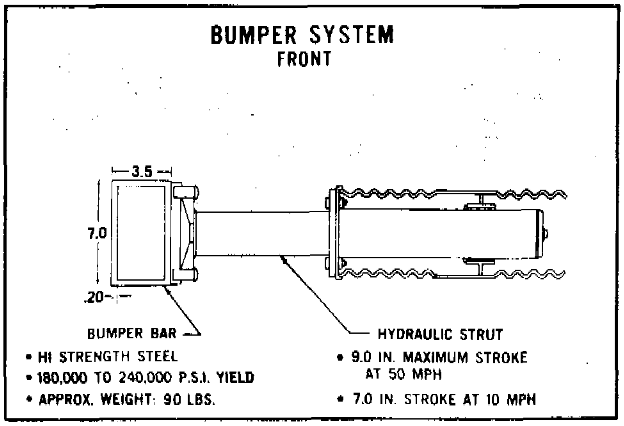
The most extreme test requirement in the entire ESV program is the 50 mph pole impact. In this respect, the design of the bumper system represents a significant design challenge. For instance, if the bumper is designed with conventional materials and a rigid front end, the bumper could weigh as much as 300 pounds. This, of course, is impractical both from a weight standpoint as well as its effect on front end approach angle and structural integrity. Also, this high concentration of mass up front would be detrimental to our design objective of considering the effect of crashes between ESV and older or lighter vehicles.

Our design approach, therefore, is to arrive at a low bumper weight as follows: we increased the portion of energy going into the body appreciably (from 10 percent to 35 percent), and applied the progressive collapse frame design described earlier, which reduces the force level to 40,000 pounds. The resulting bumper design is shown on the last line. The cross section is approximately 7x3.5 inches. Using high strength steel of 180,000 to 240,000 psi yield stress, the bumper face bar weight is approximately 100 pounds.

Tests are underway to develop this design, and the level of success we achieve will be the greatest single influencing factor of our ESV program, particularly with respect to the pole impact requirements.

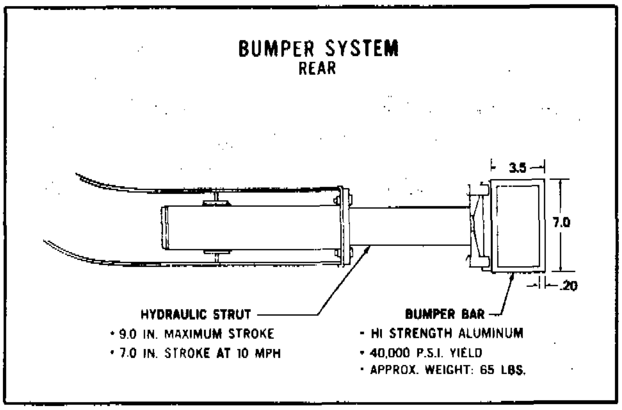
Bumper System – Front

The total front bumper system is depicted on this schematic drawing. The bumper face bar is supported by two hydraulic struts attached to the frame.



This face bar is expected to incur minimum plastic deformation during the pole test and will transmit the impact forces directly to the frame. The hydraulic struts are velocity sensitive and exhibit a low reaction force level at 10 mph for the no-damage feature. They provide a higher reaction force level at 50 mph for effective energy dissipation during the 9 inches of bumper stroke.

As stated previously, the success of the bumper pole test will depend almost entirely on the ability of the face bar to transmit impact forces to the frame.



Bumper System – Rear

The rear bumper system was designed to meet the 10 mph "no-damage" objective during impact. Because the requirements for the rear bumper system are less than the front, we selected an aluminum alloy with a projected weight of 65 lbs. The supporting struts are smaller and lighter than the front bumper struts.

To meet the ESV program objectives, Ford is pursuing development of a passive restraint system employing air bags. In addition, we are pursuing parallel design programs on active restraint systems with energy absorbing belts and a system combining lap belts with passive upper torso restraints.

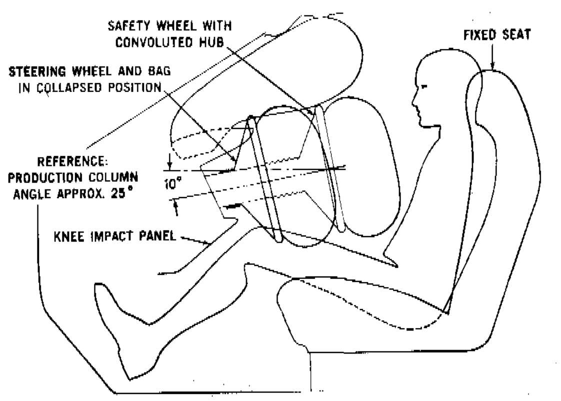
VEHICLE DESIGN

RESTRAINT SYSTEMS

- PASSIVE RESTRAINT
- ACTIVE RESTRAINT

All these systems are a take-off from Ford's current development programs on restraint systems.

PASSIVE DRIVER RESTRAINT SYSTEM

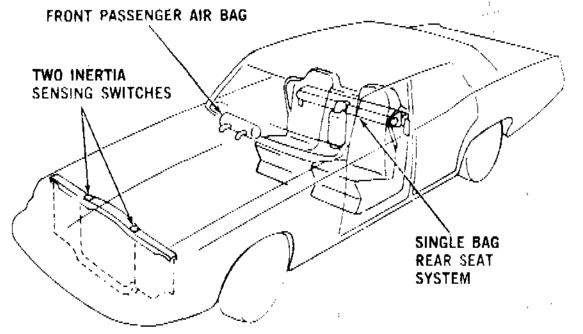


The design and development of this system presents a far greater challenge than the passenger restraint system because of severe space limitations and the complexity of this multiple component arrangement. It consists of one air bag in the steering wheel, a second bag in the cluster, and a controlled collapse steering column. A knee panel augments the system to prevent submarining.

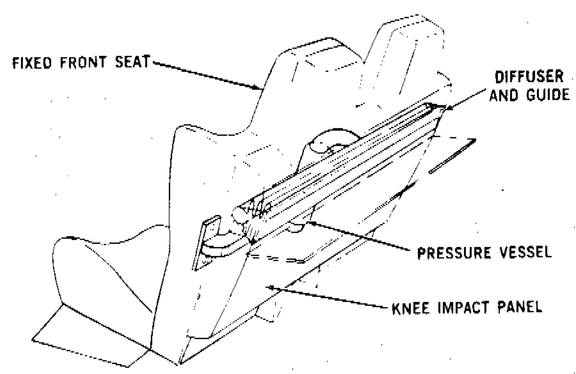
For optimum performance, a rather flat column angle with close coupled steering wheel is required, impairing driver comfort and entry/egress.

The passenger air bag system consists of a single air bag for the front passenger and a common air bag for protection of all rear passengers. Deployment probably will be triggered by two inertia sensing devices mounted on the radiator support, tied in parallel to a 1 g sensor mounted at the firewall to prevent inadvertent firing.

PASSIVE PASSENGER RESTRAINT SYSTEM
ARRANGEMENT



PASSIVE PASSENGER RESTRAINT SYSTEM
REAR BAG DETAILS



Passive Passenger Restraint System – Rear Bag Details

The fixed front seat design allows for direct mounting of the rear air bag, diffuser and knee impact panel rigidly to the seat back. The pressure vessel with gas generator is located at the center of the seat.

Although the passive restraint system remains the primary objective of the ESV program, Ford is developing an active restraint system for 50 mph crashworthiness as a parallel program.

Provided a satisfactory active system can be developed, certain advantages will acrue, such as protection for secondary impacts, prevention of ejection, protection for a wider range of crash modes, positive positioning of occupants, and no noise problem. In addition, the system would be inherently less costly and would weigh less.

VEHICLE DESIGN

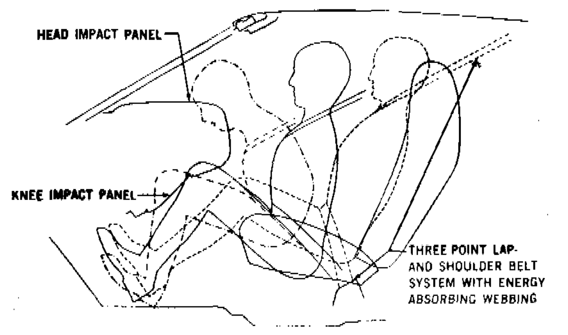
ACTIVE RESTRAINT SYSTEM

- PARALLEL PROGRAM WITH PASSIVE SYSTEM
- COMPARISON WITH PASSIVE SYSTEM

The active restraint system on which we are concentrating consists of impact panels and bolsters coupled with 3-point harness and belt made of energy absorbing webbing. Progress made in energy absorbing webbing has been encouraging at speeds up to 42 mph.

Development will continue to determine impact speed limits of the belt system within package limitations of the interior space available.

ACTIVE RESTRAINT SYSTEM WITH ENERGY ABSORBING BELTS



This slide shows the movement of the occupant restrained by 3-point lap and shoulder belt system made with energy-absorbing webbing. The movements depicted are from kinematics recorded by actual tests.

The success of this system is based on the development of two factors:

1. Development of energy-absorbing webbing with a quick onset rate to constant force level with large elongation.
2. The design and positioning of impact panels for head and knee.

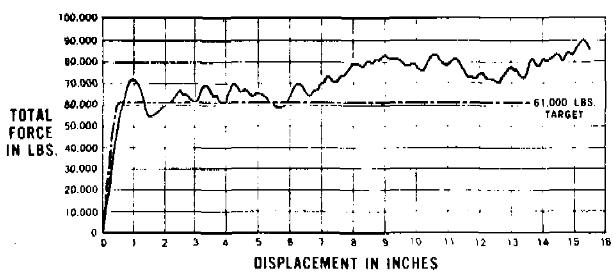
Essentially all the occupants including the driver have the same belt and impact panel system. The steering wheel and column are designed to move forward out of the way at a certain g-level to clear space for the driver movement during the crash.

SUBSYSTEM TESTS

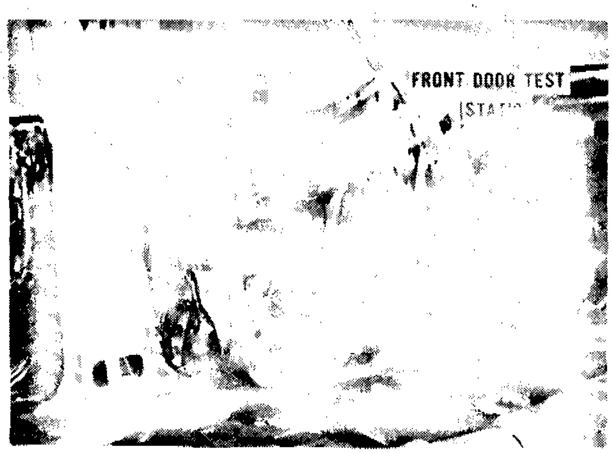
- FRAME AND ENERGY ABSORBERS
- BODY — FRONT END, ROOF, DOORS
- BUMPER SYSTEM — CART TESTS
- RESTRAINT SYSTEMS — SLED TESTS

In this segment, we will discuss a sampling of subsystem tests, both static and dynamic, that were performed before incorporation of that subsystem into completed vehicles. These tests are used to develop subsystems to expected performance levels.

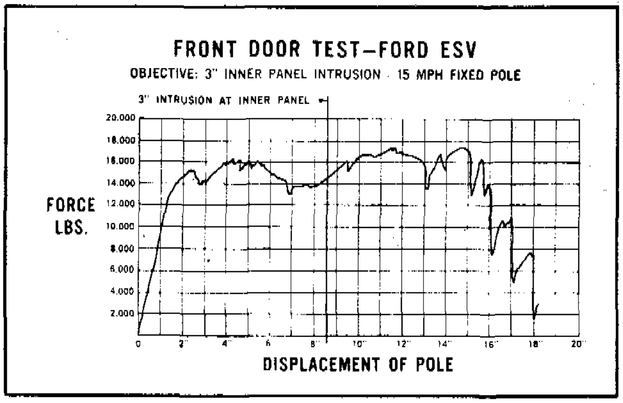
FRONT RAIL & SIDE ABSORBER TEST



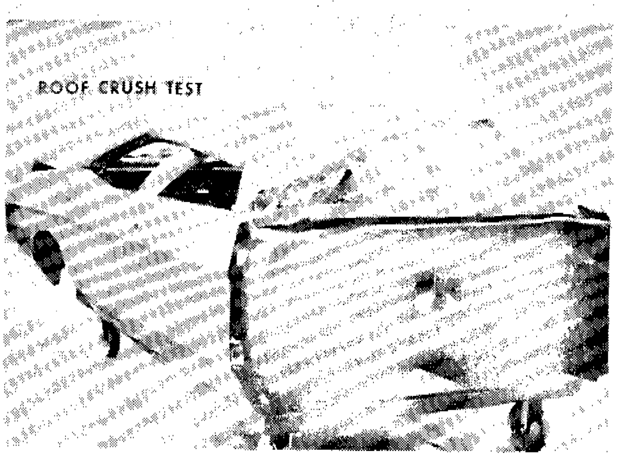
This graph shows a typical force versus displacement curve of a frame sample. The objective was to generate a square wave curve — the absorber section loading up within a short distance and then displacement continuing with application of a constant force level. This sample came close to that objective.



Here you see an early test of the front door to check side loading. A pole impactor of the same size and configuration as the pole for the side impact test was utilized. This particular door was loaded to failure and as you can see, the door latch broke.

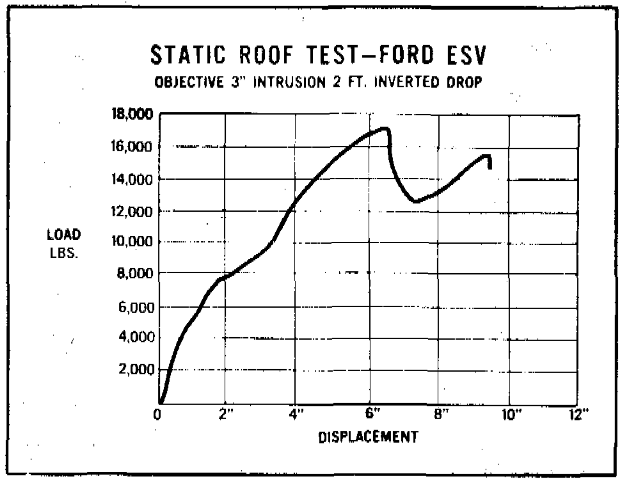


This slide represents the results of a static test conducted on an interim design of strengthened door structure to meet the 15 mph pole test intrusion requirements. The force levels shown here are significantly higher than current production and approach our objectives for force levels compatible with the intrusion requirements.



Static crush tests were also performed on the roof corner to determine the capability of the roof and pillars to withstand rollover loads within the allowable intrusion limits.

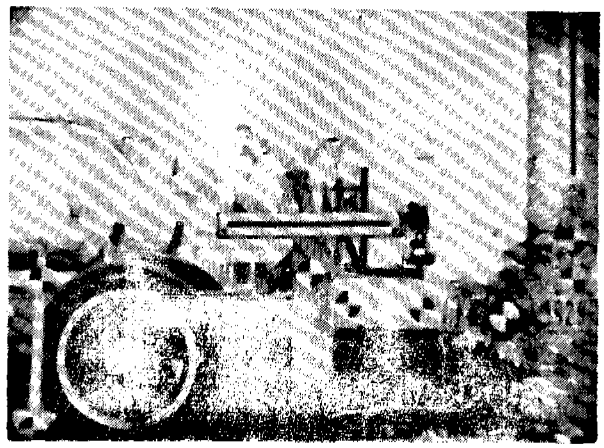
This slide shows a typical static load deflection curve of a reinforced roof and pillar structure of an interim design, to meet the rollover requirements. Test results showed that additional reinforcements were required to meet the three inch intrusion objectives.



Movie Segment A – Narration

Pole Test – 40 MPH

This movie shows a bumper pole test run with a cart at 40 mph. The force level of the struts and the frame convolutions were selected to approximate 50 mph impact loading.



This is a verification of analysis, which showed that a steel forged tube with 6.5 inches in diameter and .5 inches wall thickness would be the sort of device needed to meet the pole test requirements. Obviously, it is not a practical bumper proposal.

As mentioned before, our objective is to develop a bumper face bar of high strength steel with a 90-pound weight target. Work on test samples is currently in progress.

Movie Segment B – Narration

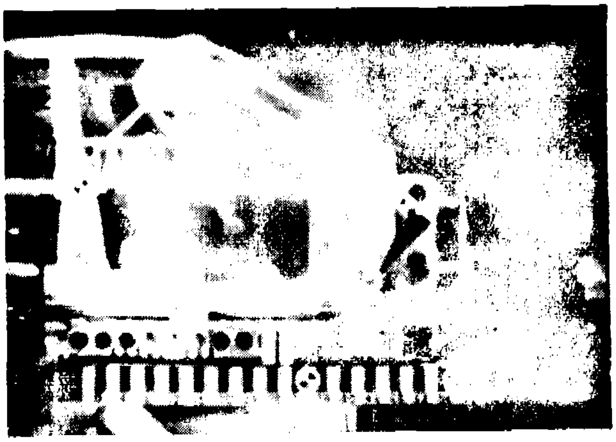
Hy-Ge Sled – Driver System With Air Bags

We shall now show several film clips on the development of restraint systems. This first sequence is the unrestrained driver on Ford's "Hy-Ge" accelerator. The test was conducted at 50 mph. The passive system consists of both a steering column and a cluster air bag. We have not been able to as yet meet the g-level specifications in a 50 mph impact. This is apparently due to the short time the bag has to inflate to the pressure required to reduce the relative velocity between the vehicle and occupant. The windshield fracture in this test was due to cluster bag inflation and not to occupant head impact. At the present time, these bags are sensitive to the occupant's position which has made it difficult to develop a complying design.

Movie Segment C – Narration

Right Front Passenger
Passive Restraint System

These tests were conducted on the linear accelerometer at the University of Michigan. At only 42 mph



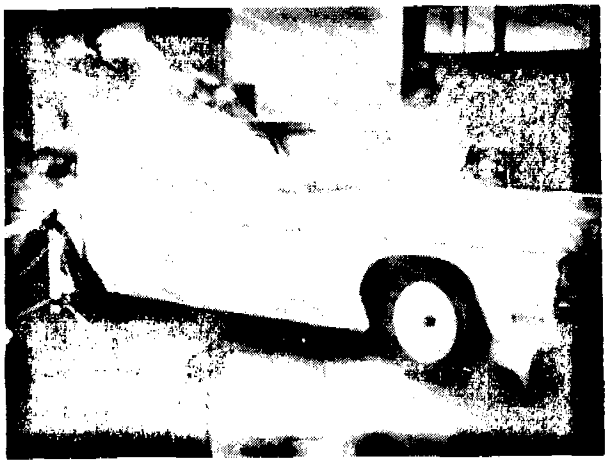
the 50th percentile dummy testing series has met all the contract requirements for head and chest g's in forward impacts, but not for femur loads.

Note the complete encapsulation of the occupant. The checkerboard flag attached to the occupant's head is only a marker used for film analysis and in no way interacts with the air bag. There was some rotation of the occupant during this test. This is due to the positioning of the occupant, and will be corrected in the next test series. Rebound is very minimum and has not produced head deceleration levels above the tolerance criteria.

Movie Segment D – Narration

Air Bag Sound Test

This film sequence is a static sound pressure test in the proposed interior of an ESV. As you can see, all the



tempered side windows are blown out. The rear view mirror twisted and broke during inflation of the cluster bag. The vehicle roof was deformed approximately two inches.

A full complement of dummy occupants was placed inside the car. Microphones and pressure transducers were located approximately one inch away from the dummies' ears. The sound levels ranged from approximately 174 to 176 db. When analyzed according to the criteria recommended in the Bolt, Beranek and Newman Report, it appears that approximately 15-25 percent of the population would incur hearing impairment.

In previous tests, tempered side windows were retained in frames and did not blow out, but vehicle doors and window frames incurred approximately two inches of permanent deformation.

A considerable amount of additional work will be necessary to bring the sound pressure levels within the human tolerance range, and still maintain the required inflation times to reduce the occupant's relative impact velocity.

Movie Segment E – Narration

The next film will show tests with energy absorbing shoulder and lap belts. The test was run in a sled at 42 mph in the absence of windshield and roof header. The test run shows a comparison between the dummies with the current production belt on the left side and the energy absorbing webbing belt on the right side. Notice that the production shoulder belt broke while the energy absorbing webbing on the right side elongated and retained the dummy. Notice also the absence of severe rebound of the dummy restrained by the energy absorbing shoulder belt.

RESTRAINT SYSTEMS
STATUS OF DEVELOPMENT

42 MPH SLED TESTS – PASSENGERS ONLY

HAVE ESV CRITERIA BEEN MET?

	AIR BAGS		E.A. BELTS	
	50TH PERCENTILE	95TH PERCENTILE	50TH PERCENTILE	95TH PERCENTILE
HEAD	YES	YES	NO	NOT YET TESTED
CHEST	NO	NO	YES	
FEMUR	YES	NO	YES	

This table summarizes the status of current development with restraint systems at 42 mph impact speeds.

Head loads with E.A. belts were slightly over the specified limits. We suspect this is a function of test dummy kinematics, rather than a reflection of exposure to hazardous load levels.

Chest criteria were slightly exceeded with air bags for both the 95th percentile dummy, but were acceptable with energy absorbing belts.

Femur loads pose a problem for the 95th percentile with air bags: The load far exceeded specified limits. Much more development with impact panels will be needed to bring these loads down.

Testing of the 95th percentile dummy with energy absorbing belts is planned for the near future.

It should be pointed out, however, that the sled test serves primarily as a tool to improve restraint systems, but the test results do not necessarily reflect system performance in a vehicle crash test.

VEHICLE CRASH TESTS

BARRIER	• 50 MPH BARRIER – BASELINE '71 FORD • 50 MPH BARRIER – FORD ESV • 50 MPH REAR MOVING BARRIER – FORD ESV
POLE	• 50 MPH FIXED POLE – FORD ESV
SIDE	• 35 MPH ESV TO ESV SIDE IMPACT • 15 MPH SIDE IMPACT – FIXED POLE – FORD ESV

Vehicle Crash Tests

We are now going to show you film clips of complete vehicle crash tests, which were conducted at our Dearborn test facilities during the preliminary phases of our program. These clips include 50 mph barrier crashes, one pole impact test aand side impact tests at 35 and 15 mph respectively.

Movie Segment F – Narration

50 MPH Barrier – Ford Baseline

The first film shows a 50 mph barrier crash of a production Ford to establish a baseline. Notice in this

slow motion shot the kick-up at the rear end, which results in imparting a severe bending moment into the system.

This test clearly demonstrated the tremendous energy levels generated in a 50 mph crash. It further demonstrates the magnitude of the task ahead of us.

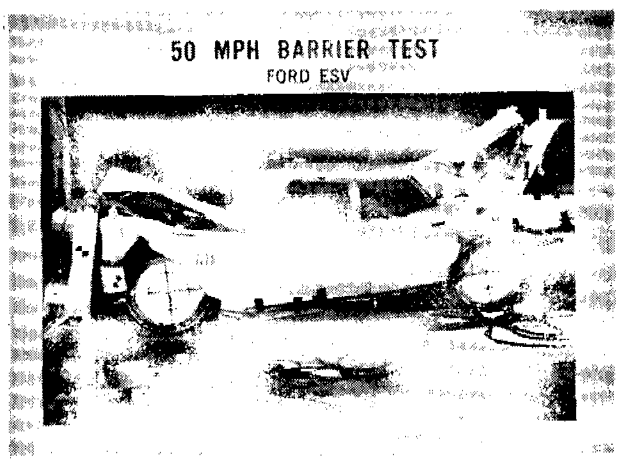
Movie Segment G – Narration

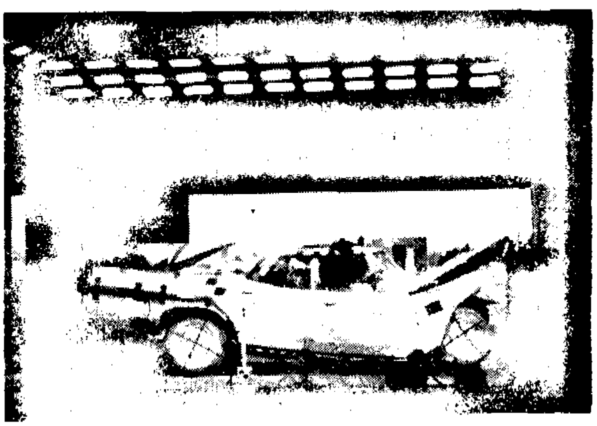
50 MPH – Barrier ESV

This is the first 50 mph barrier crash of our safety car. Notice the energy absorbing convolutions in both the front and side rails of the frame. It is also evident that the rear end kick-up has been controlled considerably. The occupants were restrained by energy absorbing belts. Since our primary interest at this time was the occupant kinematics while restrained with active systems, the steering column system was removed.

Compartment integrity was maintained and instrusion was greatly reduced. The fuel cell did not rupture. Although the frame crush mode did not quite perform as designed, crush distance was very close to prediction.

We believe that our efforts have been successful with respect to passenger compartment integrity and vehicle rebound from the barrier. As far as g-level readings are concerned, our analysis indicated that relatively "soft" frames would not withstand a 50 mph barrier crash satisfactorily because of a high spike at the end of the sequence when the frame ran out of crush distance. On the other hand, this initial attempt at stiffening the structure resulted in g-levels much higher than desirable for an acceptable ESV.



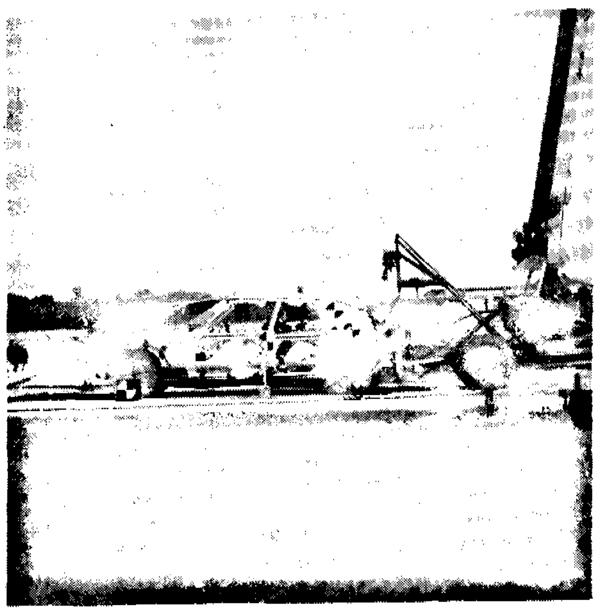


A review of these findings led us to adopt the design approach in which we are attempting to incorporate design features in our ESV that would produce controlled crush progressively increasing energy absorption in order to limit the g-levels on the occupants.

Movie Segment I – Narration

50 MPH Rear Moving Barrier – Ford ESV

The next film shows the rear impact of our ESV by a movable barrier at 50 mph. The frame and the reinforced rear end sheet metal absorbed all of the energy as projected. The fuel cell was located above the axle in a space completely enclosed by sheet metal. There was no fuel spillage during this test. As the vehicle was turned over to one side for undercarriage inspection, there was slight leakage through the filler cap, which was caused by a faulty filler cap gasket and not by the crash.



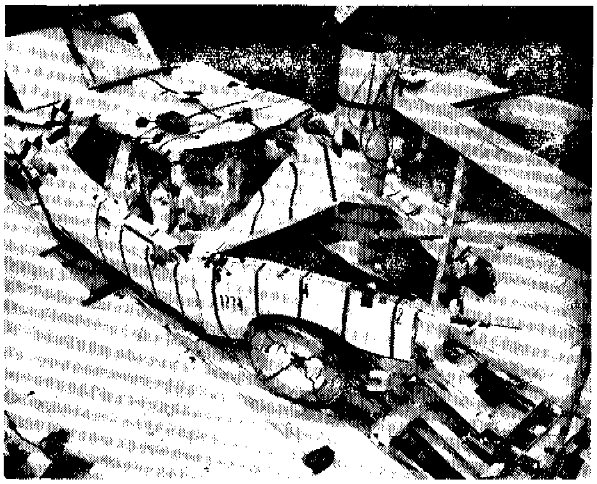
The collapsable spare tire is located in a horizontal recessed well below the trunk floor level.

The g-levels of the front dummies were within specifications. The unbelted left and right rear dummies moved up, which caused contact with the backlight header resulting in high g loads.

Movie Segment J – Narration

50 MPH – Pole – Ford ESV

This film shows the first 50 mph pole crash with our initial high impact bumper system concept. The vehicle had the same initial, rigid frame design seen in the preceding barrier crash film. It demonstrates once again that the bumper face bar design is the key to the success of the pole test.

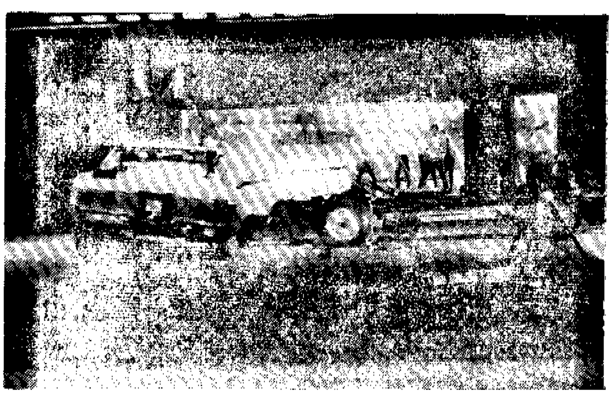


Our bumper development program described earlier, along with the approach of controlled front body sheet metal and frame crush, should permit us to improve pole crash performance significantly. We have seen no evidence to date, however, that would allow us to conclude that a 50 mph pole impact objective can be achieved with a practical design.

Movie Segment K – Narration

35 MPH – Car To Car – Side Impact

This is the first 35 mph safety car to safety car side impact crash test. The struts collapsed to their stroke, thereby absorbing all of the impact energy; consequently, there was no collapse of the front convoluted frame of the bullet car. The bumper impact covered the entire length of the body between the "A" and "C" pillars. Compartment intrusion was moderate, although it was slightly above ESV specifications. The tempered side windows were blown out due to inertia loading rather than vehicle contact. The occupants were unrestrained in this test which accounts for the excessive rolling toward the impact site. There was severe head "banging" in the rear seat. The 50th percentile right rear occupant's head severely impacted the center right occupant's head. The occupants were not entrapped by the intrusion of the inner panels.



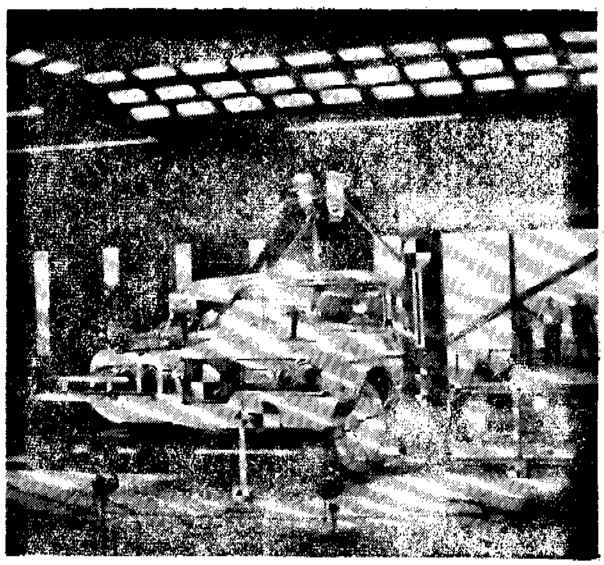
Movie Segment L – Narration

15 MPH Side – Fixed Pole – Ford ESV

This film shows an ESV side impact into a pole at 15 mph; this was the second test of this type. The first indicated the need for additional side structure, which were incorporated here. All doors remained closed, and there was no excessive amount of compartment intrusion, nor was there very much frame side rail deformation.

The occupants in this test were lap belted. In our previous test the occupants were not restrained, and severe head banging between rear seat passengers resulted. This was considerably reduced in this test due to the restricted occupant movement with lap belts.

This test is considered a success, since there was no entrapment of the occupants. However, we did not meet the objective of a maximum 20 g for occupant lateral impact loads, and we do not expect to meet this objective within limitations of the ESV package with regard to width and three rear passenger seating.



FORD ESV PROGRAM

CONCLUSION

Conclusion

Now, in conclusion, let me make some general observations which come to mind as a consequence of our recent experience in the ESV program and offer one or two constructive suggestions as to the course that future efforts ought to take if experimental safety vehicles are to play a significant role in the realization of the highway safety goals we hold in common.

First of all, I'm sure my report on our efforts to date must have sounded promising in terms of reaching the objectives set for the program, for we have, indeed, made progress. Lest anyone be misled with respect to the significance of our accomplishments, however, I must emphasize that we have not yet developed designs that satisfy the contract objectives, nor have we achieved the additional Ford goals of manufacturing feasibility in mass production and acceptable safety in real world highway operation. As we all must recognize, it is one thing to develop a theoretically adequate solution to a design problem and quite another matter to make it work effectively, time and again, in practice.

It is also appropriate to note that the analytical processes that must go into responsible design of an experimental safety vehicle will necessarily identify areas of performance that deserve additional attention. The solutions that must be found in order to achieve meaningful occupant protection in a 50 mph barrier crash without resorting to designs that actually endanger occupants in lower speed collisions is a good example of invaluable by-products that should come from experimental safety vehicle research. Data recently generated by Ford studies of the distribution of speeds at which fatal accidents occur have highlighted the critical importance of the designer's task in maintaining occupant protection in lower speed crashes while striving for improvements in 50 mph impact protection. We are confident that recognition of the overriding importance of "real world" safety performance will lead to the addition, in future safety experimental vehicle programs, of cross-checks aimed at assuring that one or another goal of a development contract is not achieved at the sacrifice of occupant protection in real-world highway accidents.

Similarly, much of our optimism about experimental safety vehicles stems from our confidence that all involved parties – development contractors and contracting agencies alike – will maintain open minds toward the refinement of project objectives to recognize and accommodate the latest developments in safety technology. We expect, for example, that the intensive efforts now underway in government and in industry to identify a realistic means of correlating instrument readings derived from test manikins with the responses of human beings who are subjected to collision impacts may yield data from which it will be possible for the first time to honestly predict the significance of such instrument readings in the real world of highway accidents. The same can be said about the design and use of our basic working tool, the manikins themselves.

As information of such fundamental importance develops, we intend to share it, and we have every confidence that DOT will not only encourage the other contractors to do likewise, but will facilitate the refinement and application of such knowledge so that it does, in fact, contribute to further reductions in the rate of highway deaths and injuries.

Finally, the formidable challenge of designing a vehicle that is both suitable for widespread highway use and feasible for volume manufacture deserves to be mentioned again. We are sure that Ford is not alone in imposing on itself the basic design constraints of compatibility of its experimental safety vehicle design with older and lighter vehicles it will encounter on the highways, as well as feasibility of its designs for economic, mass production.

Whether or not we can successfully meet all of our goals remains to be seen. But I can assure you, we intend to give everyone a run for his money.

SECTION 2

PART 2

THE GERMAN TECHNICAL PRESENTATION ON ESV DEVELOPMENT

THE VOLKSWAGENWERK A.G. – *General View about Progress and Problems Concerning ESV*

Prof. Dr. E. Fiala

Work on the ESV of Volkswagenwerk was begun in Autumn 1971 with the object of investigating the realisability of the specifications by means of the laws of physics. The first investigations have led to the following information which has subsequently been verified by basic tests.

> 1. CONSTANT DECELERATION OF PASSENGERS AND VEHICLE
> 2. BEGINNING OF DECELERATION OF PASSENGERS WITH THE SMALLEST POSSIBLE TIME DELAY

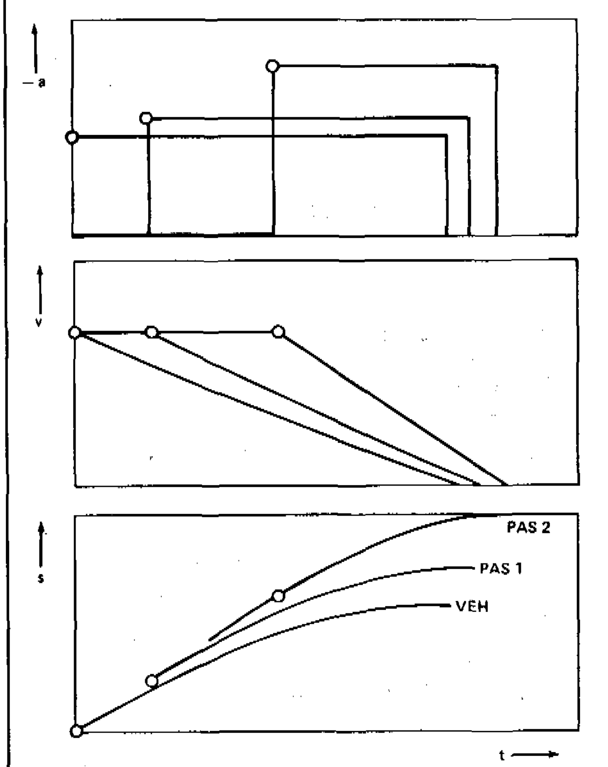
Slide 1

1. Constant deceleration of both occupants and the vehicle must be aimed at.
2. The commencement of the occupants' deceleration must follow the commencement of vehicle deceleration with the minimum delay possible.

Slide 2 shows that a later time of commencement of deceleration of the occupants (red curve compared with the green one) leads to an unacceptable great forward displacement of the occupant also at raised rates of deceleration. This means that the restraint elements must be either rapidly effective (e.g., by preloading belt) or already in action prior to the commencement of vehicle deceleration (airbag).

These two basic findings have resulted in furthei theoretical investigations on acting together of vehicles with different weights and of various restraint systems. These will be reported on at the meetings.

A short film is used to show the stage reached in these basic trials which are also for ESV component development.

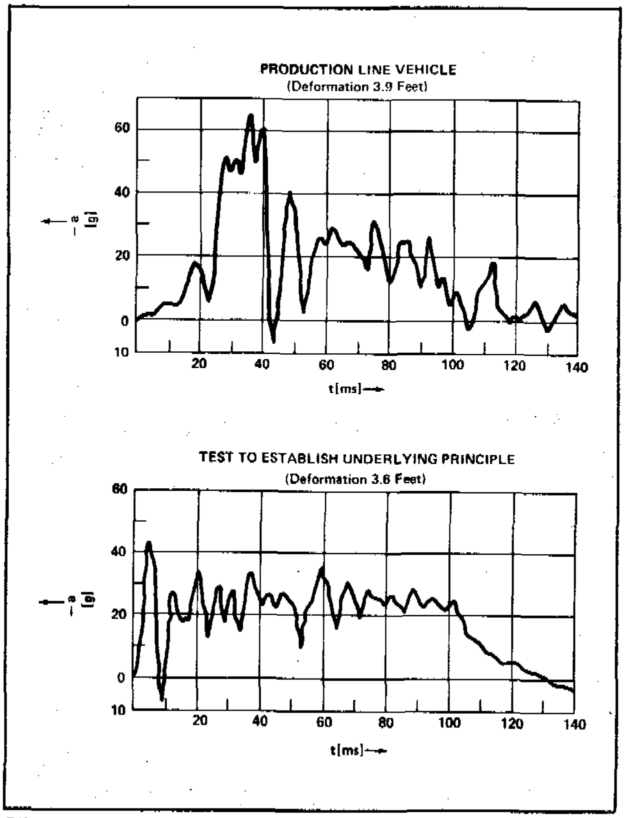


Slide 2

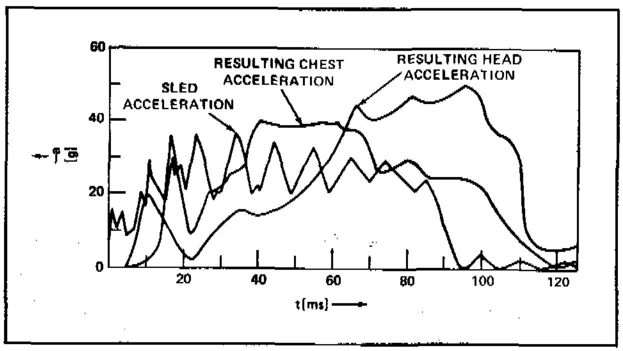
Film

a. 3 scenes of a pole-crash at 50 mph
b. 2 scenes on the effectiveness of the water damper at 30 mph
c. Sled tests at 50 mph with 50% dummy and shoulder and knee belts with preloading and force limiting.

Slide 3 shows the deceleration versus time of a vehicle made up to the ESV specifications as compared with a vehicle of 1070 kg which is no longer in production. Resulting from the constant acceleration a much lower peak acceleration is reached with less total deformation.



Slide 3



Slide 4

Slide 4 illustrates the resultant chest and head accelerations on a 50 mph sled test. In this test a 50% Alderson dummy was used and the restraint was comprised of a belt with pretensioning and force limiting. The relative displacement of the chest was 260 mm and of the head 380 mm. The resultant accelerations have an adequate safety margin within the ESV limits.

Equivalent considerations and tests have been also conducted on other specifications (side and rear impact) with the aim of developing serviceable components to meet the details of ESV specifications.

These basic considerations however, led only to the real problems of the ESV, that is

1. Integration of the components developed into the conception of the ESV, taking into account the feasibility of manufacture and the price economics, and
2. The question for the cost-benefit-ratio of such a safety vehicle.

Cost-Benefit-Ratio

Although a detailed study will only be possible after the development work on the ESV is complete and further statistical material is available, a rough estimate based on statistics already on hand and on optimistic assumptions should provide a general picture.

COST-BENEFIT ANALYSIS

Safety Measures		Reduction In Injuries %	Estimated Use Of Effect %	Effectiveness %	Benefit (N) (Relative)	Cost (K) (Relative)	N/K
30/20/30	4 Hipbelts	35	30 30	10.5	1	1	1
	4 3-Point Belts	45	30	13.5	1.28	1.2	1.07
	4 3-Point Belts With Forced Application	55	70	38.5	3.67	2.0	1.83
	Passive Belt	55	90	49.5	4.81	3.0	1.6
	Airbag	55	90	49.5	4.81	6.0	0.8
Passive Backholding Systems	45/30/45	57	90	51.3	5.14	10.0	0.51
	ESV	60	90	54	5.43	15.0	0.36
	60/40/60	61	90	55	5.53	20.0	0.28
NHTSA April 71	30/20/30	–	–	–	~2	~3	~0.67
	45/30/45	–	–	–	~4.83	~4	~1.21
	60/40/60	–	–	–	~5.83	~5	~1.16

Slide 5

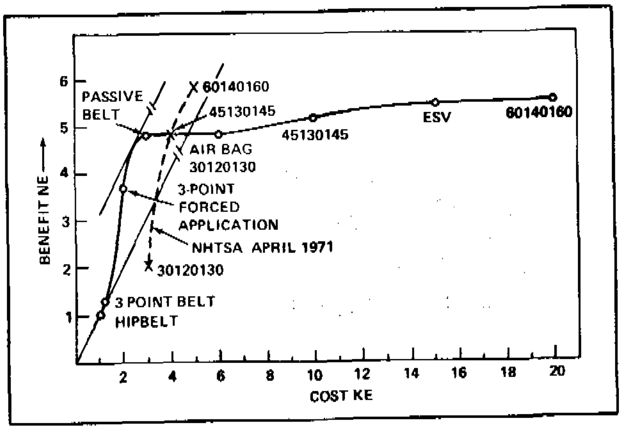
In line with NHTSA studies in April 1971 the following figures have been assumed for the area of the United States:

40,000 fatalities per annum
1,800,000 injured per annum
10,000,000 new vehicles per annum

Benefit: The value lost through one fatality is rated for economics purposes as equivalent to that for 20 injured. The basis used is that of a vehicle which complies with the 1970 US Standards but which is not fitted with safety belts. The first investigations are on the effects of measures taken for the various types of accident in 30 mph rear-end collisions. It is, for example, assumed that the lap belt can prevent death or injury in 35% of typical accidents. The effectiveness of the belt is reduced from 30% to 10.5%, due to the frequency of use. Benefit and costs of these measures will be used as unit term for the remainder of the proceedings.

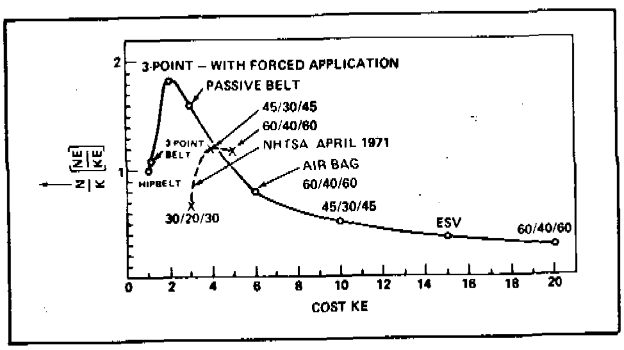
With regard to the requirements at higher rates of impact (e.g., 45 mph head-on, 30 mph side-on, 45 mph rear-end) an optimized passive restraint system has been assumed. The values so estimated are then compared with the results in the NHTSA studies.

The results are detailed in Slide 6. The estimations illustrated here show a marked increase in benefit in consequence of improved restraint systems under the currently customary speed requirements (30-20-30). The



Slide 6

increase in benefit through increased speeds is limited compared with this, whereas there is a vast increase in costs. These results are in contradiction of these of NHTSA according to which it is anticipated that there will be a considerable increase in benefit for only slight increase of costs with increase of the speeds.



Slide 7

Finally in Slide 7 the cost-benefit-ratio is demonstrated. According to these estimates a maximum is obtained for compulsory wearing of a 3-point safety belt. Even the passive belt shows a lower cost-benefit-factor because the increase of costs by more than 50% over the compulsorily-worn 3-point belt is not balanced out by the greater frequency of use. There is however undoubtedly an increase in comfort which could not be taken into account in these investigations. The NHTSA study shows a maximum for a vehicle more or less corresponding to the ESV specifications.

Because of the essential differences in these comparative investigations and the importance given to these problems for social reasons further work on them is urgently necessary.

In conclusion it may be stated that the investigations so far conducted on the ESV by the Volkswagenwerk have indicated that the engineering problems appear to be soluble but the economic and social aspects urgently require further investigation.

THE DAIMLER-BENZ A.G. – *The Development of the ESV as seen by Daimler-Benz*

Dr.-Ing. Hans Scherenberg

Outline of Technology in the Federal Republic of Germany

The effort towards safety must involve people, the road and the vehicle. Automobile engineers can only influence the last factor. The Daimler-Benz AG has been endeavoring for more than four decades to increase both active and passive safety of its Mercedes-Benz vehicles. Initially, these efforts were concentrated primarily on improving driving safety in accordance with the then existing level of vehicle technology. The introduction of independent wheel suspension, double-action shock absorbers and the first version of a dual circuit vacuum power braking system as milestones of this development should be mentioned in this connection. A highlight in the development of active safety was the introduction of the Mercedes-Benz/Teldix Anti-Bloc-System in December 1970.

In the years after 1946 the continuing further development of driving characteristics was accompanied by numerous improvements of the interior safety, such as safety door locks, crashworthy passenger compartment, elimination of sharp edges in the interior, safety steering system, etc.

Utmost Safety for Production Vehicles

The efforts of Daimler-Benz toward safety were always and still are characterized by the fact that all proven concepts were and are introduced into regular production as soon as feasible. The aim was not and is not to produce a safety vehicle as a demonstration object, but to achieve continuous progress which can be used to the benefit of drivers on the increasingly overburdened roads in as short a time as possible.

This progressive vehicle concept proved its worth in 1967 when the first "Motor Vehicle Safety Standards" for the 1968 US model year were published. After a few minor technical modifications those specifications were met by Mercedes-Benz production passenger cars – export of these vehicles to the USA was never affected. The changes of production, however, simply on account of minor changes in the corner radii of instrument panels, or mirror bezels for example caused considerable difficulties and tooling costs.

In November 1970 the well-known "Memorandum of Understanding" between the Federal Republic of

Germany and the United States was established. This posed the important question as to who in the Federal Republic would be in a position to organize and finance this project. Unfortunately the German automobile manufacturers could not expect financial support from the authorities to undertake such a project.

The German automobile industry therefore founded the working committee for the "safety vehicle" which, in the space of a few months, formulated the specifications for a safety vehicle of the lower middle range – a document which it submitted to the German Federal Minister of Transport in December 1970.

The Mercedes-Benz Experimental Safety Vehicle

It proved impossible to create a joint German project. It was only possible for Daimler-Benz to commence with a certain amount of exchange of experience and division of effort together with BMW in the field of component-development. It was therefore decided in February 1970 to extend the on-going work in the safety area by developing our own Experimental Safety Vehicle. The basis was to be a production car – the Mercedes-Benz 250.

This fundamental decision was followed by the conclusion that one should proceed according to a step-by-step concept, so that here too, any interim results could be put into practice in regular production and the separate stages of the experimental safety vehicle would not develop too far away from production applications.

In the field of active safety the decades of safety-oriented development, particularly of handling characteristics, have brought Mercedes-Benz production vehicles close to the limits of the physically possible optimum. It was therefore only a question of tuning in order to achieve the handling characteristics required by the Specifications. The safety requirements for occupant environment, visibility and operational control systems were achieved within a few weeks, even though the views of the Daimler-Benz engineers concerning the optimum solutions in some of these areas and in part also the handling characteristics varied greatly from those defined by the Specifications. Strict criteria had always been applied in this regard which necessarily led to a very definite design. At Daimler-Benz the safety concept of an automobile has always started with active safety. Hence also the successful efforts in the development of the Anti-Bloc-System.

The degree of passive safety achieved in the first prototype did not meet the requirements of the Specifications in all respects, and in fact no one had expected the possibility of increasing passenger protection–taken as a whole – by a factor of 2.5 within just a few months.

Even today the final target has not yet been reached completely with the latest ESV (Figure 1) despite

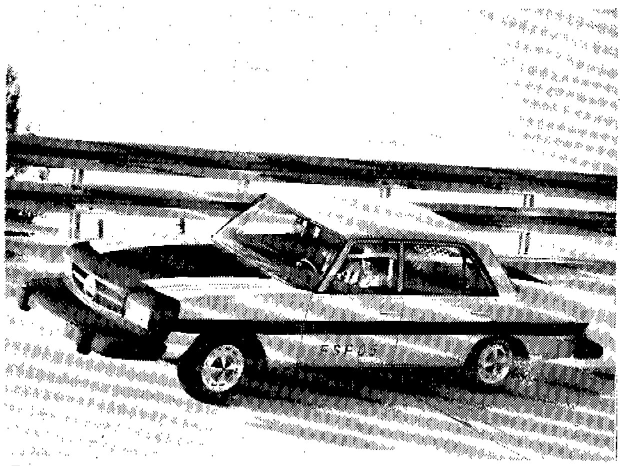


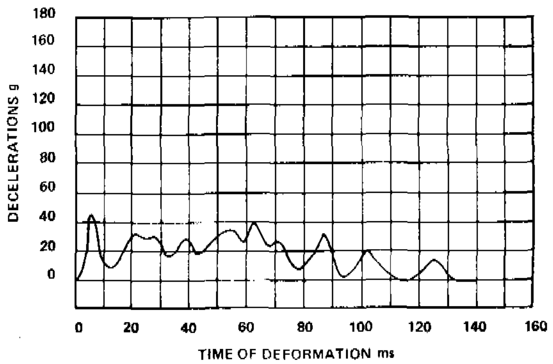
Figure 1

extreme weight and design effort. The passenger compartment stands up to the enormous impact forces in a head-on collision against a fixed barrier at 50 mph (80 km/h). The crush structure in front of and behind the passenger compartment – a principle applied also to this vehicle – has been shown to absorb the impact energy in a satisfactory manner. The passenger compartment deceleration rate is lower than the American requirements but Daimler-Benz considers that these values do not necessarily constitute an optimum.

Investigations concerning other possibilities of absorbing energy, instead of deformation of car body parts, are being carried out parallel to this work. These include, for example, very large volume hydraulic shock absorbers as already proposed by other firms. Such elements promise more favorable and more easily controlled deceleration characteristics, but at the present stage of technology they impose considerably greater weights and higher costs. Therefore these methods are at present only conceivable for an experimental safety vehicle in as much as the reliability of proper operation of such units over a longer period of time is yet completely unknown. Such units must remain functional for 5 or 10 years, i.e., the lifetime of a vehicle, perhaps even being required to operate for the first time after such a long period.

Against a Wall at 50 mph (80 km/h)

Head-on collisions in street traffic are responsible for more than 50% of the deaths and injuries. Therefore the requirements for the Experimental Safety Vehicle are particularly stringent in this regard.



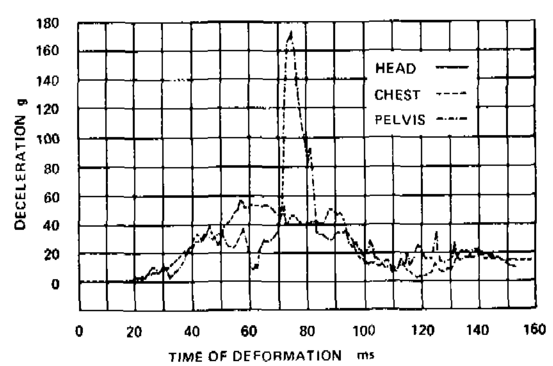
DECELERATION $a_{0.005}$ = 31 g

Figure 2

The values obtained during a crash test with the ESV at 50 mph (80 km/h) convey an impression of the level achieved at this time. Figure 2 shows the deceleration of the passenger compartment versus the deformation time. With 31 g the value remains below the requirements set by the American Specifications, but the required front end crush is then relatively great.

The injury criteria of the occupants have been established in the Specifications for the head (max. 80 g), for chest and pelvis (max. 60 g) and for the femurs (max. 640 kp). The values obtained with dummies for the occupant positions (Figs. 3 to 6) vary greatly from each other. This may be due partly to differing adjustment of the restraint systems and partly to shortcomings inherent in the dummies – which will be dealt with later. The restraints combined the use of belts and air bags.

Figure 3 shows that the pelvis deceleration and the force acting on the left femur of the driver exceed the permissible limit, since the three-point safety belt and



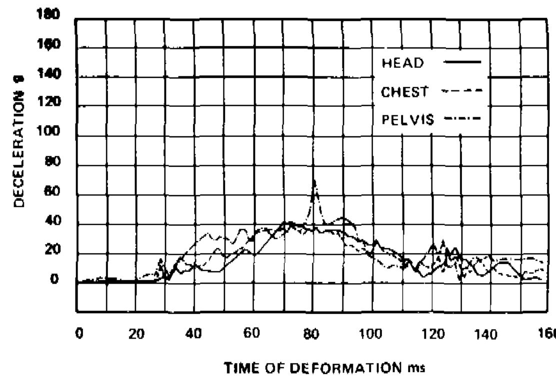
DECELERATION $a_{0.003}$		THIGH FORCES	
HEAD	*		
CHEST	54 g	LEFT	1080 kp
PELVIS	157 g	RIGHT	600 kp

* MEASUREMENT INCOMPLETE

Figure 3

the air bag located in the steering wheel both failed at the same time. (The head deceleration failed to be recorded since one of the three signal amplifiers had failed and the resulting deceleration could not be evaluated.)

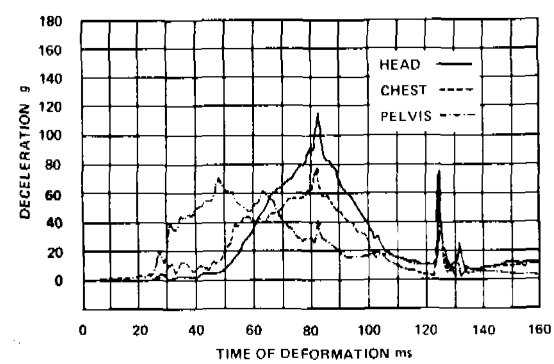
In the case of the front passenger, who was protected by a lap belt and air bag, all requirements of the Specifications were complied with (Figure 4).



DECELERATIONS $a_{0.003}$		THIGH FORCES	
HEAD	64 g *		
CHEST	36 g	LEFT	520 kp
PELVIS	54 g	RIGHT	440 kp

Figure 4

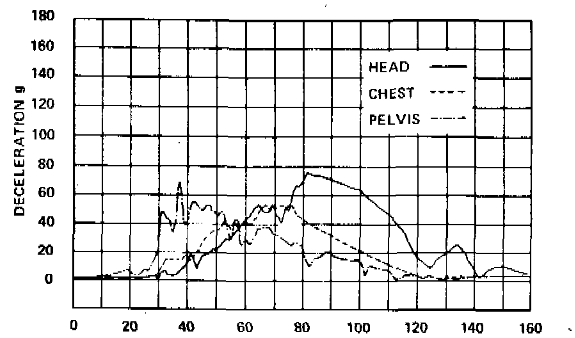
Also in the case of the left rear occupant the deceleration values are relatively favorable (Figure 5). Only the maxima of the head and pelvis deceleration values are a little too high. All data recorded for the



DECELERATIONS $a_{0.003}$		THIGH FORCES	
HEAD	91 g		
CHEST	60 g	LEFT	320 kp
PELVIS	64 g	RIGHT	440 kp

Figure 5

right rear passenger were lower than the injury criteria (Figure 6).



DECELERATIONS $a_{0.003}$		THIGH FORCES	
HEAD	73 g		
CHEST	51 g	LEFT	520 kp
PELVIS	52 g	RIGHT	480 kp

Figure 6

If the results for these two rear passengers are compared a discrepancy is apparent which is probably attributable to shortcomings in the dummies. Both rear passengers were protected in exactly the same manner with lap belts and air bags. Even so different deceleration values were recorded.

During this test and in many previous tests some restraints, air bags as well as belts, failed to function as required. None of these has yet been developed to a satisfactory level to meet these high impact speeds, while the safety belt is known to function reliable up to about 30 mph (50 km/h) and analysis of collisions on the road has confirmed that it offers a satisfactory degree of protection in actual accidents.

Injury Criteria and Biomechanics

The values obtained with dummies partly exceeded the injury criteria for occupants even though the restraints functioned as intended. This poses the questions as to whether the presently specified values have been adequately substantiated by biomechanical research. The aim of this research is to ascertain the degree of mechanical stress the human body can stand. The aids used are mathematical models, experiments with animals, volunteers and finally also human cadavers. Unfortunately each process imposes limits on the researcher. The validity of mathematical models and the conclusions drawn from experiments with animals are under dispute; volunteers can usually only be subjected to a degree of stress far below that required for accident research. Except for certain medical purposes, the use of cadavers is generally forbidden by law and also by moral principles.

Automobile manufacturers can only hope that medical institutes will carry out biomechanical research within the scope of their possibilities and above all with the support of governments, calling upon the assistance of automobile engineers, and that this research may soon produce the urgently required knowledge. Daimler-Benz has endeavored to help in this respect and important information has been gained but the call now goes out to the government to play its part in taking the appropriate measures.

Problematic Dummies

In the meantime, the automobile engineer makes do with dummies which unfortunately often do not provide reproducible results. These dummies today constitute a serious problem within the scope of development work for passive safety. They are supposed to help in determining the risk of injury to passengers in terms of exact measurements. Is that really possible at the present stage of development of these dummies? The answer must be, no. They fail to meet two basic prerequisites:

1. The correlation between the dummy and the human body is not known.
2. The results obtained with dummies are not reproducible.

Despite this, dummies are to be used to prove compliance with ESV Specifications or even legal requirements – a totally unsatisfactory situation.

It is therefore a supremely urgent present day task to standardize a dummy according to the very latest knowledge, to define the correlation between dummy and the human body and to ensure that its behavior and indicated values are reproducible.

The shortcomings of the dummies are naturally also reflected in the development of restraints. The automobile engineer develops and compares safety belts, padding and air bag systems. The functional efficiency of these devices does not differ in orders of magnitude. How therefore are we to determine a conclusive difference of 10% or 20% in the injury level when the values of the dummies vary by ±35%?

The legal deadline for the introduction of passive restraints in the USA has meanwhile been postponed. It is to be hoped that with the belt restraint systems, thus coming into the foreground – with warning systems and ignition interlocks if the belt is not fastened – more people will actually use their safety belts and that eventually clear statistical evidence can be obtained of the success of this measure. This would leave open the possibility that passive restraints would not be necessary in the near future.

Side and Rear-End Collisions

Lateral collisions with trees are usually of devastating effect. The side impact on the middle of the door at 15 mph (25 km/h) against the pole as required by the Specifications produced a 4 inch (10 cm) deep intrusion of the inner surface into the passenger compartment of the Mercedes-Benz ESV. The remaining decisive factors in the risk of injury are the restraint systems and interior side padding. The injury criteria of the German Specifications are fulfilled.

While the development of the front vehicle structure and restraints for the head-on collision was very difficult, the requirements of the German Specifications for the rear-end collision could be met with the very first prototype. When the rigid, movable barrier was driven into the rear end of the car at 50 mph (80 km/h) the structure was shortened by 3 ft. (90 cm), the passenger compartment remained almost completely intact (rear bulkhead intrusion of 2 in./5 cm). The doors could be opened, the dummies be taken out without any damage. This also meets the criteria of the German Specifications. But naturally these results have not been achieved without considerable added weight and correspondingly higher costs. It is obvious that a certain technical progress can be achieved. However, how this can be transferred to mass production at an economically justifiable cost is quite a different question.

Checking Specifications for Feasibility

Both the American as well as the German Specifications for Experimental Safety Vehicles have been under discussion for months. Many shortcomings have been recognized but there are certain difficulties involved in removing these, at least with the American Specifications. A way must be found here to rectify recognized shortcomings as quickly as possible; for specifications and regulations are only meaningful when they are adapted in a short space of time from the original ideal concept to the practicable state of the art. The German Specifications are subject to frequent revision and we hope to make this a continuing process.

There will be detailed discussions in work symposiums on special modifications of certain limit requirements. But, quite apart from these changes, the basic fact must always be faced that we must reckon with considerable increases in weight and costs. For this reason weight itself should not be kept as one of the requirements in the Specification.

The main reason for the considerable increase in weight and cost is having to comply with the requirement in the Specifications that all occupants must have clear survival chances in a head-on impact at 50 mph (80 km/h) against a rigid barrier. In principle the engineer will not shy away from this task. He has good theoretical and experimental aids available to him. What's more: special technical solutions have already been presented, both in the USA as well as in Europe.

However, one must ask: is there any point in reaching this goal? Are the solutions indicated anything more than a very interesting, but probably utopian, experiment? Are they feasible in practice? In other words, can passenger cars with the qualities of the experimental safety vehicles be successfully produced in large quantities? Can they take their place in modern road traffic? Will the motorist of the 80's be able and willing to buy such vehicles? Will there be room – particularly in Europe – for such monstrous vehicles on all roads? This must be doubted for several reasons: The laws of physics demand dimensions and strength values of an order which are considerably beyond that of the present European passenger car. This inevitably leads to considerably higher weights and costs. Many motorists will no longer be able to afford such vehicles- they will perhaps be forced to ride a motorcycle again, which would be a step backward as regards safety. The larger dimensions will make the vehicles more difficult to handle and impede the flow of traffic. There will be more risks of collisions on narrow, winding roads; the available parking space will be sufficient for still fewer cars.

Only a limited number of road users will be able to profit from the greater safety in these vehicles.

A Step-by-Step Plan for Technical Feasibility

From all these considerations, the aim emerges not necessarily to strive to meet all the demands of the Specifications at once, but rather to indicate in several steps the solutions which are technically feasible. Only then will it be possible to use the great efforts and financial and personal capacities not only for an experimental safety vehicle, but also to apply them step by step to regular production. The periods until individual steps can be introduced will thus be shortened, and motorists can in each case make use of progress which may be less spectacular but contributes to their safety at an earlier date.

An important prerequisite for determining the efficiency of this measure, however, would be reliable statistics for Germany which give information on both the frequency of the individual types of accidents as well as the numbers of fatalities, serious injuries and lesser injuries in relation to the actual driving as well as effective speed at the time of impact. This statistical analysis cannot be provided by the automobile companies but must be initiated and directed by the government, so that the whole traffic scene may be covered. Attempts to get such statistical evaluations are indeed already well known from the accident analyses of Cornell Aeronautical Laboratories in the USA. However, there is considerable reason to doubt whether these could be directly applied to the European traffic conditions. Fortunately, the Minister of Transport, Georg Leber, has declared himself willing to discuss this special matter of statistics with the German industry.

Summary

In conclusion the Requirements, which in the opinion of Daimler-Benz should be met before development of Experimental Safety Vehicles continues are summarized as follows:

1. Discussion of the targets which may be reached in the forseeable future with a justifiable use of people and money. Only if this choice of targets is reasonable, can the development take place in a "good atmosphere" without coercion caused by the possibility of sudden extreme legal requirements.
2. Working out a step-by-step plan for the experimental safety vehicle project which sets reasonable targets at sufficient time intervals.
3. Promotion and extension of bio-mechanical research.
4. Compilation of statistical data which most importantly will clarify the relationship between accident severity and impact speeds.
5. Setting up a well-founded cost-benefit analysis.

The automobile engineers welcome the cooperation of all bodies in achieving these requirements. Within the limits of what is possible and justifiable, Daimler-Benz AG will render its contribution. This company has never shunned the investment of considerable funds nor the use of its technical know-how in the interests of increased safety. Safety was never a mere slogan for Daimler-Benz. It was and remains a design principle which takes high priority not only in the interest of the Mercedes-Benz name and its customers, but also in the service of the general public and engineering progress.

Figure 1. Mercedes-Benz ESV 05

Figure 2. Deceleration of passenger compartment at 50 mph (80 km/h) head-on barrier impact

Figure 3. Deceleration of dummy in driver position at 50 mph (80 km/h) head-on barrier impact

Figure 4. Deceleration of dummy in front passenger position at 50 mph (80 km/h) head-on barrier impact

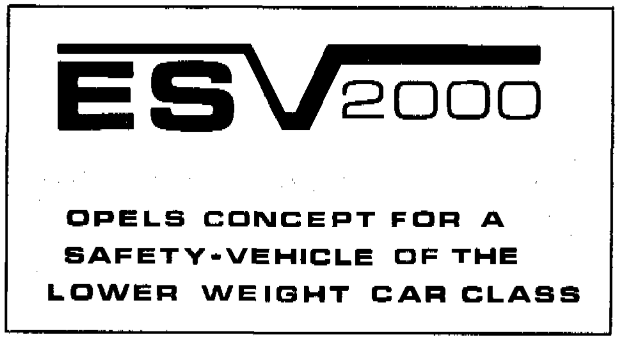
Figure 5. Deceleration of dummy in left rear seating position at 50 mph (80 km/h) head-on barrier impact

Figure 6. Deceleration of dummy in right rear seating position at 50 mph (80 km/h) head-on barrier impact

---

THE ADAM OPEL A.G. – *The Opel Conception of an ESV in the Low Weight Category*

Mr. Karl Brumm

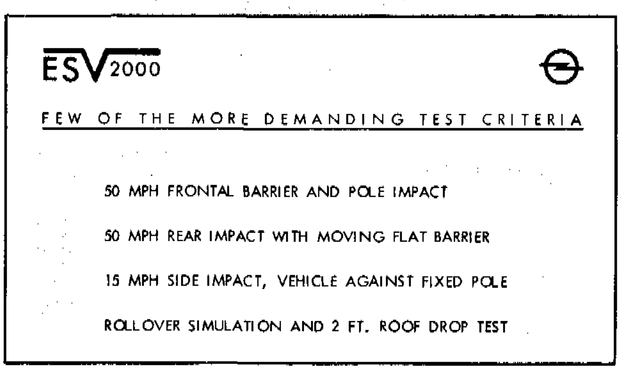


Slide 1

Ladies and Gentlemen,

Our program to develop a 2000 lbs. experimental safety vehicle has initially been directed towards achievement of the proposed performance levels developed by the German Automobile Manufacturers Association which are closely parallel to the 4000 lbs. ESV concept being developed in the USA.

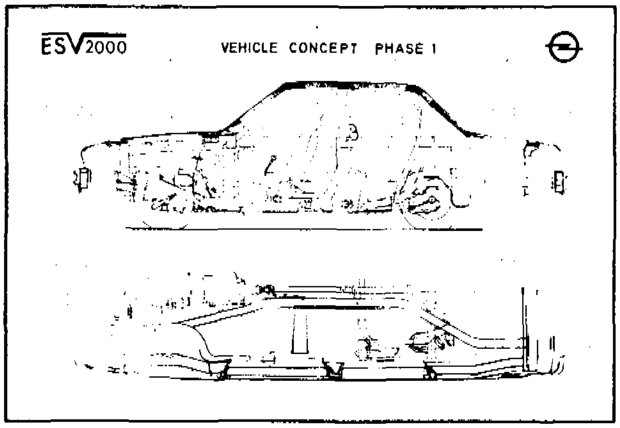
A few of the more demanding test criteria are as follows:



Slide 2

- 50 mph frontal barrier and pole impact
- 50 mph rear impact with moving flat barrier
- 15 mph side impact vehicle against fixed pole
- Rollover simulation and 2 ft. roof drop test

In addition to withstanding these severe accident simulations structurally the vehicle must also provide occupant protection systems which meet certain injury criteria under these test conditions.

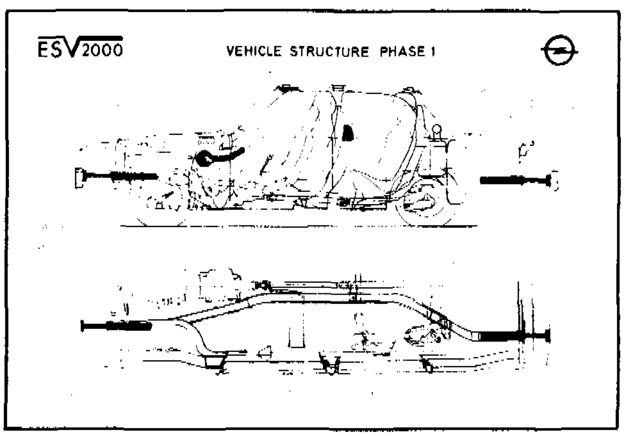


Slide 3

The vehicle configuration upon which our initial ESV studies were based consisted of a four-door sedan version of the Kadett, featuring four seating positions and a curb weight between 2,000 and 2,430 pounds, as specified by the German Automobile Manufacturers Association.

The total realization of the magnitude of the challenge was brought to bear when we subjected a current production Kadett to a 50 mph barrier crash test to establish a baseline of performance.

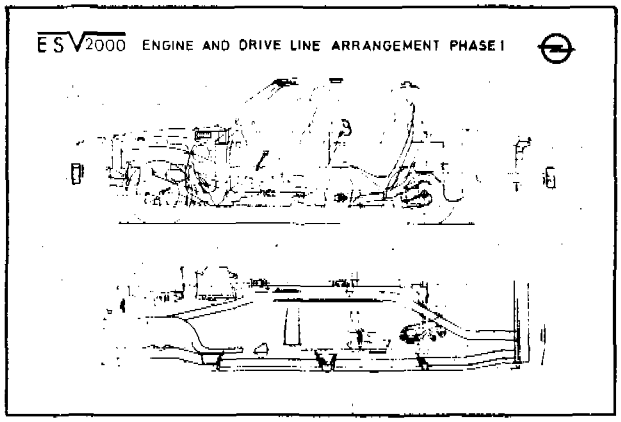
The 50 mph barrier crash performance level is equivalent to almost 2.8 times the energy content of the 30 mph level met by the current Kadett.



Slide 4

Based on the results of this test our improved structure consisted of the incorporation of door beams, rollover bar, front and rear upper frame members with strategically located cross braces. In addition reinforcements running along the tunnel area connecting the front and rear frame structure were incorporated.

A self-restoring 10 mph EA-bumper system in front and rear, and an air cushion restraint system for all seating positions have been provided.



Slide 5

To power this structurally improved vehicle we planned to install an emission controlled 1.9 ltr. engine with increased performance characteristics capable of accelerating the car from 30 to 70 mph in less than 12 seconds.

As shown in this sketch the vehicle package finally consisted of a conventionally located engine and drive line arrangement using a reinforced Kadett rear suspension.

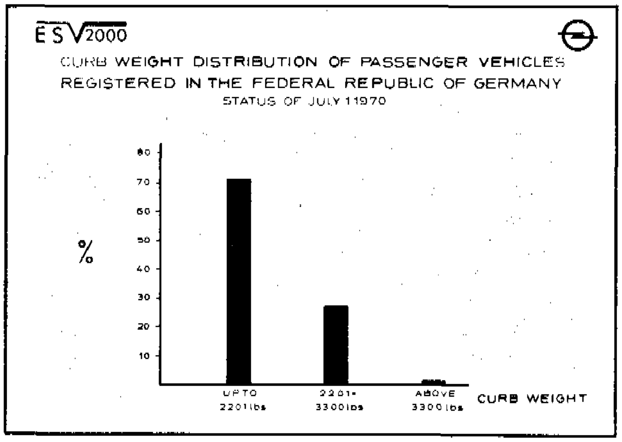
Various front suspension configurations for the vehicle with improved crush behaviour and weight saving characteristics have been studied.

Usage of both manual and automatic transmissions were proposed.

Slide 6

The evaluation of the concept indicated that to achieve the performance criteria would require a vehicle configuration longer, heavier and more expensive than our Commodore model and at best would provide utility space equal to the current Kadett.

We actually ended up at 2,600 pounds, exceeding the given weight limit due to the degree of added structure required to meet the injury criteria. For cost reasons we did not consider the usage of any unconventional material, although we could have solved the weight problem by such means.



Slide 7

From statistics we know that over 70% of all passenger cars in the Federal Republic of Germany belong to the small and intermediate car class up to 2200 lbs. and that during the first quarter of 1971 almost 60% of all new vehicles registered have fallen into the same category.

We feel that it is essential to protect the majority of all passenger cars on the roads from potentially being eliminated by law due to barrier crash test capabilities.

ESV2000

PHASE 2

UPPER WEIGHT LIMIT: 2200 LBS
MATERIAL : CONVENTIONAL
MANUFACTURING: HIGH VOLUME PRODUCTION

Slide 8

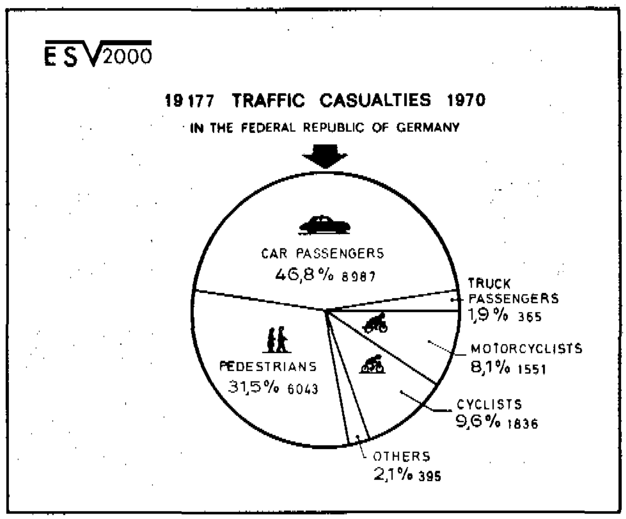
Several months ago we have therefore started phase two of our program which is directed towards the development of a 2000 lbs. passenger car concept with an upper weight limit of 2200 lbs., based on high volume production technology and the utilization of conventional materials to achieve the highest level of safety performance possible within these parameters.

Our objective therefore is not the creation of a show car far removed from the real world of automobile manufacture but rather to provide the customer in the shortest time possible a safer passenger car which he can afford to purchase.

It is our opinion that a significant improvement in the current European traffic casualty situation can be realized if these safer vehicles get into the hands of the driving population.

With this direction firmly established our program now consists of further improving existing safety systems and the development of additional safety features in both the chassis and body field.

It should be mentioned that we are closely cooperating with Vauxhall Motors, the British daughter of General Motors.



Slide 9

In order to set the proper priorities we have carefully studied statistical material published by the German Automobile Manufacturers Association (VDA), the Federal Office of Statistics and other sources.

This slide shows in what kind of accidents the 19,177 people have been killed in the Federal Republic of Germany during the year 1970. The main portion with 46.8%, which equals almost 9,000 people, is the section we have to be most concerned about, because these people died as drivers or passengers of automobiles.

The second largest section represents 31.5% of fatally injured pedestrians where the influence of the vehicle exterior design may improve the situation to a minor degree.

All other areas will practically not be changed by safer and better passenger cars.

The next slide is based on statistical accident research results compiled by Opel, Folksam, MIC (a US insurance corporation) and Volvo, giving a good survey about the priorities to be set for safer vehicles.

Concerning the relation between accidents and impact directions it is quite evident that the frontal impacts are ranking in the first position followed by side impact, rear impacts and rollover.

ESV2000

ACCIDENTS RELATED TO IMPACT DIRECTIONS IN %

	OPEL	VOLVO	FOLKSAM	MIC
FRONT	55,85	35,7	42,2	34
SIDE	16,76	33,5	41,9	15
REAR	7,27	8,7	13,4	14
ROLLOVER	20,2	4,9	2,5	2
OTHERS	–	17,2	–	35

Slide 10

It should be mentioned that the Opel data are based on severe accidents only and vary somewhat from the other data.

ESV2000

FATAL ACCIDENTS RELATED TO IMPACT DIRECTIONS IN %

	OPEL	MIC
FRONT	33,7	42
ROLLOVER	33,9	19
SIDE	22,04	19
REAR	6,76	3
OTHERS	–	11

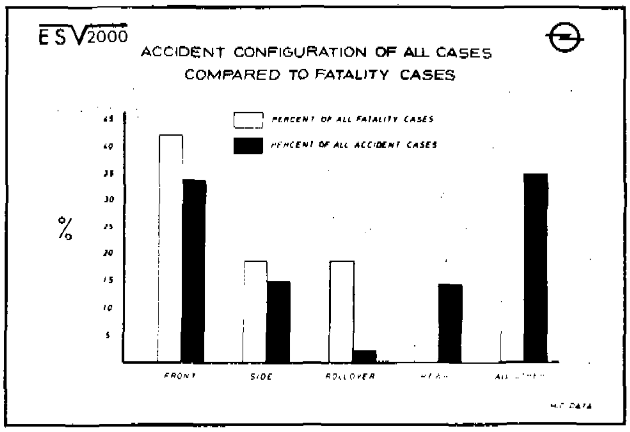
Slide 11

Looking at the few fatal accident data sources on hand which are related to impact directions we will recognize a very interesting shifting. The highest percentage of fatalaties occur in frontal impacts followed by rollover cases. Side impact and rear end collisions are ranked in positions three and four.

The percentage of fatalities can be reduced considerably if we will be able to increase the frontal barrier capabilities of our vehicles and if the occupants participate in the vehicle deceleration process by application of adequate restraint systems.

This next slide has been taken out of material published in a General Motors Proving Ground Report and it indicates the relation between fatalities in the red columns and the type of accident in blue columns in the USA.

It is obvious that rollover accidents which occur at a rate of 2% cause 19% of the fatalities, whereas rear accidents occurring at a rate of 14% cause only 3% of the fatalities.

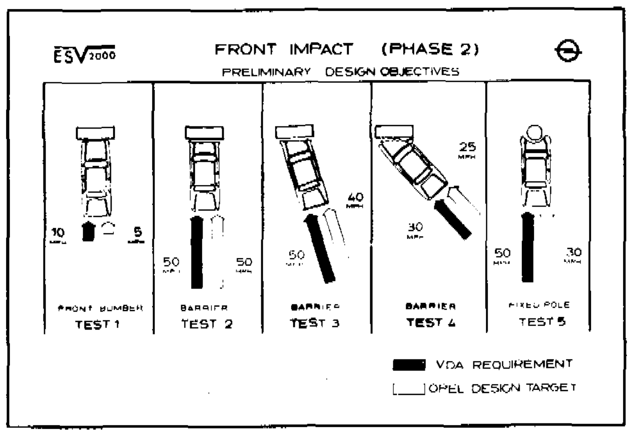


Slide 12

As far as the position of the passengers is concerned 91% have been killed on front seats and only 9% on rear seats.

These figures are reflecting the situation in the US whereas the situation in European countries will probably be different due to occupation rate, car size and traffic conditions, which are presently being investigated.

Here it should be mentioned that additional and improved statistical data are required to enable us to concentrate our development work on areas where improvements are most effective.



Slide 13

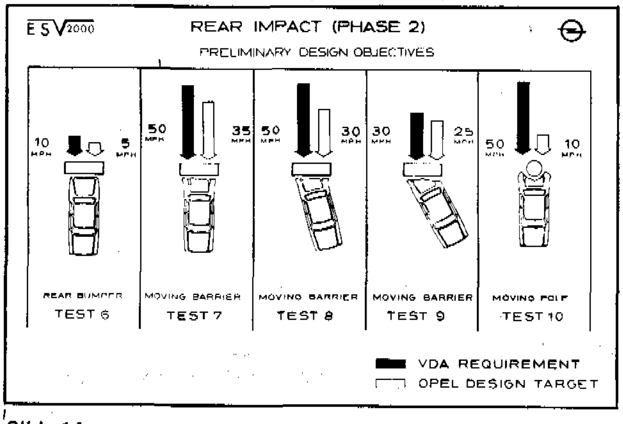
Having all the aforementioned material in mind we have set preliminary design objectives which deviate from the specifications issued by the Automobile Manufacturers Association as shown in the following slides.

The blue arrows represent the VDA requirements, the red ones the preliminary Opel targets.

In test 1 we have reduced the bumper impact speed from 10 to 5 mph because we are of the opinion that the energy absorbing bumper feature is of minor importance as a safety feature as will be explained later.

Test 2, the 50 mph front barrier, remains unchanged for reasons given earlier.

Test 3, 4 and 5 will be made at a reduced speed, however, the final target will remain to meet the VDA requirements.

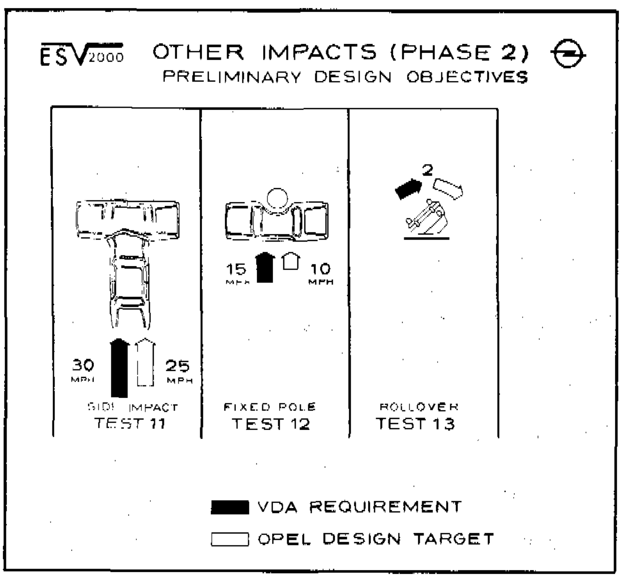


Slide 14

Test 6 is the low speed rear bumper impact which will be treated similarly as test 1 for the front bumper, i.e., the impact speed has been reduced from 10 mph to 5 mph.

The rear impacts under various angles in test 7, 8 and 9 will be made at reduced speeds as indicated. For reasons which have been discussed earlier concerning the reduced danger of rear impacts we do not intend to increase the Opel specifications.

In test 10 the rear pole impact speed has already been reduced from 50 to a more reasonable speed of 10 mph in both the US and the German requirements.

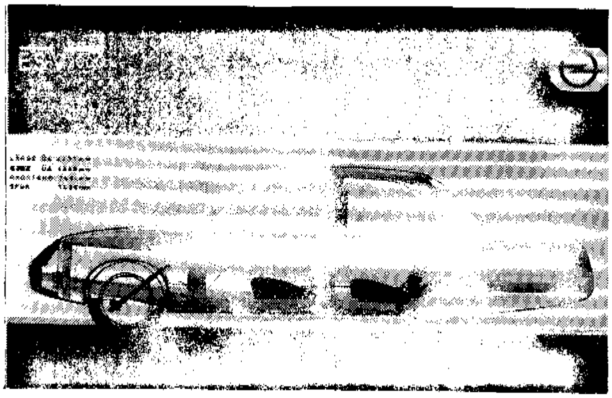


Slide 15

The preliminary target for the car to car side impact in test 11 has been reduced to 25 mph knowing that most side impacts occur in city traffic below city speed limits.

Test 12 has also been reduced where we start with a preliminary test speed of 10 mph.

The rollover test number 13 will remain unchanged versus the VDA specifications.



Slide 16

The safety vehicle now proposed will also be a car with conventional engine and drive line arrangement powered by a 1.9 ltr. 4 cyl. engine with an increased performance output and an exhaust emission control system to meet future specifications.

A foam filled sheet metal fuel tank located on the kick up above the rear axle in combination with a self sealing fuel line system will insure a high degree of protection in this respect.

An improved lock control brake system with fluid level warning device will be employed and manual as well as automatic transmission will be provided.

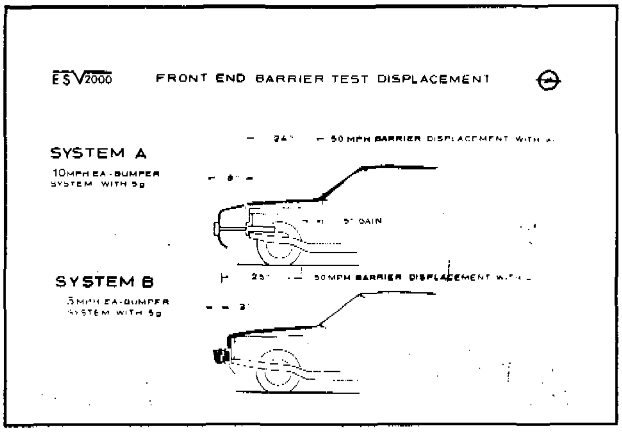
It is recognized that to meet the injury criteria will necessitate a concentrated effort in the development of new crush behaviour characteristics. A new unconventional body structure concept has been developed, which not only absorbs energy but also maintains the integrity of the passenger compartment at impact speeds higher than the present ones.

In combination with the new structure passenger protection will be guaranteed through the utilization of newly constructed and shaped seats and a passive restraint system for each occupant.

We are also continuing our development of an air cushion restraint system which could also be incorporated into this vehicle.

The concept of energy absorbing bumper systems is currently receiving a significant amount of attention and we have considered this feature in our studies.

Our findings indicate that a self-restoring energy absorbing bumper system designed to meet 10 mph front and rear barrier performance criteria as shown in the upper portion of the slide absorbs only 4% of the total energy content of a 50 mph barrier impact when

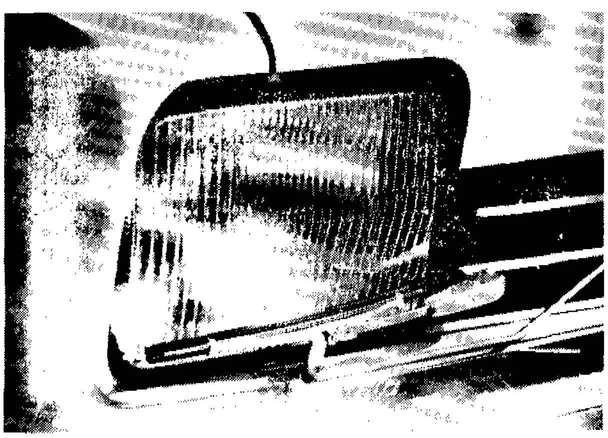


Slide 17

utilizing a full bumper travel which is equivalent to about 25% of the total theoretical crush distance.

Based on this evaluation we feel that it will be a better trade off to use the system shown above where we gain a space of five inches for high level energy absorption since the self-restoring bumper systems under discussion are directed towards the reduction of property damage and should not be overestimated with respect to actual vehicle safety.

A new bumper system is under development to provide a 5 mph property damage protection considering cost and weight factors in relation to overall crash behaviour improvements.



Slide 18

Another feature receiving prime attention is the development of cleaning systems for headlights.

When driving under adverse weather and road conditions the headlight lenses are being contaminated gradually and as a normal consequence the driver does not recognize the reducing visibility and the increasing danger.

In order to demonstrate the status of our pretest work concerning future body structures I will show you now a short movie. Current production Kadett vehicles which meet the present safety standards are being subjected to higher barrier impact speeds and you will recognize the magnitude of the challenge to fulfill the requirements of a 50 mph barrier impact with a passenger vehicle of this size.

For comparison we will show you then one of our ESV pretest cars in the 50 mph barrier test.

Comments To The Movie

The pretest vehicle you have seen in the 50 mph barrier impact test was not fully functional because, e.g., the window mechanism had to be taken out completely in order to provide sufficient space for the inner door structure.

In order to prevent any optimistic speculation, it must be emphasized that all structural development work being conducted today and in the near future will not reflect production earlier than in the late seventies.

In summary we can say that a higher degree of safety can be achieved and also be sold if simultaneously the customer's wishes with respect to styling, comfort, performance and economy are approximately met.

For this reason we feel that it is our duty to not only offer the customer more safety, but also to preserve his ability to buy and to drive such a vehicle without creating any physical or psychic compulsion feelings.

Such a compulsion could give vent to other not foreseeable emotions, since we must also remind you of the following fact: Approximately 90% of all traffic accidents are caused by human failures. These human failures are not always based upon a lack of abilities, but very often – perhaps in most cases – upon motions which escape the rational control. These defects of control occur especially during times of tension or stress.

For this reason, the safe motor vehicle of the future must not only be adapted to traffic but also to the human being.

THE BAMERISCHE MOTORENWERK A.G. (BMW) – *Tendencies of Development Concerning Vehicle Safety at BMW*

Director Bernhard Osswald
Outline of Technology in the Federal Republic of Germany

The number of accidents in road traffic in Germany, as well as in all other highly industrialized countries of the world is alarming, and among those who bear responsibility, there can hardly be anyone who would not want to reduce these figures to a minimum for humanitarian, ethical, sociological and also for economic reasons. Quite understandably, however, there are considerable differences of opinion as to the ways which will lead to this target. There are proposals exclusively concerned with protecting vehicle occupants, and there are others which mainly protect the other road users. All of these proposals, as far as they are technically practicable, are likely to be successful to a certain degree. However, a decision to make use of one or the other proposal can be taken only on the basis of very detailed and exact knowledge of traffic and accident structure. Such knowledge is available, and it is also known that there are considerable differences from country to country. Thus, for example, in the USA the number of accident victims among vehicle occupants is higher, whereas in Germany the great majority of accident victims are other road users. Therefore, all measures intended to reduce the number of accidents in highway traffic must be differentiated accordingly.

In the previous lectures, it has repeatedly been pointed out that in Europe, due to the many urban agglomerations with a high traffic density, active safety has for decades played a particularly important role, and it is certainly not by coincidence that, in this respect, the legal requirements of various countries as well as the requirements of Statements of Work have mostly been met *a priori* by our vehicles, if not, for reasons of principle, compliance with certain requirements was dispensed with, in which connection I am particularly thinking of requirements concerning vehicle dynamics.

Seen from this angle, the requirements on the active safety of passenger cars, as laid down in the Statements of Work, only confirm that during decades of development the right course has been followed, also by my company. If I say decades of development, this encompasses the gradual progress which for the vehicle user has become apparent in the form of solutions which were both technically practicable and economically feasible.

This being so, we are now of the opinion that also for implementing the increased requirements on passive safety, such a gradual procedure should be chosen, whereby particular care should be taken to achieve practicability in high volume production and efficiency to the consumer within periods of time that are acceptable for all concerned. In this connection, I do not want to enlarge once more on the fact that, in particular, our understanding of the load carrying ability of the human body which, after all, forms the basis for passive safety, is still unsatisfactory. What I should rather like to do is to interpret the course followed by my company and to explain its motives.

More than a year ago we, too, were faced with the decision of developing and building prototypes of a special experimental safety vehicle. We have, for the time being, decided not to adopt this course, because it is our belief that our entire research and development capacity should be put to work in an effort to introduce the already developed safety devices as quickly as possible into our production vehicles and that, with the actual distribution of accidents in Germany, the present concept of the experimental safety vehicle which overemphasizes occupant safety at relatively high speed, would harm all the other road users more than it would help them.

We have further assumed – and we believe this to be realistic – that the development of such safety vehicle prototypes would have taken from one to two years, and that another year would have been necessary to complete testing. If we then assume that these vehicles could be produced economically and could also be sold, another 2 to 3 years would be required for developing, designing and testing them to the point where they could go into production. It would only be then that the exchange of the, let us say, conventional vehicles against these safety vehicles could begin, and under European conditions, this would take at least 5 years. However, during this phase which would last for about 12 years, general safety on the roads and highways will certainly not improve since, no doubt, the possession of a safety vehicle will be conducive to aggressive driving behaviour. Moreover, accidents involving a heavier safety vehicle and a conventional vehicle will become much more serious for the conventional vehicle and its occupants. Consequently, when adopting this course, we could not expect any improvement in accident statistics for the next 10 years. You may now object that, of course, one could in the meantime incorporate the results from the prototypes into production vehicles, and you are certainly right, but it should be borne in mind that these results can also be obtained step by step with sample vehicles taken out of production, without constructing an experimental safety vehicle prototype which will meet requirements which by themselves are still controversial.

Thus, for the time being, we deliberately follow the course which Dr. Scherenberg has shortly mentioned in his lecture, i.e., that of gradually improving our production vehicles, whereby our objectives are in keeping with the progress of science and technology and with existing economic conditions. In adopting this course, we are creating development capacity for those vehicles which will dominate the traffic scene within the next 10 years, and we shall use this capacity to make these cars, as we have already done with our current models, progressively safer in any respect. We shall further profit from this capacity by planning, within the indicated period of 10 years, systems which, independent from the human factor, will help to reduce accidents in road traffic.

SECTION 2

PART 3 THE UNITED KINGDOM TECHNICAL PRESENTATION ON ESV DEVELOPMENT

PASSIVE SEAT BELT SYSTEMS

Mr. J. A. Shingleton, Auto
Restraint Systems Limited

Gentlemen

One factor that clearly stands out in the safety programme is the need to restrain the vehicle occupant at the time of impact in some way or other. Even in the so called cushion car as envisaged by Dr. Foster et alia it is recognised that within the terms of a feasible and acceptable interior design some form of restraint is essential.

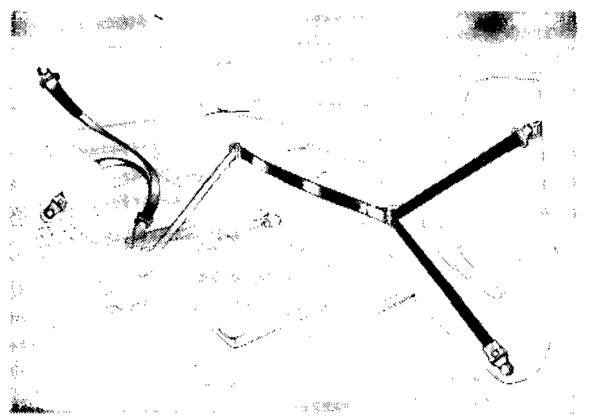
Substantial work has already been undertaken in the field of inflatable bags, a field in which, whilst very promising results have been achieved, a number of important problems still require an acceptable solution. It is important, also, to note that this approach does nothing to protect the occupant in impacts below a predetermined speed at present 15 m.p.h. (24 K/hr) or even in heavy braking conditions when injuries can occur.

The present lap and diagonal seat belt system has already proven itself to be a very valuable form of restraint and a substantial volume of data is available to support this statement. The U.K. Road Research Laboratory has, over a long period, carried out an accident investigation programme with particular reference to the wearing of seat belts which programme reveals conclusive results in support of seat belts of the type described. It would be a fundamental error of policy if such a proven system was allowed to be discarded without further study and effort in that area of development. No one can deny that whatever form the ultimate solution takes it must be cost effective.

The present problem with seat belt systems is the reluctance on the part of the public to use them. This arises partly from the inherent dislike of any form of restraint but in particular from the inconvenience of use arising from the need of adjustment to individual occupants.

These problems, have to a large extent been overcome by the development of the modern automatic inertia reel belts which by definition virtually eliminate the adjustment problem and allow the occupant a reasonable degree of freedom in use. Nonetheless utilisation of the system – whilst slowly improving – still falls a long way short of universal use. It is. therefore an urgent requirement to find ways and means of removing the optional element of their use. The U.K. Road Research Laboratory is actively investigating, by contract, various methods of automatically applying the seat belt system to the occupant.

The problem is one of removing the belts out of the occupants' way to ensure unhindered ingress and egress to and from the vehicle, whilst at the same time not destroying the integrity of the system by interference with the point of attachment where stress will occur. Following my comments we will be showing a short film of one possible approach to this problem, although we must emphasise that the development programme is still at an early stage and we do not offer this as a final solution.



In this system the arms which move the belt out of the way employ "running loops" and do not carry any stress in use. At the point of attachment to the door, steps are taken to transfer the stress from the door to the B post.

We have not overlooked the question of freedom at rest when, for example, on a picnic, and provision has been made to override the system on such occasions. However, release of the hand-brake will automatically cancel any such overriding action.

Problems that still require a solution are ones such as egress across the vehicle and situations where only restricted door opening is possible.

Whilst conducting this development we are also examining the ability of the belt system to meet the criteria as laid down by the United States Authorities.

It is readily recognised that this is a field of study in which there is much imprecise data ranging from the actual tolerance capacity of the human body to present lack of adequate correlation between the dummies in use and the human body with particular reference to the neck structure. Considerable doubt has been cast on the ability of seat belts to meet the criteria and yet, we repeat, the seat belt has proven itself in actual use.

It is also recognised that seat belts might well not meet the high speed crash requirement. Here again the U.K. Road Research Laboratory is conducting an intensive study into actual impact speeds. Only with factual data can a true cost/effective relationship be established.

Passive seat belts, therefore, is an area of development to which a concentrated effort is being applied without prejudice to and in parallel with work on crash deployed systems. These latter developments are also being supported by the U.K. Government through the Road Research Laboratory.

FACTORS AFFECTING THE CHOICE OF STANDARDS FOR ACCIDENT AVOIDANCE

Presented By
Mr. A. W. Christie, Road Research Laboratory

1. General Considerations

The problem about which I am going to speak is that of setting realistic standards for primary safety. By that I mean standards which really will improve safety on the road and which are acceptable from other points of view such as the traffic capacity of roads and the cost of the vehicles themselves. For a number of reasons standards for primary safety are more difficult to establish than standards for secondary safety.

Firstly, it is usually easier to decide what happened after the initial impact in an accident than before.

Secondly, it is usually easier to suggest ways of reducing the severity of injuries sustained in any type of accident than to suggest ways of preventing such accidents in the future. For example, the value of collapsible steering columns can be assessed by a combination of physical and medical science, whereas to estimate the value of improving the cornering performance of a car requires a much better knowledge of driver psychology than we have at present. Drivers may be tempted to use improved cornering capability to drive faster than they did before with the result that some or all of the potential safety value of the change is lost.

Thirdly, it is more difficult to foresee *all* the consequences of changing the response characteristics of a car than of changing its structural features. For example, modifications which produce desirable changes to steady state performance could conceivably produce undesirable transient responses.

The main difficulty is probably that of determining what use will be made of improved performance capabilities by the human operator. It is possible that, from the point of view of safety, a high performance capability is less important than a predictable response and a gradual failure with adequate warning to the driver as limiting conditions are approached.

It is difficult to see how such questions can be answered without turning to accident information. Ideally standards for primary safety should be based on adequate accident evidence. We, in the UK, believe that a thorough programme of accident analysis is necessary for a successful safety car programme and are making a substantial effort in this field.

2. Evidence Available From Accident Studies

At present the evidence available from accident studies is small. I should like now to review briefly evidence relating to primary safety.

We would expect handling characteristics to have the greatest effect on "loss of control" accidents. Estimates (Fig. 1) of how many of the cars involved in accidents

LOSS OF CONTROL AS A FACTOR IN ACCIDENTS

Proportion of cars involved which went out of control :-

POLICE ESTIMATE	(National fatal and serious accidents, 1968)	13%
RRL ESTIMATE	(Pilot on-the-spot investigation, 1968)	23%

Figure 1

are out of control vary considerably (13-23%). It is hoped that by expanding on-the-spot investigations that a more reliable estimate can be made. Even so not all of these accidents can be blamed on faulty handling characteristics – driver behaviour is almost certainly of great importance.

We would like to know where loss-of-control accidents occur. Again information is available at present from only a very small number of accidents (Fig. 2).

TYPES OF LOSS-OF-CONTROL ACCIDENT INVOLVING CARS
(RRL Pilot investigation 1968)

	Surface condition: Dry	Wet or damp	Snow or ice	All
Car diverged from straight road	9%	9%	3%	21%
Car spun round on straight road	9%	11%	1%	21%
Car spun round at bend	4%	6%	0%	10%
Car left road on outside of bend	6%	29%	3%	38%
Car left road on inside of bend	3%	8%	0%	11%
Totals (79 accidents)	30%	63%	6%	99%

Figure 2

From this it may be seen that drifting out at a bend was the most common type of loss of control (38%) and that a wet road was involved on a surprisingly high proportion of occasions (63%), bearing in mind that the road is wet for only about one third of the total time. Handling standards should therefore give due importance to cornering and to performance on wet surfaces.

Braking is known to be involved in about half of the loss-of-control accidents even on dry surfaces. The adoption of anti-lock systems could probably eliminate a substantial proportion of the total.

We would like to know also what types of car are most likely to go out of control. Here again (Fig. 3)

RELATIVE LOSS-OF-CONTROL ACCIDENT RATES
FOR DIFFERENT TYPES OF CAR

* Travel estimated by different methods
Ø Relative rates adjusted to give mean of 1.00 for each investigation

			National * accident statistics 1961 - 1963	RRL Pilot * 'on-the-spot' investigation 1968
SMALL CARS	Front engine / rear drive	Car A	1.16	
		Car B	86	
		Unspecified		94
	Front engine / front drive	Car C	1.02	
		Unspecified		64
	Rear engine / rear drive	Car D	1.54	
		Unspecified		1.16
MEDIUM CARS	Front engine / rear drive	Car E	·79	
		Car F	60	
	Layout unspecified	Unspecified		76
LARGE CARS	Front engine / rear drive	Car G	·91	
		Car H	1.12	
	Layout unspecified	Unspecified		1.50
Mean for the investigation Ø			1.00	1.00

Figure 3

there is little evidence at present and there are no clear indications from it. Perhaps rear engined cars are more difficult than cars with other layouts. Perhaps large cars are more difficult to control than small cars. Much more evidence and a stricter examination of it is required.

Vehicle stability, especially liability to roll over, must also come under the heading of primary safety. The USA data (Fig. 4) indicate that small cars, particularly rear engined small cars, are most likely to roll over. However rollover accidents are less frequent in the UK than in

ESTIMATES OF PERCENTAGES
OF CARS OVERTURNING IN ACCIDENTS

		In USA*	In GB †
Imported cars	Small rear engined A	45%	11%
	Small rear engined B	62%	
	Other sedans	36%	
USA cars	Rear engined	28%	
	Light conventional	23%	
	Medium conventional	21%	
	Heavy conventional	16%	
British cars	On motorways		30 %
	On A and B roads		10 %
	Other roads		7 %
	On all roads		10 %

* Data - cars in which occupant was injured
Source - CAL (1952 - 1968)

† Data - car drivers injured
Source - GB national statistics 1969

Figure 4

the USA though this frequency varies with the class of road (Fig. 4).

3. Use Of Practical Handling Tests For Standardisation Purposes

In the absence of fuller accident evidence it seems natural to turn to practical tests in which situations, which arise on the road, are simulated.

The first problem is the choice of situations to be studied. So many can be suggested that their relative importance must be estimated so that a realistic selection can be made. From what is known of "loss of control accidents" it seems likely that performance on wet as well as on dry road surfaces should be considered and performance with low tire pressures as well as normal tire pressures.

I should like to discuss briefly some tests of this type. Two tests are used (Fig. 5) a cornering test and a lane change (chicane) test. The test courses marked by cones (pylons) were as in the figure. Two types of road surface are included – a dry high coefficient surface and a wet slippery surface. The tests were performed at constant speed so far as possible. There were two criteria a performance criterion (maximum speed) and a warning

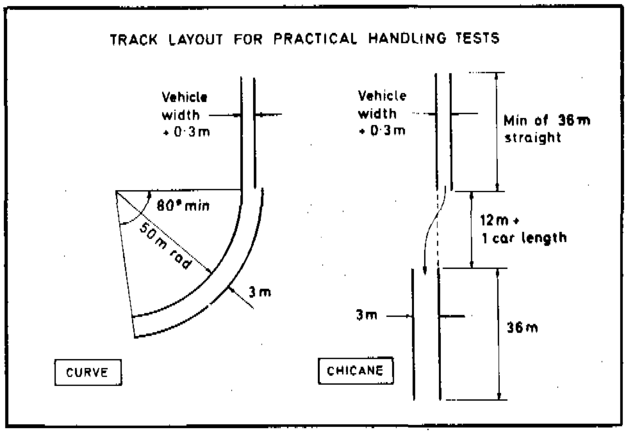


Figure 5

criterion (which is defined later). The tests were all made with a single expert driver.

In figure 6 maximum speeds for the curve on the dry surface have been plotted against vehicle size (the diagonal dimension of the vehicle). There is a significant

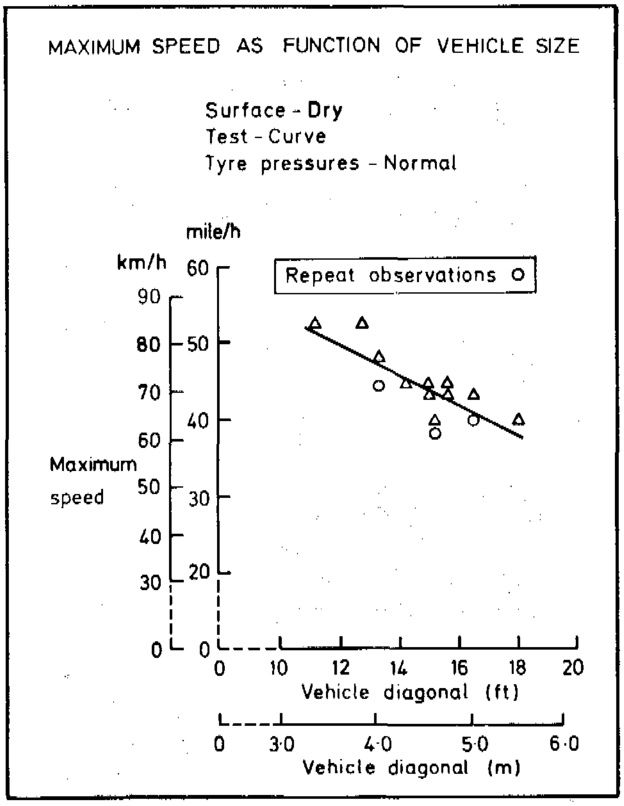


Figure 6

correlation with vehicle size – the larger vehicles being the slower. It is not surprising that there is a considerable scatter about the line fitted to the data because a wide range of vehicle types was covered. A considerable amount of scatter undoubtedly arises from various forms of experimental error as can be seen from the repeat results obtained after a period of several months. Somewhat similar results were obtained in the chicane test on the dry surface.

Figure 7 shows the maximum speeds obtained for the curve test on the wet slippery surface plotted in the

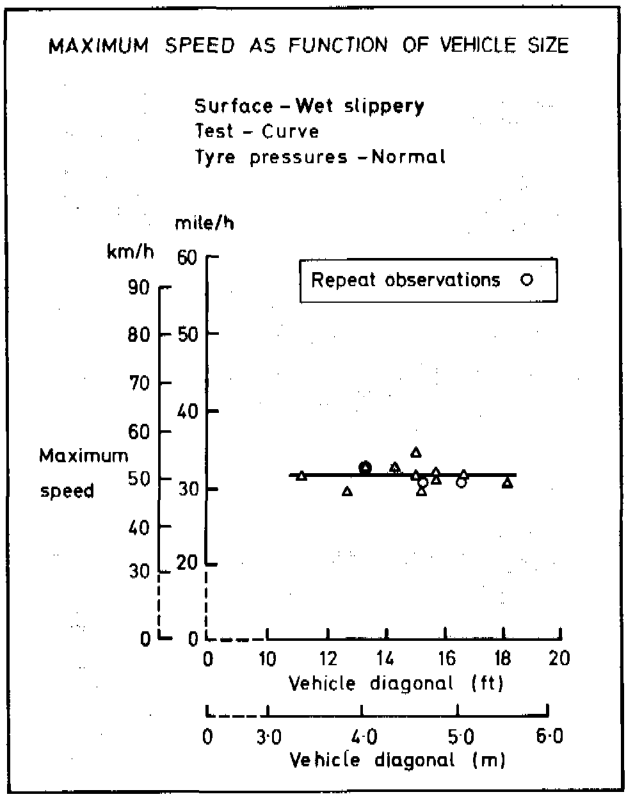


Figure 7

same way. In this case there is no correlation with vehicle size. Speeds are much more constant, probably being limited by the available friction between tire and road. Similar results were obtained in the chicane test on the wet slippery surface.

Most of the reductions in tire pressures gave significant reductions in maximum speeds (Figs. 8 and 9). However the speed reductions were small considering that the pressures were reduced by 50%.

I now come to the second criterion. The driver was asked to estimate the speed at which he felt he was just losing control of his vehicle. This he called his first sensation speed. The difference between this speed and the maximum speed is therefore a measure of how much warning he had. The results for the warning criterion (maximum speed minus first sensation speed) have been plotted in the same way as before. In figure 10 there still appears to be some dependence on vehicle size in the dry – apparently there was more warning with the small vehicles than with larger vehicles. In the wet (Fig. 11) there was little warning with any size of vehicle.

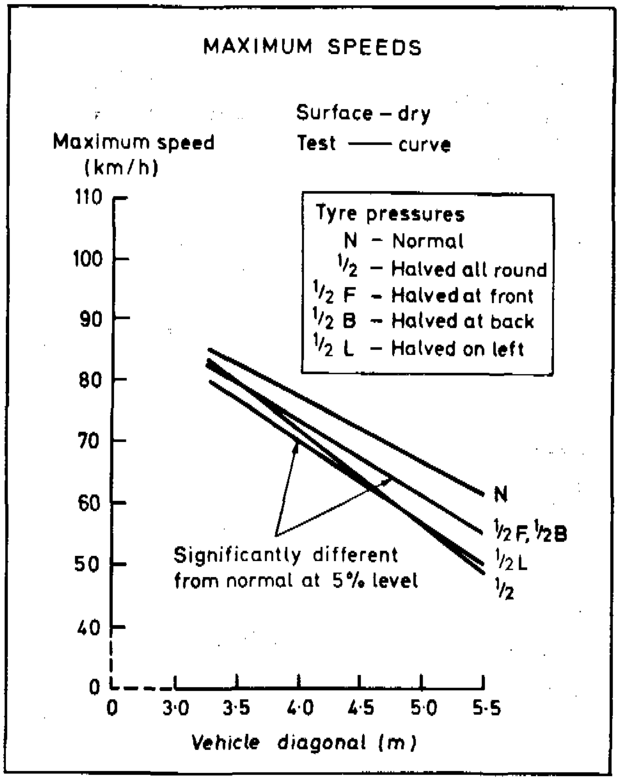


Figure 8

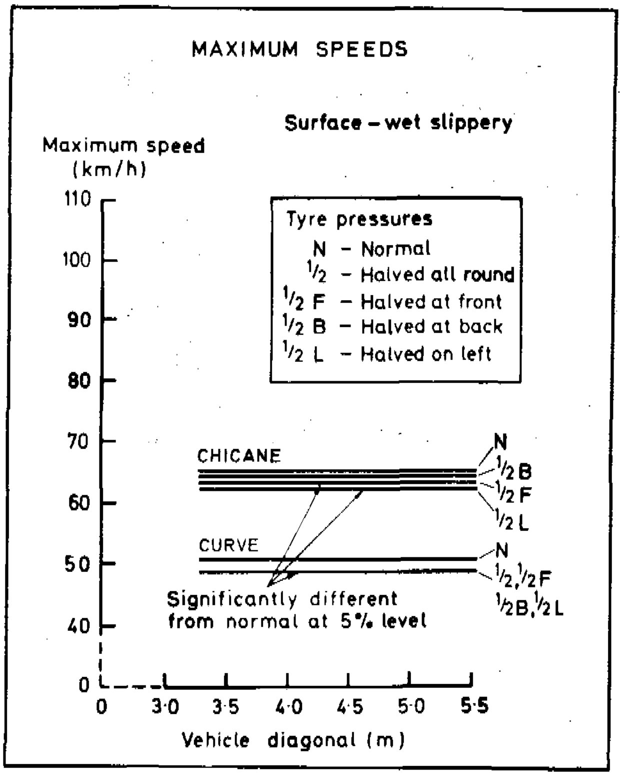


Figure 9

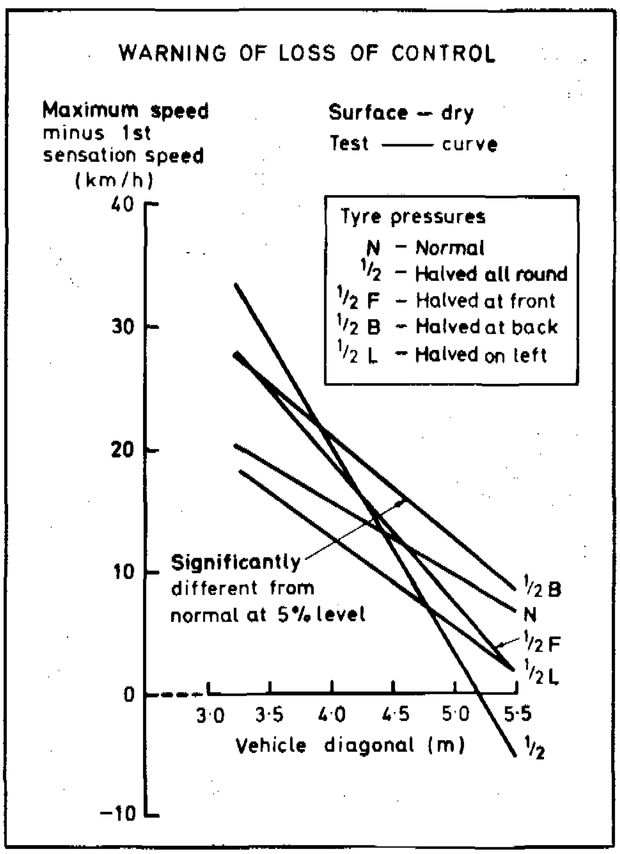


Figure 10

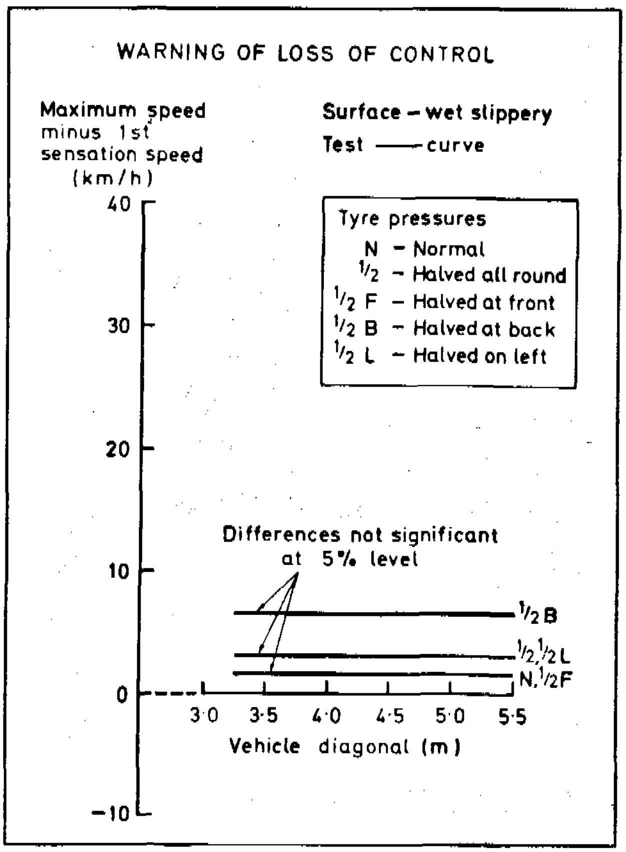


Figure 11

It would not be justifiable to try to draw conclusions about the warning signals noticed by the driver. First, sensation speeds are much less definite than maximum speeds. They are subjective and affected by unintentional bias on the part of the driver which can only be avoided by taking very strict precautions; this could not be done in these preliminary tests. In addition, warning sensations are likely to vary considerably over the range of types of driver. To study them many drivers would have to be used. These results are introduced today merely to indicate possible ways of developing criteria for accident avoidance.

The main aim of the tests was to find a means of comparing the handling characteristics of different types of car in a way which is relevant to safety. The order of merit of the cars however tends to change according to the test, the surface on which the test is carried out and the criterion of performance chose. This fact illustrates the dangers of setting arbitrary standards. Ideally the results of practical tests such as these should be compared with the accident rates of the same vehicles It is hoped to do this when more information becomes available.

4. Use of Basic Response Characteristics For Standardisation Purposes

Another form of testing consists in the measurement of basic response characteristics under idealised conditions. The steady state and transient yaw tests in the American ESV specification are examples. Some of these tests have been carried out on three British cars.

One of these cars, a medium sized car by British standards, with front engine and rear drive gave steady state results generally in line with the USA ESV requirements especially if some allowance is made for the reduced wheel base (Fig. 12). In the case of a second car (a slightly smaller one with front drive) the results lie mainly above the band labelled acceptable (Fig. 13), although the steering characteristics of this vehicle are highly praised in the UK and the vehicle does not appear

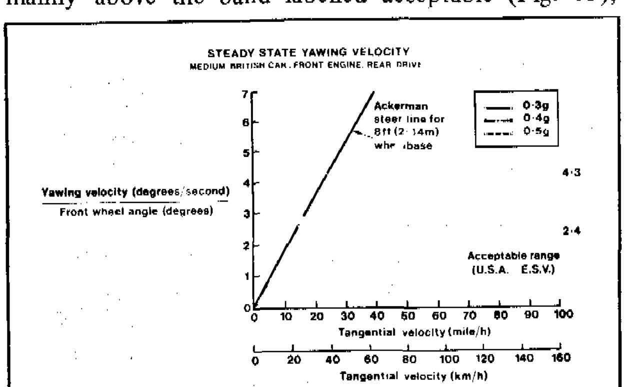


Figure 12

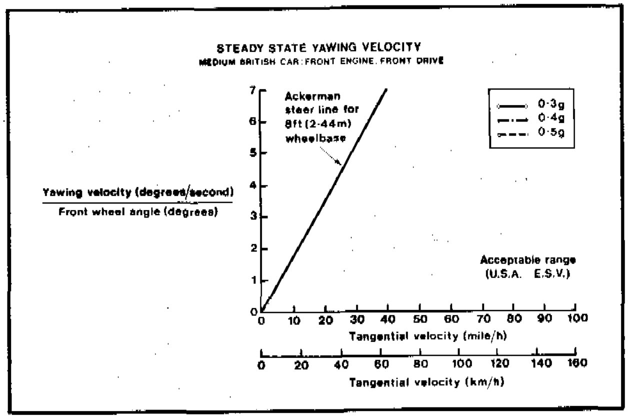


Figure 13

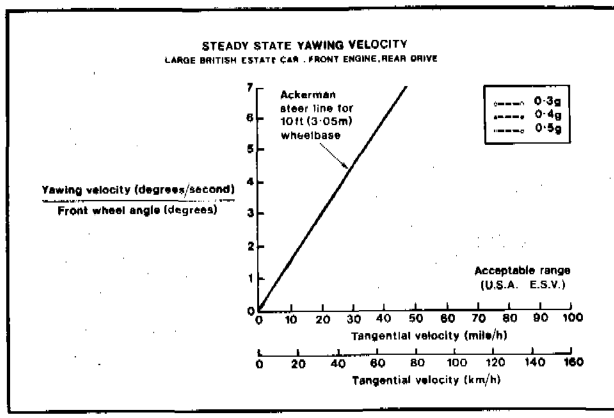


Figure 14

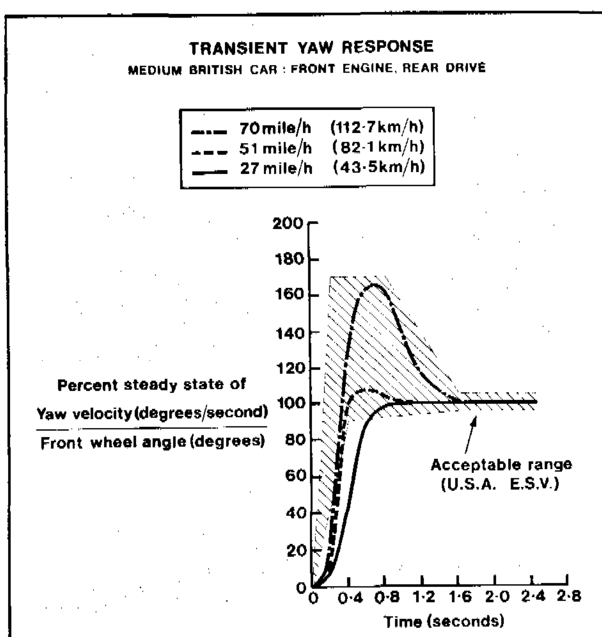


Figure 15

to have an unusually high accident record. A larger vehicle, an estate wagon with front engine and rear drive, gave steady state results somewhat below the acceptable band (Fig. 14). The steering characteristics of this car are probably less well liked than those of the other cars but there are no accident data to quote either for or against it.

The transient yaw responses of all three vehicles are generally within the acceptable band of the US ESV specification (Fig. 15).

5. Summary of Main Points In The Presentation

5.1 Use Of Accident Evidence As A Basis For Specifications

(a) Ideally specifications for primary safety should be based on evidence from accident analyses.

(b) At present such evidence is inadequate and a substantial effort is needed to rectify this situation.

(c) It is not even known whether it is better to design for the utmost in handling capabilities or to design for a predictable response under limiting conditions together with a clear warning to the driver when loss of control is imminent.

(d) There is some evidence, by no means conclusive, that, in the UK, it may be more important to specify handling response on wet surfaces than handling response on dry surfaces.

(e) Braking is involved in about half of the accidents in which loss of control occurs. Anti-lock braking systems could probably eliminate a substantial proportion of these.

(f) In accidents in which car occupants are injured roll over appears to be involved less frequently in the UK than in the USA.

(g) USA data indicate that small cars, particularly rear engined small cars, are the most likely to roll over.

(h) There is a slight indication, worthy of further investigation, that large cars and small cars with engines at the rear may be more frequently involved in loss-of-control accidents than are small cars with other layouts.

5.2 Specifications Involving Practical Handling Tests

(a) It is difficult with practical handling tests which simulate accident situations and involve the use of drivers to obtain precise and repeatable results.

(b) There are many possible tests and these can place cars in different orders of merit. An appropriate choice of tests can probably only be made when there is adequate evidence from accidents to guide the choice.

(c) There is evidence from handling tests on dry surfaces that small cars are inherently more maneuverable than large cars.

5.2 Specifications Involving Basic Response Characteristics

(a) Compared with the results from the complex referred to in 5.2 the results of measurements of basic response characteristics are probably more precise and repeatable. but are also likely to be less easily correlated with accident experience.

(b) Some British cars of approximately 2,000 lb. weight have steady state yawing response characteristics which fall outside the range specified for the USA ESVs. They include at least one car whose steering characteristics have been highly praised in the UK.

6. Conclusions

There is a lack of convincing evidence on the effect of handling characteristics on safety. This means that tight specifications cannot, at present, be justified in this area.

SOME OBSERVATIONS ON ESV DEVELOPMENTS

Mr. R. D. Lister, Road Research Laboratory

In the United Kingdom we regard it as vital to keep the main objectives in mind when considering this ESV work in preventing accidents and minimising injury severity and that the success or failure of any safety feature should be measured by the extent to which these objectives are achieved. It is for this reason that we lay great stress on linking our accident and injury studies as closely as possible to design features in order to guide the progress of our own Car Safety Programme and we regard this as a most important factor in the programme. In this connection Mr. Christie has just discussed the problems of establishing handling specifications and test procedures which will be related to accident reduction and it may well be that the handling performance which results in a reduction in some types of accidents proves to be one that the driver does not like. I might add that drivers in general do not like speed limits but nevertheless they play a part in increased safety.

The same consideration applies in the choice of an injury criteria when assessing restraint systems. This point has been raised by other speakers too; we are particularly concerned that any injury criteria used should be related as far as possible with accident experience. In particular, in the case of passive seat belts we are extending an established and proven conventional belt restraint system about which we have a considerable amount of accident and injury data and there is no doubt about their value in reducing injuries in accidents. Furthermore, our dynamic testing of passive seat belt systems show that they are comparable in performance with conventional systems of the same configuration. Looking at our evidence, using the conventional 3-point seat belt, we have sufficient data to say confidently that head injuries do not occur by virtue of this type of restraint. Even when the impact is severe enough to the point at which some skeletal fracture occurs from the loading of the seat belt, we have not yet experienced any head injuries unless the head actually impacts some interior structure of the vehicle. However, the results of tests using dummies often give the Gadd Severity Index for the head as being in excess of the accepted tolerance level of 1000. Figures well in excess of 1000 are sometimes quoted. It is therefore apparent that dummy testing of belt restraint systems as carried out at the moment, and the head injury criteria used, are not consistent with accident experience. We are not questioning the validity of the 1000 Severity Index as applied to humans but quite obviously this figure is not the correct one to apply to current dummy test devices and it is unwise to exclude the seat belt type restraint systems solely on the head injury criteria.

One solution of course is to change the dummy but this would need further correlation with accident experience as the only adequate representation is by another human body. Alternatively, one could accept that seat belt restraints are giving a satisfactory performance and then run some tests with a specified dummy test device using seat belts and accept a new level of severity index for the dummy based on the results of these tests. I offer this for consideration.

SECTION 2

PART 4

THE JAPANESE TECHNICAL PRESENTATION ON THE ESV PROGRAM

GENERAL REMARKS ON THE SPECIFICATIONS FOR JAPAN ESV

Mr. Yoshiro Okami
Japan Automobile Research
Institute, Inc. (JARI)

To comply with the Japanese Government's request for drawing the Specifications for a Japanese Experimental Safety Vehicle, the ESV Subcommittee was established within Japan Automobile Manufacturers Association, Inc. (JAMA) in November, 1970. The Subcommitte, comprising of technical experts from the Government, subordinate manufacturers and Japan Automobile Research Institute, Inc., started operation on the basis of the U.S. specifications for the 4,000 lb. ESV, and completed an original draft in January, 1971.

Consideration was later paid to the criticism of the U.S. National Highway Traffic Safety Administration, which had been levelled against the Japanese specifications. The Subcommittee decided on the final specifications in May, and JAMA submitted them to the Government.

Our specifications will, in general, meet the requirements, described in the U.S. specifications. However, some differences will be noted because our ESV is a smaller type and traffic regulations in Japan are not the same as those in the U.S.A.

I will explain, from the Japanese point of view, the main differences.

1. The specifications for the Japanese ESV were drawn to enable them to also meet the Safety Regulations for Vehicles for Road Transportation (JAPAN). One example is that the requirement for an outside rearview mirror was added.

2. The automobile engineers in Japan have made every possible effort towards the reduction of curb weight, and we have considered it as an indication of technical progress. However, there arose the fundamental necessity of reinvestigating the weight of vehicles. The reason is that passengers should be protected in the collision to a fixed flat barrier at the impact speed of 80 kilometers per hour, and such requirement will lead to an increase in curb weight. It is doubtful whether the increase in curb weight will be able to be compensated by a decrease in the weight of other components, but this will doubtless be proved through the achievement of subsequent technical developments. In the first stage of the programme, we consider that curb weight is one of the subjects for the research into crashworthiness.

The Graph in Figure 1 shows a conceptual diagram of the relation between curb weight and the characteristics of crashworthiness with the number of occupants as a parameter. The following two ideas can be drawn from this:

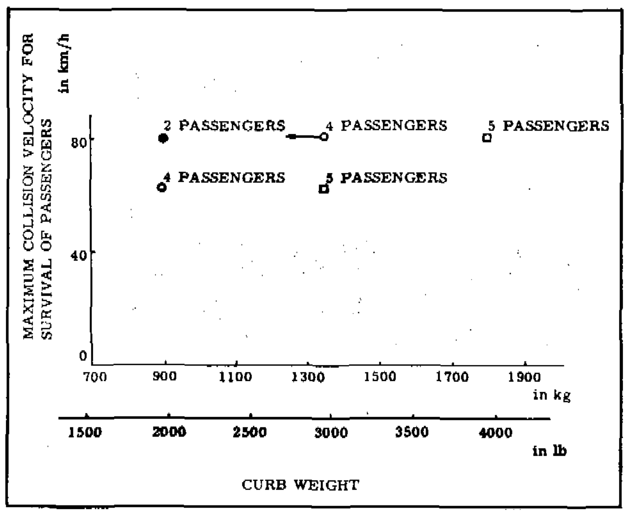


Figure 1

1. How much will the minimum weight of ESV be for four passengers?

2. Under what condition will it be possible to make a 900 kilogram-weight ESV?

We thought that in the present stage we should not conclude which type would be more pertinent to the future traffic system. We therefore adopted two specifications for the design based on the curb weight and the number of passengers (Fig. 2). The choice will be left to the participating manufacturers. Through the research into crashworthiness on the vehicles of these different

ITEM	SPECIFICATION	
NUMBER OF PASSENGERS	4 OR	2
CURB WEIGHT	1150 kg (2530 lbs)	900 kg (1980 lbs)
VEHICLE CAPACITY WEIGHT	322 kg (710 lbs)	161 kg (355 lbs)

Figure 2

types, we believe that more technical information will become available, thereby assisting the achievement of our programme.

Nissan Motor Co. Ltd. will develop an ESV for four passengers, and Toyota Motor Co. Ltd. will develop an ESV of 900 kilogram weight designed for two passengers. Furthermore Honda Motor Co. Ltd. will develop a 750 kilogram weight ESV for four passengers, which is smaller in weight than that prescribed in the specifications. The details of these vehicles will be explained in the technical presentation by the individual Japanese manufacturers.

3. Our opinions were divided as to whether intrusion should be adopted as the criterion for judging the integrity of the occupant compartment. We have not sufficient information on the relation between intrusion and human tolerance, and the injuries to the occupants will depend very much on the construction of the vehicle and on the method of the occupant restraint system. With these in mind, we are doubtful whether a uniform standard should be applied or not. We adopted a standard prescribing that "there shall be no passenger compartment intrusion greater than 125 millimeters at such places where the safety of occupants is involved."

We believe that this standard can be accepted as reasonable for a Japanese ESV, whereby the two approaches on curb weight and the number of passengers are adopted.

4. The Japanese specifications fail to describe the front bumper, which is sensitive at impact velocity. But the condition of collision is the same as that in the U.S.A. and also the requirement on occupant protection. The protection of occupants is related to such factors as vehicle configuration, body structure, occupant restraint system, interior design, etc. Therefore, in the original specifications, we decided not to specify for the front bumper, leaving room for flexibility in design. The progress of research may require further review of this problem.

5. We have tried to utilise the principles of the U.S. specifications on braking, steering and handling into a smaller type ESV, and found our results resembled the German specifications. As there is still room left for research in regard to the relation between steering and handling characteristics and the avoidance of accidents, we consider that all possible factors relating to accident avoidance should become the object of future study.

Our specifications will be increased depending on how our future research develops on these pending problems.

6. We can point out many differences in technical terms when expressed in English and also, as this programme will be extended to cover a new field of research, new terms will be introduced. Such differences could lead to confusion in the exchange of information and we earnestly hope that consideration will be given to the standardisation of technical terms.

THE TOYOTA MOTOR COMPANY

Mr. Jiro Kawano
ESV Chief Designer,
Toyota Motor Co., Ltd.

I'm a chief designer in charge of ESV project at Toyota Motor Co. in Japan.

It is indeed a great honor for me, to engage in the ESV project, which contributes to welfare of people and society of the world, and to be in cooperation with DOT in U.S.A. and many authorities in the world.

Toyota Motor just started the development of this project under the approval of Japanese Government in accordance with Japan ESV specification. This is the first time for Toyota to attend at the international conference as a member of this group, and also our project is just on the first stage.

Therefore, I would like to explain briefly the concept of our specification and programming plan, and show you a short film of our testing facilities and ESV tests by using some current vehicles on production.

Toyota decided to develop the 2,000 lb. ESV with two-seaters for the following reasons.

1. This is the opening stage in the long running term project, so to start with the simplified arrangement was thought to be the best for us.

2. We think it is very significant and fruitful to develop various kinds of ESV by many manufacturers in the world.

3. Most of Toyota's products are classified in this 2,000 lb. class, and to make the safety car within this weight range, the specification of two-seaters was thought to be the most suitable one for us.

Generally speaking, the crashworthiness mechanism with two-seaters is essentially the same with that of four-seaters except for the rear seat problems. Therefore

I believe that the result of the crashworthiness study in this experimental vehicle shall have some good fruit for the future research and development study.

As for accident avoidance performances, by making good use of characteristics of light weight on this 2,000 lb. specification, the vehicle design shall be intended to be fully analyzable of these performances.

With regard to the size of the vehicle, it will be necessary to have 4.3m overall length and 1.8m overall width, in order to satisfy the crashworthiness requirement. I would like to explain more details concerning our design, but unfortunately we can't do it now, because we are just on the first page of this program and we are under the investigation on the crash behavior of the vehicles which were locally modified from our production sedan.

As for accident avoidance, we think it is the most important item for traffic safety. We will study the technical feasibility on this subject making best use of the characteristics of the small sized car.

We have many things to do to meet the specifications – vehicle handling and steering, brake performance, visibility and so on. So we are intending to make moderate model giving careful consideration to these specifications.

With regard to the vehicle weight, we will do the best effort to reduce it down to 2,000 lbs. However, unfortunately if trade-off between the weight reduction and the safety performance may become necessary, the choice shall be made according to the principle of safety priorities, and hereby for instance the use of expensive special light alloy to reduce the vehicle weight shall be avoided as much as possible.

Next, I would like to show you the time schedule of our ESV project.

The delivery date of Japan's ESV is at the end of 1973. We have the following program to accomplish the vehicle within a term.

Up to the end of 1971, we will lay stress on the analysis of crashworthiness performance and investigation of each subsystem on the proper modified current models.

By the middle of 1972, the evaluation test of the primary prototype shall be made.

By the end of 1972, the secondary prototype shall be made considering the results of the previous model.

By the beginning of 1973, the final design and specification shall be fixed.

After various tests and improvements on the final design, the delivery of the complete vehicles shall be planned by the end of 1973.

About 100 units of test vehicles shall be prepared, that is, about 60 units of newly fabricated prototype vehicles, and about 40 units of partially modified vehicles.

Next, I would like to present a short movie film, which shows our testing facilities and various tests which we have conducted at Toyota Higashi Fuji Proving Ground.

THE NISSAN MOTOR COMPANY

Mr. Yoshio Serizawa

Mr. Teruo Maeda

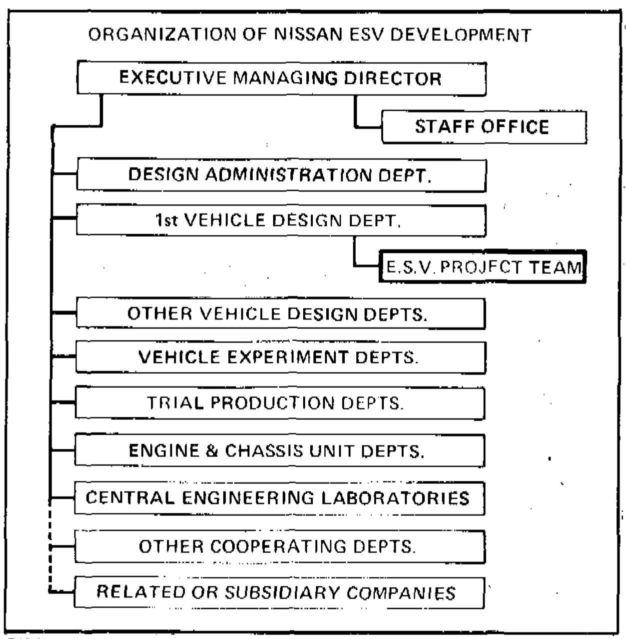
It is a great pleasure for me to present the technical efforts of Nissan Motor Company at this International Conference.

I am the deputy manager of the design administration department at Nissan, and the chairman of the Safety Committee of the Japan Automobile Manufacturers Association.

I would like to present this report with the high degree of social and technological responsibility which is Nissan's philosophy in regard to vehicle safety.

As for the ESV program, it was organized by Nissan Motor Company early this year under the general supervision of Dr. Nakagawa, Executive Managing Director who is attending today's conference, with five others from Nissan. The ESV Project team composed of 30 design engineers is headed by Mr. Teruo Maeda.

Many cooperating departments, which are engaged in various new production models, are also supporting this project team (Slide 1). For instance, a clean engine will



Slide 1

be developed and supplied from the engine department, and all experiments including ESV compliance tests are now underway in the vehicle experiment department using our various facilities.

The main specification we are working under is the same as Japanese ESV specification. We selected 4-passenger, 4-door sedan of 2,500 lbs., which is 1150 kg.

I think this specification is market-minded and applicable to future production cars. However, it is the most challenging specification in weight and size. We must accomplish almost the same specifications and characteristics as those of American vehicles of 4,000 lbs. or more, within a small and compact package. There are a few differences between U.S. and Japanese specifications, some of which are shown here (Slide 2).

NISSAN ESV SPECIFICATIONS
DIFFERENCE FROM 4000 lb E.S.V.

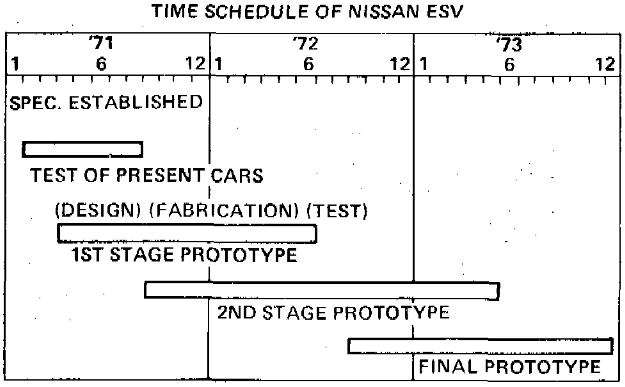
ITEM		NISSAN E.S.V.	4000 lb E.S.V.
Dimension	Size	None	max min 5588x2032x1473
	Weight	1150 kg	1800 ± 90 kg
	Seats	4	5
Slalom	Speed	80 km/h	72 km/h
Forward Visibility	Up/Down	13°/6°	17°/8°
Crashworthiness	Intrusion	< 125 mm	< 75 mm
	Deceleration	None	Specified for Front End Structure

Slide 2

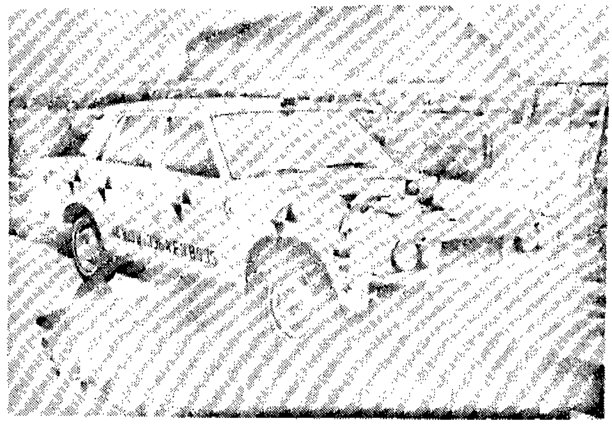
Our project team with the help of other Nissan departments is going to build about 20 final ESVs before the end of 1973. These vehicles will be tested and assured under the given specifications as far as possible in Nissan Motor Company.

For this purpose, we set up four stages of testing (Slide 3). The initial stage is that of establishing a "Bench Mark" on the status of present cars. The next one is that of testing the vehicle modified from the present cars, which we will call the 1st stage prototype. We used Datsun 510 and 610 as the basic models. The 1st stage is under way and will continue until the beginning of next year (Slide 4). The 2nd stage is that of designing and testing the 2nd prototypes. This stage has started in some fields including the development of various parts such as periscope, tires, glass, shock absorbing units and materials. This stage will be the area of maximum effort next year.

TIME SCHEDULE OF NISSAN ESV



Slide 3



Slide 4

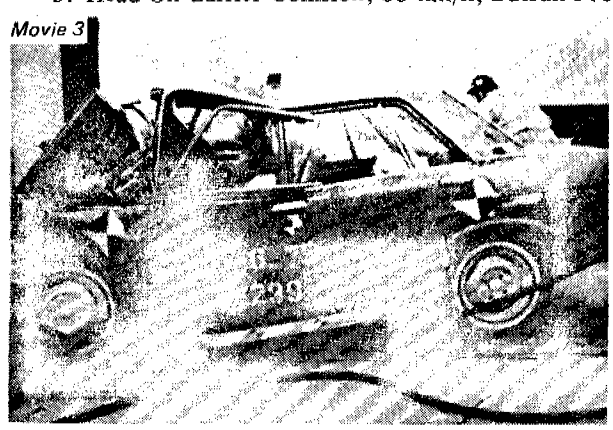
Through this experience, we will design the final ESV, and after testing and correcting again, we will accomplish the final ESV.

Now, I would like to present several testing results so far finished in Nissan by movie. Through this movie, you will see the difficulties and challenges which are encompassed in the ESV project.

(Movie)

1. Head-On Barrier Collision, 50 km/h, Datsun 510
2. Occupant Protection at Head-On Collision, 50 km/h
3. Head-On Barrier Collision, 80 km/h, Datsun 510

Movie 3



4. Head–On 45° Barrier Collision, 50 km/h, Datsun 510

5. Bench Test, Static Collapse of Front End of Datsun 510

6. Bench Test, Dynamic Collapse of ½ Scale Model

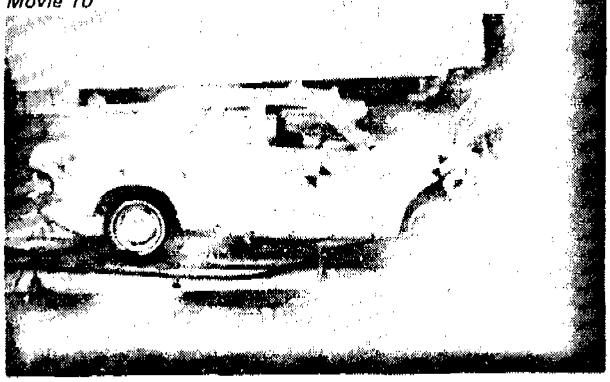
7. Bench Test, Dynamic Collapse of Tire

8. Head-On Barrier Collision, 80 km/h, Datsun 510 without engine

9. Head-On Barrier Collision, 15 km/h, 1st Stage Prototype

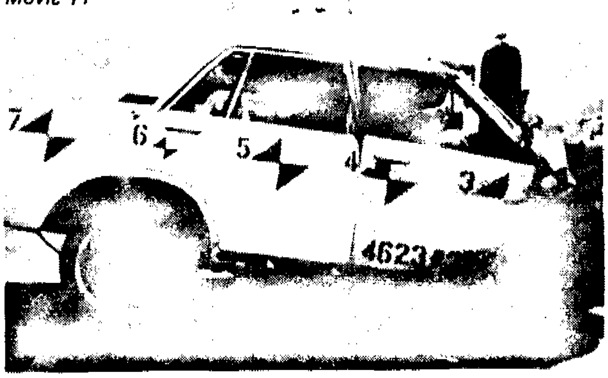
10. Head-On Barrier Collision, 80 km/h, 1st Stage Prototype

Movie 10



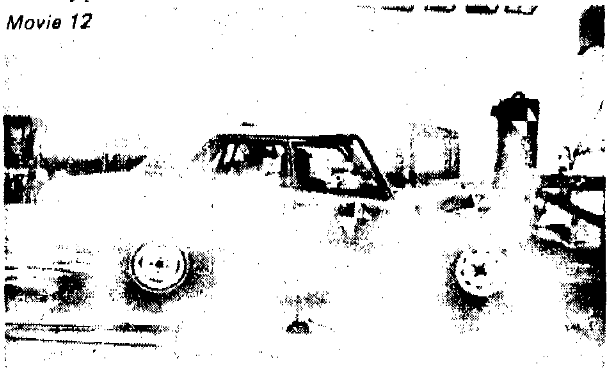
11. Head-On Pole Collision, 80 km/h, Datsun 510

Movie 11



12. Head-On Pole Collision, 80 km/h, 1st Stage Prototype

Movie 12

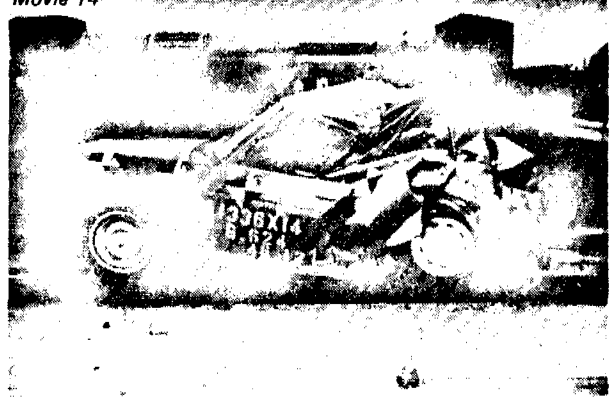


13. Rear-End Collision, 70 km/h Moving Barrier, Datsun 510

Movie 13

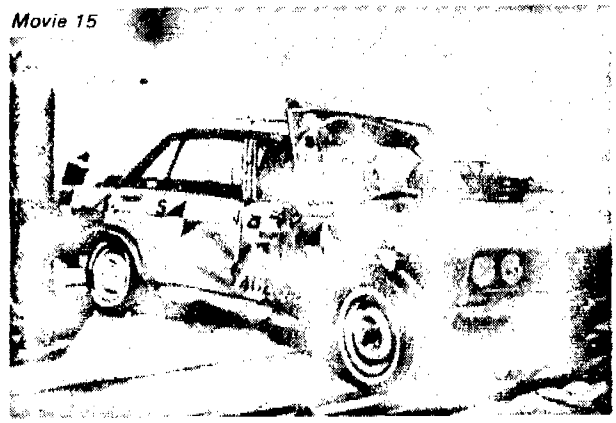
14. Rear-End Barrier Collision, 64 km/h, 1st Stage Prototype

Movie 14



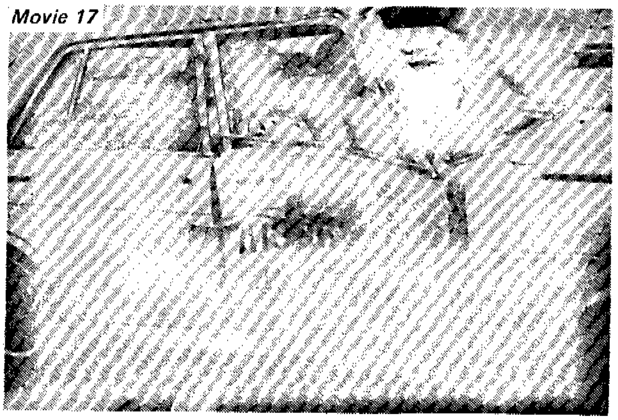
15. Occupant Protection at Side Collision, 25 km/h, Datsun 510

Movie 15



16. Side Pole Collision, 25 km/h, Datsun 510

17. Side Pole Collision, 25 km/h, 1st Stage Prototype


Movie 17

18. Vehicle Submergence
19. J-Turn, Datsun 510, 110 km/h
20. J-Turn, Datsun 510 – Overload on the roof, 110 km/h

(Slide) Experimental Components

5. Periscope
6. Front Bumper System
7. Front Suspension and Steering System
8. Rear Suspension System
9. Tire

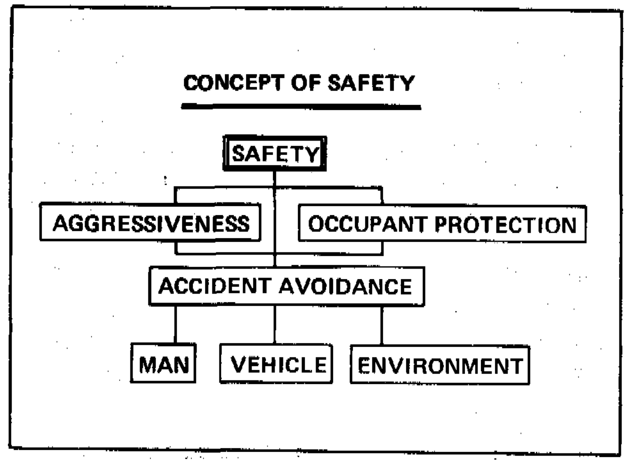
As you have seen in this presentation, we are encountering various difficulties.

For the small-sized vehicle, body crashworthiness and occupant protection are really the toughest problem. The 80 km/h head-on barrier collision is one of the most difficult requirements. We feel these problems are very challenging, and we are extending every effort to meet this requirement.

Taking the vehicle size into account, an 80 km/h rear end collision by a 4,000 lb. moving barrier is also in the same situation. The energy absorbed in the moving barrier collision is much higher than that in the actual rear-end collision. We are trying to find a more practical and suitable test condition for this purpose. We may presumbably adopt a "car to car" collision between the same weighted cars or a collision with the same weighted moving barrier instead of the present specified collision.

As for the other specifications such as visibility, brakes, and vehicle handling, we do not see much difficulty in the present cars and the modified ESV.

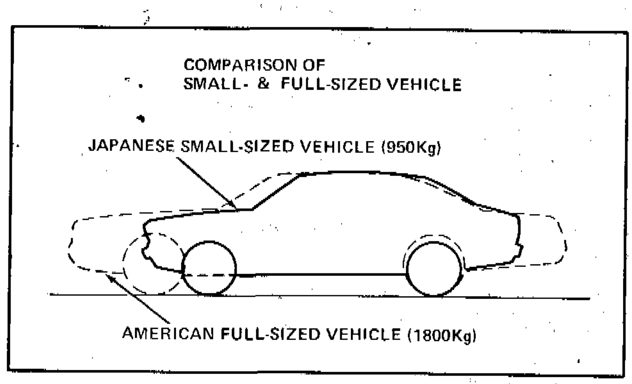
Safety itself consists of many factors (Slide 10). I would like to state our general concept of safety in ESV design. Accident avoidance is the first objective, of course. If all the accidents could be avoided, safety would be completely assured. Accident avoidance consists of three factors. One is the factor on the vehicle side such as handling, brakes, etc., which are defined to a certain extent by the ESV specifications. The other is the factor of traffic environment. The last is that of driver's conditions, such as manners, mental and physical conditions, education, enforcement, and so on. We consider the last factor to be the most important and the most emphasized by our president, Mr. Kawamata in various places.



Slide 10

Unfortunately, if accidents can not be avoided, we are faced with two kinds of damages or injuries. These are damages to the offender, and damages to the sufferer. We should never forget the safety on the sufferer's side. The offender's problem is how to reduce the sufferer's damage caused by the offender's vehicle. This characteristic may be called "aggressiveness." Sometimes this will be much more important if we think of the driver's responsibility to society.

We, Nissan Motor Company, do not intend to increase the weight, nor the size of our ESV to satisfy the requirements (Slide 11). These increments will bring an increase of aggressiveness. Naturally, small-sized vehicles have less aggressiveness and easier handling. We will not sacrifice this superiority even if we face very strict crashworthiness problems.



Slide 11

I would like to say that we at Nissan are doing our best to design the safest vehicle considering overall safety factors.

We will spend 1.7 billion yen, that is, more than five million dollars for the ESV project. We will use more than 200 man-years. These burdens are quite heavy on our company. But for the high objective of ESV, we will promote this project intensively. It is said, in the Olympic Games, participation itself is worthwhile. Through this challenging participation, we hope we can demonstrate to the world that Nissan Motor Company is a reliable, dedicated and socially conscious manufacturer of excellent motor vehicles.

THE HONDA MOTOR COMPANY

Mr. Hiroshi Hayano
Chief Engineer, ESV Project

Introduction

Today we would like to explain our view on the small lightweight ESV which Honda is taking up as a project, because we have a different point of view in our approach to this project than that of the large ESV represented by U.S. 4,000 lb. vehicle.

I. Needs Of Small Lightweight Vehicles

There is no doubt that a prime objective of ESV is to seek the technical feasibility of vehicle safety. In considering the uniqueness of Japan's city structure and road conditions and noting that demand for small cars is gradually increasing in the recent market trend, it is clearly foreseeable that a continuous demand for cars in the small category will remain at a significant level for years to come.

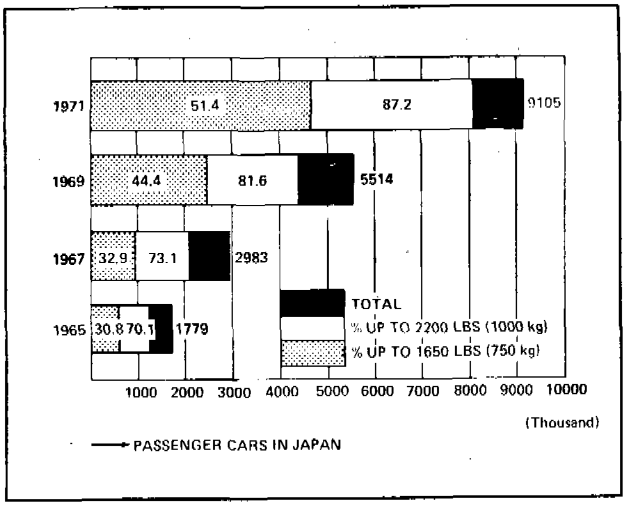
Therefore there could be small lightweight ESV to suit the social needs and its manner of use in Japan.

Considering also their usage, small cars should be capable of sustained 100 km/h cruising while being economical and easy to operate when driving at medium and lower speeds.

With this background in mind, we have decided to challenge this ESV project by developing a small ESV not only smaller than U.S. 4,000 lbs. ESV, but also the 2,000 lbs. ESV of Japan.

Because of technical hardships due only to the smallness and lightness of our ESV, the completion may take a year longer than other Japan ESVs. This is the reason why we are participating in the capacity of semiparticipant.

We shall provide JARI with the Honda ESV free of charge instead of seeking the government funds in exchange.



II. Basic Requirement Of Honda ESV

The basic requirement for a small ESV then would be as follows. The main objectives in developing such a small ESV would naturally be different from that for 4,000 lbs. vehicle.

1. Accident Avoidance
   (a) Ensure perfect controllability
   (b) Prevent erroneous and excessive operation
2. Man-Machine Communication
   (a) Automatic checking system for pre-start inspection
   (b) Monitoring system to ensure safe running
   (c) Warning system to prevent driver negligence
   (d) Improvement of visibility and identification
3. Crashworthiness
   Aimed at the specification established for Japan ESV

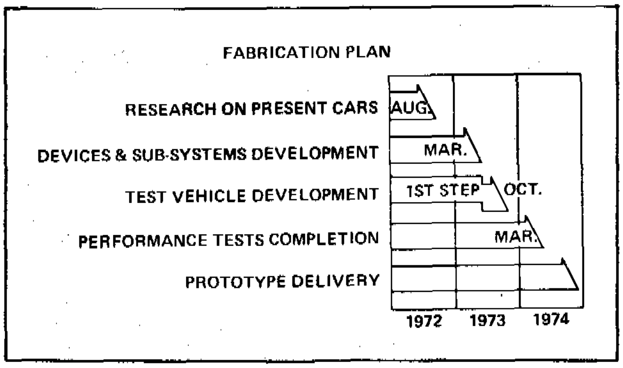
III. Particular Emphasis On The Specifications

Curb Weight	**750 kg (1650 lbs.)**
Passengers	**4**
Type	**Family Sedan**
Expected Car Dimensions	
Length	**3500 mm (138 in.)**
Width	**1500 mm (59 in.)**
Maximum Horsepower	**55 bhp**

As to the crashworthiness, we are anticipating a number of technical difficulties because of the size of this car.

IV. Fabrication Plan

Because of the circumstances within our company and expected technical difficulties, the delivery of the Honda ESV prototype will be one year later than those of formally participating companies in Japan.



THE JAPANESE AUTOMOBILE RESEARCH INSTITUTE

Prof. Dr. Masaichi Kondo
Director

We can see often the lovely scenes in which even the children less than one and a half years old wish earnestly to ride in motor vehicles. According to my feeling, this seems to mean that human beings innately love motor vehicles and like to have and ride in them, though verification for it is not enough by the above fact alone. Needless to say, the motor vehicle is very convenient, useful, economical and productive; and in addition, it affords us pleasure and enjoyment. The motor vehicle is truly the prime mover for development of economy and civilization of societies and nations.

While we are using very many machineries of various kinds in present days, we have none so social as the motor vehicle, which comes into the midst of our society, being used by almost all people and maneuvered very freely in compliance to the individual's will every day and everywhere. I would like to claim the motor vehicle has semi-human character and hence I call the motor vehicle "semi-human machine" or "semi-mechanical man."

Very regrettably, however, present motor vehicles have large demerits: they pollute the atmosphere by emissions and cause traffic accidents, etc. Considering the large merits and special characteristics of the motor vehicles above stated, we have to improve, with all and utmost endeavors, the motor vehicle into a safe and non-pollutant one. Realization of a safe and non-pollutant vehicle is eagerly requested by all Japanese people as well as by all mankind of the world.

With the background of these social situations and requisitions, Japan Automobile Research Institute, Inc. (abbreviated as JARI) was inaugurated in April, 1969, by the sponsorship of all Japanese automobile manufacturers and related industries with the cooperation of the Japanese Government. The Institute was established basing upon the establishment named Automobile High Speed Proving Ground, Inc., which had been established in 1960 at Yatabe-cho, Tsukuba-gun, Ibaraki (about 60 km north of Tokyo) with the site about 2.5 square kilometers and had already a test circuit of 5.5 km length as well as other large scale test grounds. The site is located in the neighborhood of Satellite Town for Research and Educational Institutes (Tsukuba Kenkyu-Gakuen Toshi) which was planned afterwards by Government, and is now under construction. Thus, our Institute is the recipient of the predecessor's large scale proving ground and therefore we could begin research activities comparatively earlier by adding new buildings and research equipments.

Though saying easily in words, realization of safe and non-pollutant vehicles is very difficult. From safety's point of view, following are requested: crashworthy devices which protect occupants even when collision occurs at high speeds, cushioning designs of the vehicle's front part which guard the pedestrian from injuries when the vehicle hits him, and immunity of overturning against all rough steering and braking so long as running on smooth horizontal roads, and so on. As for non-pollutant vehicles, situation is more severe and it requires: redesign and reconstruction of engines improving combustion in the cylinder, reburning and purification of the exhaust gas by means of reactors and catalizers, etc., and development of new types such as electric vehicles and vapor engine vehicles, and so on.

In our Institute, we are making allout efforts considering it the primary target to solve various problems relating to realization of safe and non-pollutant vehicles. At the same time, we are making fundamental and futuristic researches also. These research works are being conducted in harmony with the ones which are made in Japanese automobile manufactures and related industries.

Adding to the test ground including other auxiliaries already mentioned, several research laboratories with new equipments were recently completed, and the dormitories for research staff are now partly constructed. Total number of research staff and supporting members is about 165 on April 1, 1971.

As above stated, in our Institute, we are making, under the direction of Mr. K. Kawamata, President of our Institute, all endeavors day and night for the urgent target of completing safe and non-pollutant vehicles with earnest wishes to answer the requests of all Japanese people as well as of all mankind of the world. Concluding the address, I ask sincerely understanding and cooperation of the people relating to automobiles in the Governmental, academic and industrial circles as well as all the public.

BOARD OF DIRECTORS

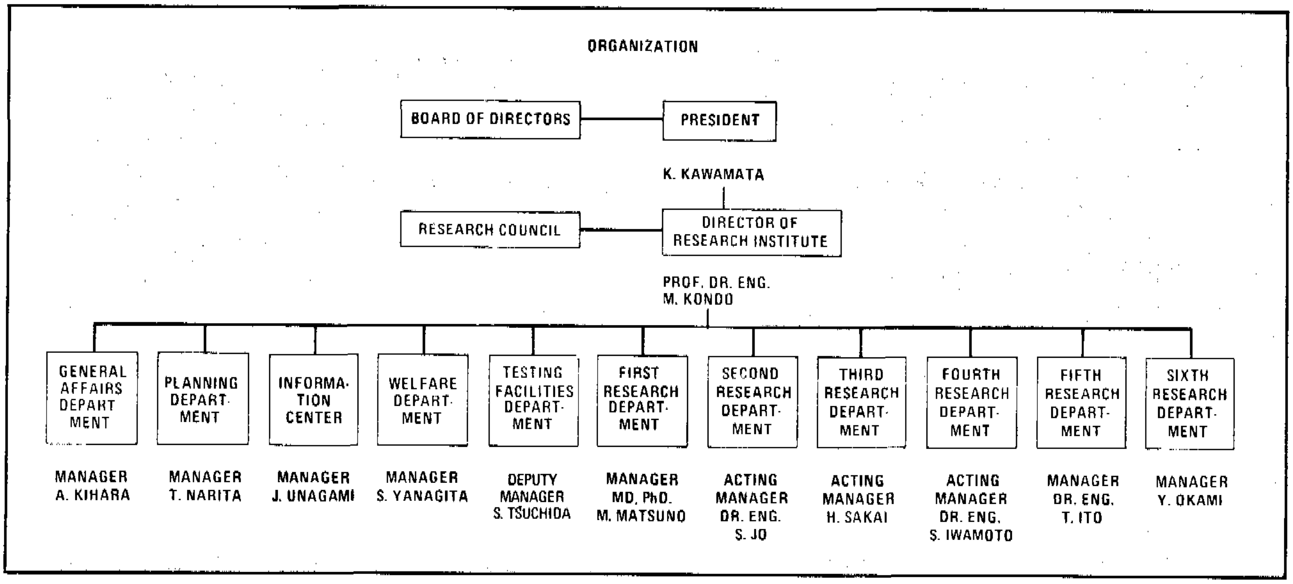
President	*Katsuji Kawamata* – President, Nissan Motor Co., Ltd.
Vice-President	*Masaichi Kondo* – Dr. Eng., Professor Emeritus, Tokyo Institute of Technology
	Tsutomu Nomiyama – Managing Director, Japan Automobile Manufacturers Association, Inc.
	Hideo Fukukawa – Formerly Vice-President of Former Automobile High Speed Proving Ground, Inc.
Director	*Torao Aramaki* – President, Isuzu Motors Limited
	Toshizo Suzuki – President, Suzuki Motor Co., Ltd.
	Yoshikichi Ise – President, Daihatsu Kogyo Co., Ltd.
	Eiji Toyota – President, Toyota Motor Co., Ltd.
	Kohei Matsuda – President, Toyo Kogyo Co., Ltd.
	Kyoichi Harashina – President, Nissan Diesel Motor Co., Ltd.
	Kiyotoshi Fujioka – President, NHK Spring Co., Ltd.
	Tatsuo Iwatsuki – President, Nippon Denso Co., Ltd.
	Masanobu Matsukata – President, Hino Motors, Ltd.
	Soichiro Honda – President, Honda Motor Co., Ltd.
	Yuji Sato – President, Mitsubishi Motors Corp.
	Mineo Yamamoto – Professor, Tamagawa University
	Ichiro Watanabe – Professor, Dr. Eng., Keio University
	Toshiro Seki – Professor, Waseda University
	Osamu Hirao – Professor, Dr. Eng., University of Tokyo
	Atsushi Watari – Professor, Dr. Eng., University of Tokyo
	Sumiji Fuji – Professor, Dr. Eng., University of Tokyo
	Tomoo Ishihara – Professor, Dr. Eng., University of Tokyo
	Takeo Narita – Formerly staff of Toyota Motor Co., Ltd.
	Masanori Matsuno – MD, PhD., Formerly staff of Nissan Motor Co., Ltd.
	Yoshiro Okami – Formerly staff of Isuzu Motors Limited
	Akio Kihara – Formerly staff of Ministry of International Trade and Industry
Auditor	*Eiichi Ohara* – President, Fuji Heavy Industries Ltd.
	Tadashi Kinoshita – Senior Managing Director, Topy Industries, Ltd.

MEMBERS OF RESEARCH COUNCIL

Masaichi Kondo	Vice-President, Director of the Institute, Dr. Eng.
Hideo Fukukawa	Vice-President
Mineo Yamamoto	Professor, Tamagawa University
Osamu Hirao	Professor, Dr. Eng., University of Tokyo
Atsushi Watari	Professor, Dr. Eng., University of Tokyo
Sumiji Fujii	Professor, Dr. Eng., University of Tokyo
Tomoo Ishihara	Professor, Dr. Eng., University of Tokyo
Hiroshi Takahashi	Director, Nissan Motor Co., Ltd.
Masao Shomura	Manager of Technical Administration Dept., Mitsubishi Motors Corp.
Tozo Yabuta	Director, Toyota Motor Co., Ltd.
Yoshio Kono	Managing Director, Toyo Kogyo Co., Ltd.
Yozo Shimizu	Managing Director, Isuzu Motors Limited
Kiyoshi Yamota	Executive Managing Director, Hino Motors, Ltd.
Ichiro Niitsuma	Engineer, Honda Motor Co., Ltd.

RESEARCH ACTIVITY

Research activities of the Institute are divided into two fields: one is conducted in each Research Department and the other is carried out by various Research Committees. Those researches are made up each other and constitute the consistent projects. Most of research



theme are based on those desired by Japan Automobile Manufacturers Association, Inc. through the deliberation made by various Committees.

It goes without saying that at present we are focused on urgent theme, that is on environmental protection and safety problems.

Although substantial research areas of each Research Department is as stated below, it is necessary systematic and mobile cooperation among research departments to promote research project, and the management of the Institute takes serious consideration on systematization and mobility.

First Research Department: Principally researches based on Human Factors

Second Research Department: Research on Power Plant

Third Research Department: Principally researches based on Vehicle Dynamics

Fourth Research Department: Principally researches based on Vehicle Mechanics

Fifth Research Department: Principally researches based on Hydrodynamics and Control Engineering

RESEARCH THEME

I. Anti-Pollutions

1. Researches on Automobile Exhaust Emission Control
   - Trial Manufacture of Perfect Emission Control System
   - Study of the Catalyst for Emission Control
   - Study of the Improvement of Fuel Supply and Combustion in Automobile Engine
   - Study of the Influence of Lead Free Fuel on the Engine Performance and Exhaust Emission
   - Study of the Influence of Fuel Composition on Diesel Exhaust Composition and Smoke
   - Smoke Suppressive Additives, NOx Suppressive Method, etc.
   - Establishment of Correct Measurement Method of Exhaust Gas
   - Study of the Exhaust Particulate and Its Removal
   - Development and Operation of Smog Chamber Vehicle and Pollution Analysis Vehicle
   - Research on Forecasting System of Air Pollution in Big City
   - Investigation of Actual State of Ozon and Oxidant Concentration in Tokyo
   - Basic Research on Oxidant and Pollution
   - Biological Study on the Exhaust Catalyzer Substance
   - Experimental and Analytical Research of Diffusion and Dilution of Exhaust Gas in the Automobile Tunnel (with Natural Ventilation)

     (Charge: 2nd Res. Dept., 1st Res. Dept., 5th Res. Dept., Combustion and Exhaust Emission Committee, Fuel and Lubricant Committee, Lead Free Fuel and Engine Performance Committee, Air Pollution Analysis Research Committee)
2. Researches on Low Emission Engines
   - Basic Study of the Development of Vapor Engine Car
   - Investigation of Engineering Feasibility in Gas Turbine, Stirling Engine and Electric Powered Automobile

     (Charge: 2nd Res. Dept., Vapor Engine Car Committee)
3. Research on Noise Reduction
   - Analysis and Experiment to Grasp the Present

Condition of Travelling Noise (Especially about Tire Noise and Engine Noise) of Trucks and Buses
Research on Tire Noise, Engine Noise and Other Related Problems as Elastic Vibration and Wind Vibration
(Charge: 4th Res. Dept., Research Committee on Vehicle Noise)

4. Research on Prevention of Radio Frequency Interference
   - Investigation of Actual Situation of Radio Frequency Noise Generated from Domestic Vehicles,
   - Investigation of Preventive Effect of Current R. F. Noise Suppressors and Various Experimental Products, and Comparative Study of JRTC Standard and CISPR Standard
   (Charge: Research Committee on Prevention of Automobile Radio Frequency Interference)

II. Safety

1. Study of Occupant Protection
   - Development of Anthropomorphic Test Device
   - Study on Work Space and Control Dynamics
   - New Standardization on the Automobile Seat
   - Researches on Restraint System including Airbag, Helmet, Seatharness, etc.
   - Biological Study of Deceleration Effects
   (Charge: 1st Res. Dept., Human Engineering Committee, Windshield Committee)

2. Research on Absorption of Crash Energy (. . . of Energy Due to Impact of Collision of Automobile)
   - Research on the Body and Its Components which Augment the Energy Absorbing Capability in Collision of Automobile
   - Development of Accelerometer or Speedometer of Simple Construction to Measure the Impact Velocity or Acceleration in Collision of Automobile

3. Researches on Vehicle's Stability and Control
   - Dynamics of Vehicle's Overturning and Test Procedures for the Limit of Maneuverability
   - Research of Handling Characteristics of Multiple Vehicle Combinations
   - Arrangement and Unification of the Methods of Test and Appraisal of the Stability in High Speed Research of the Relation between the Vehicle Shape and Running Stability at High Speed, Based on Statical and Dynamical Aerodynamics
   - Research of Movement of Automobile under Side Winds
   - Study on the Friction of Test Courses by Means of Skid Resistance Tester
   - Research on Tire Mechanics Covering Hydroplaning, Braking Characteristics, Mechanism of Tread Wear and so on
   - Development of No-puncture Safety Tire
   - Systematization of Feeling Test of Vehicles
   - Research on Methods for Measurement of Fundamental Vehicle Characteristics
   (Charge: 3rd Res. Dept., 4th Res. Dept., Stability and Control Committee, Aerodynamic Performance Committee, High Speed Stability Appraisal Committee)

4. Study on For-Pedestrian Safety Vehicle
   - Systematic Researches on Padding Material, Vehicle's Front Form, and Methods of Increasing Shock Absorbing Ability and so on, with the Object of Trial Production of For-Pedestrain Safety Vehicle
   - Study on the Motion of a Pedestrian Just before He Collides or Contacts with a Vehicle
   - Trial Production of V. T. R. (Video Tape Recorder) for Recording On-the-spot Auto Accident Scene
   (Charge: 3rd Res. Dept., For-Pedestrain Safety Vehicle Committee)

5. Studies on Lighting and Visibility of Automobile
   - Improvement of Brake Light, Turn Signal, Tail Light, etc. for Rear Collision Prevention
   - Researches on Visibility of Automobile
   (Charge: 1st Res. Dept.)

III. Experimental Safety Vehicle (ESV)

- Study on Evaluating Test of ESV
- Study of Testing Facilities for ESV

IV. Future Traffic Systems

- Research of Guided Automobile
- Research of the Simplified Control Equipments of Automobile to Control the Vehicle along the Guide Way and Further to Systematize the Traffic Research of the Electronic Guidance on the Guideway
- Research of Linked Automobile
(Charge: 6th Res. Dept.)

V. Fundamental Researches

1. Research on Elastic Vibration of Structure
   (4th Res. Dept.)
2. Fundamental Research of Aerodynamical Problems of Vehicle
   (5th Res. Dept.)
3. Research of Oil Pressure Control Apparatus
   (5th Res. Dept.)
4. Research of Dynamics of the Bearing
   (5th Res. Dept.)
5. Studies on Reduction of Body Weight and Application of Plastics to Body
   (6th Res. Dept.)

PROGRESS TOWARD VEHICLES DESIGNED FOR PEDESTRIAN SAFETY

Prof. Dr. Masaichi Kondo
Director, Japan Automobile
Research Institute, Inc. (JARI)

1. Introduction

The author explains first that statistics indicate high percentage of pedestrian accidents in Japan and Japanese experts are eager to research for-pedestrian safety vehicle. He contends ideal safety vehicle is the combination of for-occupant safety vehicle plus for-pedestrian safety vehicle. He wishes survey tests made recently by JARI would be a one-step advance for the realization of for-pedestrian safety vehicle.

2. Vehicle-Pedestrian (Dummy) Collision Tests To See The Effect Of Front Body Form

2.1. Method Of Test

Method of test used recently in JARI is as follows. A driver-less and power-off test vehicle, being guided by two rails, is pushed forward by a powerful accelerating vehicle from the rear. The test vehicle is equipped with an automatic brake pedal actuator operated by wireless signal. The pedestrian (dummy) is hung vertically facing to the test vehicle by a supporter and is let free just before collision. Thus central and symmetrical collision is achieved with prescribed impact velocity and with prescribed deceleration of the test vehicle.

2.2 Test Plan

Test vehicles are three, all belonging to 1,000kg class passenger car. Vehicle A has a long front body with a bonnet of curved contour in side view. Vehicle B has a low grill and the bonnet is composed of two planes with inclinations toward the front window. Vehicle C has a high grill and the bonnet is nearly horizontal. With each test vehicle, collision tests were made at impact velocities 10, 20, 30 and 40 km/h under the vehicle's deceleration of about 0.5g.

2.3 Some Test Results

Some of test results are explained by history curves of accelerations of various parts of the dummy, deceleration history of the test vehicle and consecutive postures of the dummy relative to the collided vehicle. High-speed cinefilms taken from right side, from front and from above are also used to show the phenomena. Test vehicles deformed by collision are shown by photographs.

2.4 Some Observations

The front body with high grill pushes, at low velocity impact, the pedestrian (dummy) forward and let the dummy fall with its backside and head hitting the ground. The front body with long nose and low bumper gives, at high velocity impact, the dummy a large rotational angular velocity and let the legs lift high, and the dummy lands with the head hitting the ground. The author thinks the desirable front body form would be such that which may let the pedestrian (dummy) fall to the ground with the legs hitting first or with flat posture, within the impact velocity range as wide as possible.

3. Collision Tests To See The Effect Of Covering Front Body With Shock Absorbing Material

3.1 Characteristics of Shock Absorbing Material

As the material for this purpose, the author adopted the following multi-layer grid structure composed of polystyrene foam: Section of the component member: 10 mm (wide) x 30mm (high); no. of layers: 5; spacing of the member: 20mm; combination: 90° crossing and 10mm staggered; total height: 150mm.

3.2 Collision Tests With A Test Vehicle Covered With The Above

With another test vehicle D, the effect of covering the front body with the above material was tested. The effectiveness was made clear.

4. Collision Tests To See The Effect of Equipping With Shock Absorbing Device

As shock absorbing device, the author adopted wire ropes arranged transversally or wire rope net set above the bonnet, both with solid friction type shock absorbing device at the side. These devices were beforehand examined by falling ball test, etc. and then tested by collision tests with the test vehicle D. The effectiveness of these devices is prospective.

5. A Trial To Use Scoop Net For Protecting The Pedestrian Against The Second Impact

The idea of receiving the thrown down pedestrian (dummy) to protect him from hitting the ground is not new. The author had tried a scoop net type about three years ago and the trial was successful. The scoop net is supported by two telescopic horizontal poles and is storaged ordinarily underneath the body. If a pedestrian (dummy) collides with the vehicle, the supporting poles and consequently the scoop net extend forward and receive the thrown down pedestrian (dummy).

6. Theoretical Investigation On Pedestrian (Dummy) Movement In Collision With A Vehicle

Our group is now making theoretical investigation, by using fundamental equations of motion of nine--degree freedoms, assuming the dummy as a jointed combination of seven rigid bodies. Investigations of the same kind are made by other organizations and some results obtained by Isuzu Motors Limited are introduced here.

7. Concluding Remarks and Future Research Plan

After reviewing the whole survey tests presented in this paper, the author introduces future research plan such as followings:

1. Researches based upon present day vehicles
2. Systematic research
3. Theoretical investigation
4. Non-central or non-symmetrical collision
5. Development of dummies more similar to real human bodies and determination of human tolerance limits
   (With regard to the last item, our Institute is only capable to take part in very limited area.)

SECTION 2

PART 5 THE ITALIAN TECHNICAL PRESENTATION ON THE ESV PROGRAM

FIAT RESEARCH PROGRAM ON MOTOR VEHICLE SAFETY

Dr. Ing. Vittorio Montanari

In the Spring of 1971 Fiat has begun to work on a wide research program regarding "vehicle safety," coordinated with the European intergovernmental program.

The work was started before knowing if, how and when the Italian Government would have contributed to finance the program.

The official program concerns the study of five subjects which Fiat undertook to develop within the Italian national program.

1st – Vehicle behaviour in collision
2nd – Vehicle behaviour in rollover
3rd – Braking improvements
4th – Occupant restraint systems
5th – Fire hazards

The studies cover two classes of cars, namely: the class "1200 Lbs all rear" and the class "1800 Lbs all forward."

The actual Fiat program instead includes, in addition to the official one listed above, also the study of all the subjects considered in the European program which are the basic safety problems:

6th – Vehicle handling
7th – Improved lighting and signalling systems
8th – Driving in fog
9th – Interior vehicle design to reduce occupant injuries
10th – Design of bumpers to reduce damage in low speed impacts
11th – Exterior vehicle design to reduce injuries to pedestrians
12th – Improved visibility conditions
13th – Improved ergonomics control
14th – Tires
15th – Driver aids

In the actual program, research and testing are extended to three classes of vehicles:

1200 Lbs all rear
1800 Lbs all forward
2200 Lbs with front engine and rear wheel drive

The work was started on current production cars, typical of the three classes.

The first stage of the program, concerning the "study and development of the themes," will span over two years and end in the Spring of 1973 with the definition of the design of new experimental cars.

For this first stage, approximately 1,200,000 working hours are required, corresponding to a continuous activity by about 280 highly qualified technicians, and an expense of $16,000,000 is anticipated, including the investments for special testing equipment.

As regards investments, a few months ago our new Safety Laboratory started its activity: practically, it was opened by Mr. Toms in June during his visit to Turin.

This Laboratory covers a surface of approximately 6,000 sq. meters and is equipped for making indoor almost all the safety tests and, in particular, crash testing of vehicles up to 4,000 lbs at 50 mph.

The Laboratory is now considered already inadequate to meet the test requirements envisaged for the near future and we are therefore urgently trying to define the design of a new Laboratory with facilities about three times bigger than the present one. The expected cost is $8,000,000.

CRASHWORTHINESS IMPROVEMENT—TESTS AND RESULTS

Mr. Enzo Franchini, *Fiat*

In the ESV as well as in the European programs, the requirement is to pass front, rear and side impact and rollover tests. The following information concerns the tests performed and the results obtained using the three types of cars towards which our investigations have been aimed. The test program is not yet over and, hence, the information on the three models is not equally ample.

It should be emphasised that, basically, the various requirements in terms of passive safety for the occupants can be whittled down to two as follows:

1. survival space should remain after impact
2. occupant impact, against the car interior, should be as soft as possible.

Our experimental approach was that of arriving at satisfactory results primarily in terms of the first above requirement, which poses considerable problems on small-volume, low-weight cars.

Frontal Impact

Concerning the 1,200 lb. car, in the current production version results are satisfactory for front-end impact against barrier (Fig. 1) at speeds of 30 mph. It may be seen how intrusion is limited to the front trunk and how the passenger compartment has remained practically unaltered.

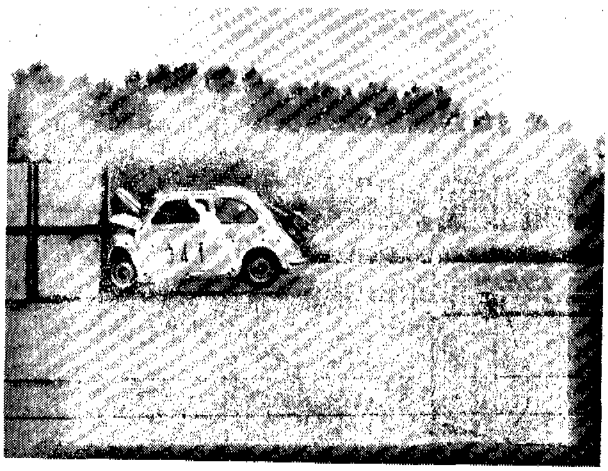


Figure 1

The current version, after substantial modifications and reinforcements was retested at 40 mph (Fig. 2), further reinforced and tested again at 50 mph (Fig. 3). The outcome is that the appearance of the reinforced car, impacted at 50 mph, is similar to that of the current car, as impacted at 30 mph; that is to say that reinforcement (Fig. 4) has almost trebled the energy-absorbing capability of the front end. This fact is clearly evidenced by the static forebody crushing test (Fig. 5) for current version and (Fig. 6) for the reinforced version the results of which have been used to plot the load/car crushing chart (Fig. 7).

In this connection attention should be drawn to the different maximim load figures reached in the two curves plotted on the chart. This means that in the

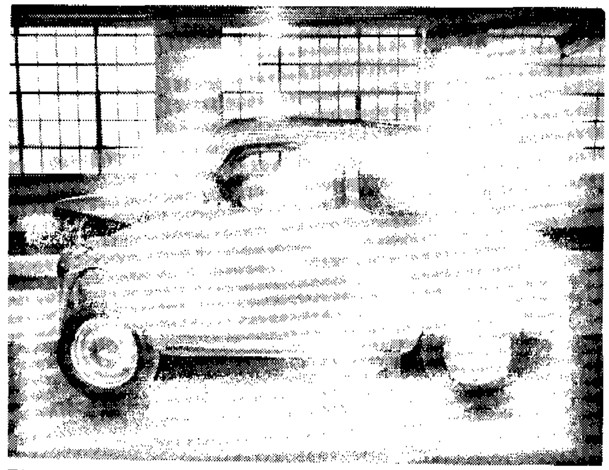


Figure 2

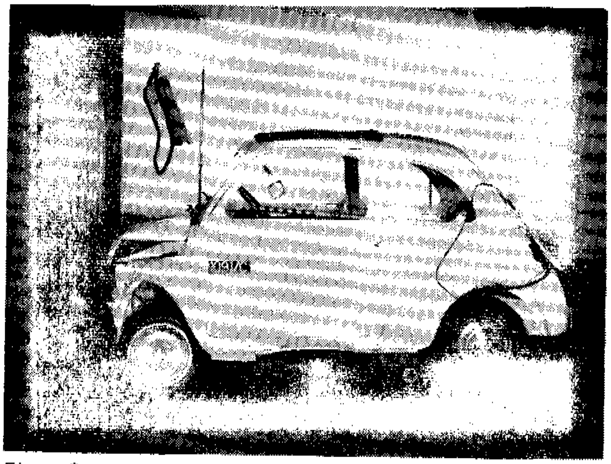


Figure 3

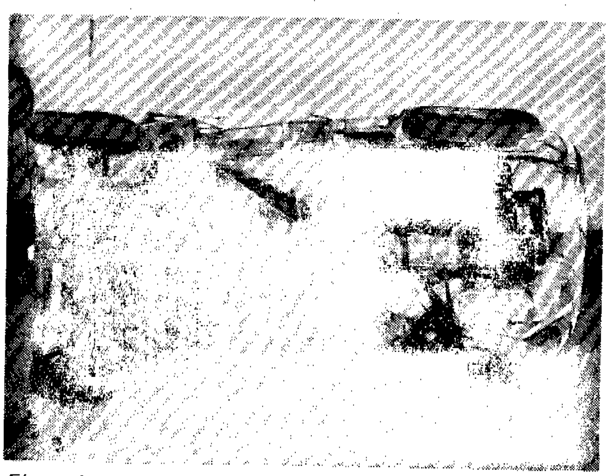


Figure 4

course of impact the reinforced car undergoes maximum deceleration values higher than those incurred by the normal car. Therefore, we should like to emphasise that in our opinion it would be desirable to review the principle of fixing limits to the deceleration on the

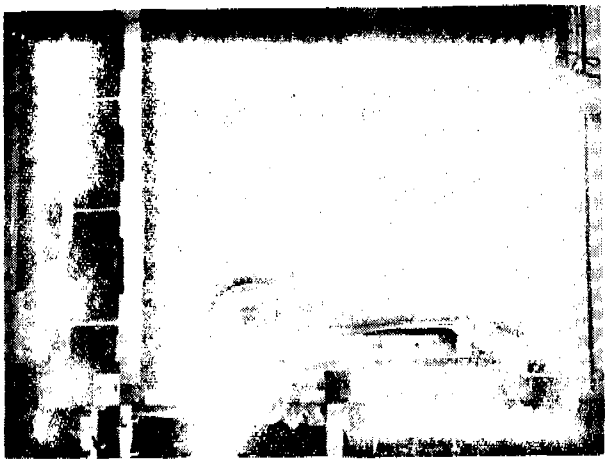


Figure 5

Figure 6

structure, as this would involve a considerable extension of the car front-end which, in turn, would entirely change the nature of the small size car concept. As regards the 2,200 lb. car, the chart (Fig. 8) evidences how less important localised reinforcements have brought about a considerable increase in crushing value without affecting the initial slope. As in the case of the normal version impacted at 30 mph (Fig. 9), thanks to this increase the passenger compartment has remained unaffected, also in the reinforced version impacted at 40 mph (Fig. 10), and in the further reinforced version impacted at 50 mph (Fig. 11).

Impact From Rear

The stationary 1,200 lb. car (Fig. 12) has been impacted at 30 mph from the rear by a moving barrier, of size and mass as specified in SAE J972, installed on board a radio-controlled car. The behaviour of the normal version is satisfactory (Fig. 13). The reinforced

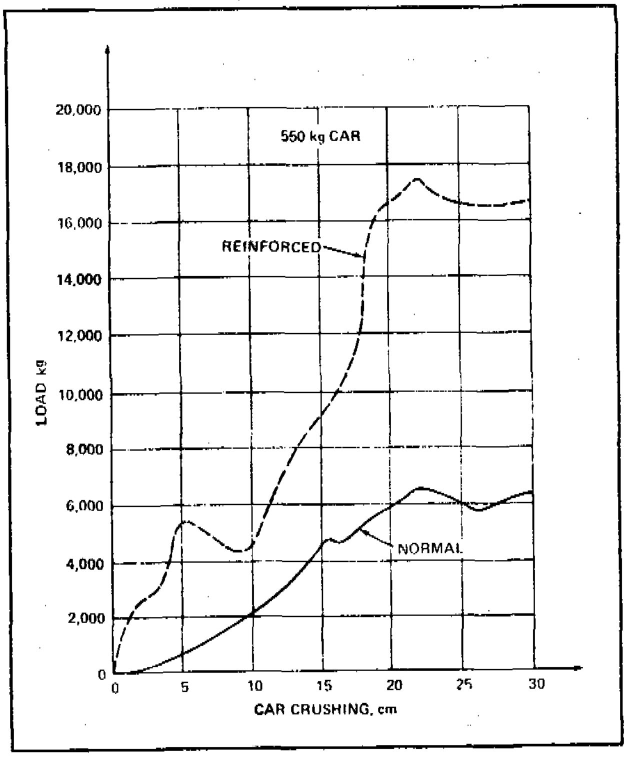


Figure 7

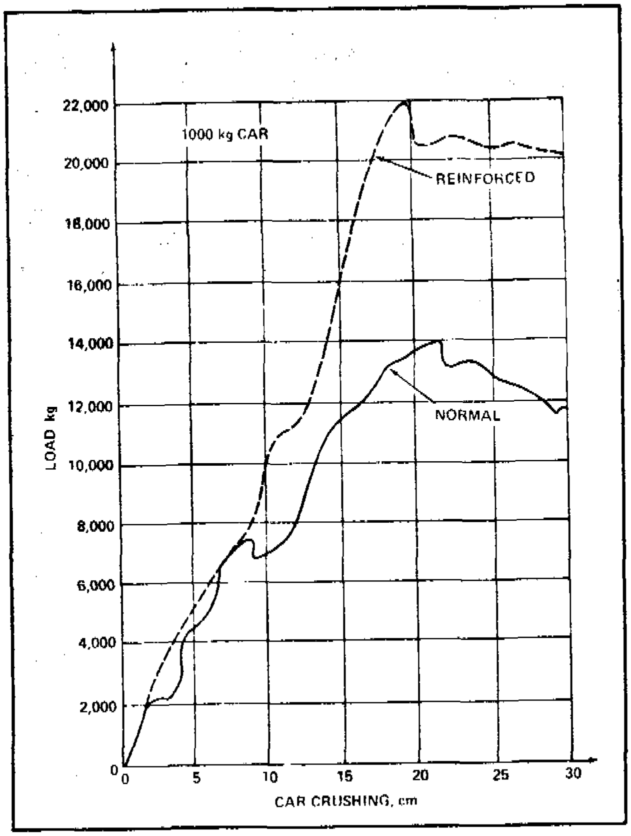


Figure 8

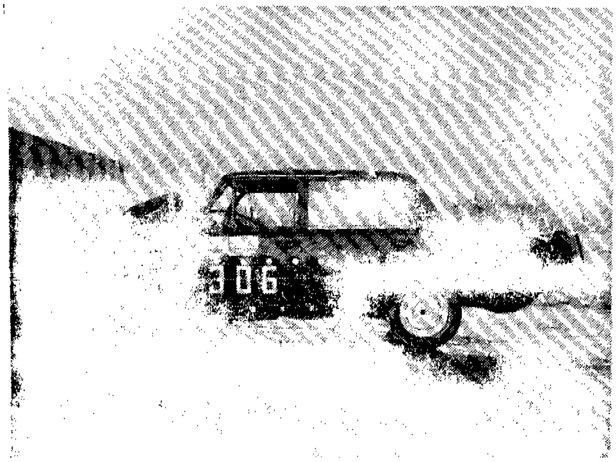


Figure 9

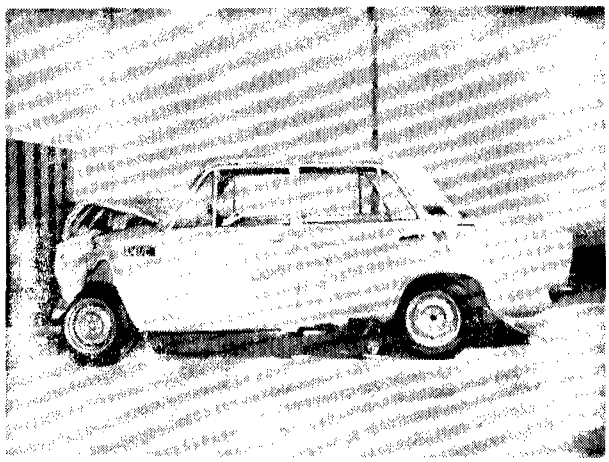


Figure 10

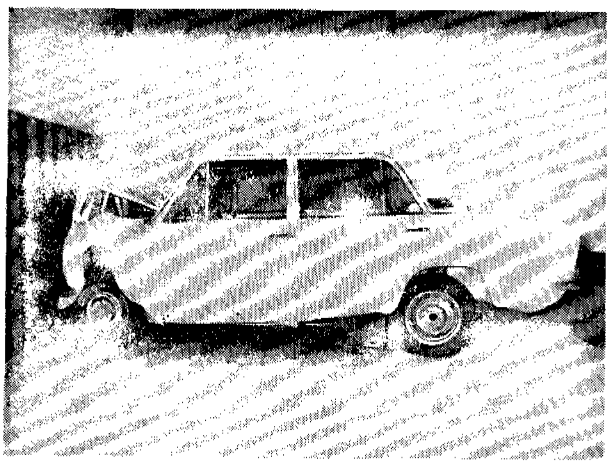


Figure 11

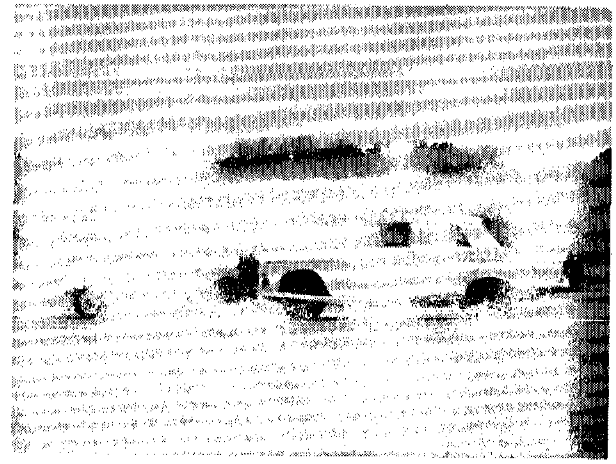


Figure 12

Figure 13

Figure 14

version has been impacted at 40 mph (Fig. 14) and, after further reinforcement, at 50 mph (Fig. 15), with consequent crushing almost equal to that incurred by the normal version impacted at 30 mph.

It is interesting to note that, from the viewpoint of test methodology, similar crushing values have been obtained not only during static testing with a press (Fig. 16), but also in the course of dynamic tests with a pendulum (Fig. 17), that we use currently in particular for side impact testing. The different degrees of deformation for the various cars are merely due to the different energy levels obtained in the cases in question.

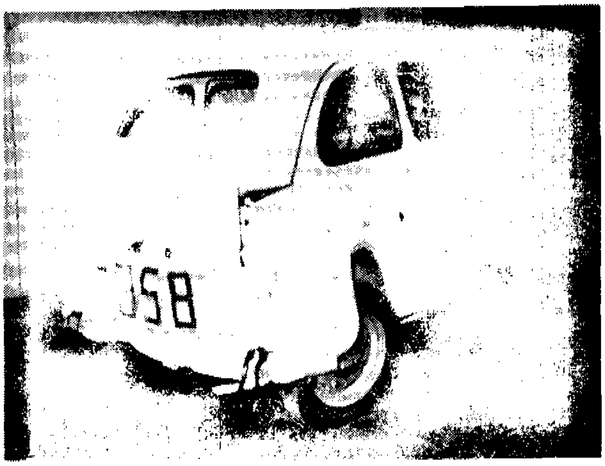


Figure 15

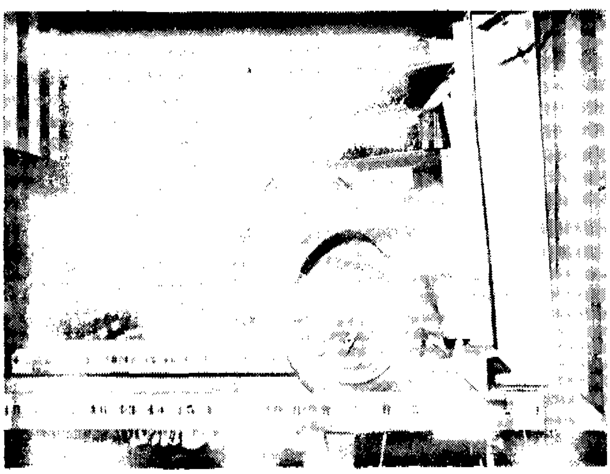


Figure 16

Figure 17

Side Impact

The normal version 2,200 lb. car, stationary and in a crosswise position (Fig. 18) has been side impacted at right angle by a car of the same type radio-controlled at 20 mph. The resulting side intrusion (Fig. 19) has been reproduced (Fig. 20) with an extra-long arm pendulum test (Fig. 21), featuring mass (Fig. 22), frontal size and speed equal to those of the impacting car. Compared with the outdoor test, this indoor procedure not only obviates to the inconveniences caused by adverse weather conditions, but also requires simpler equipment, involves easily computable energy and yeilds highly reproducible results.

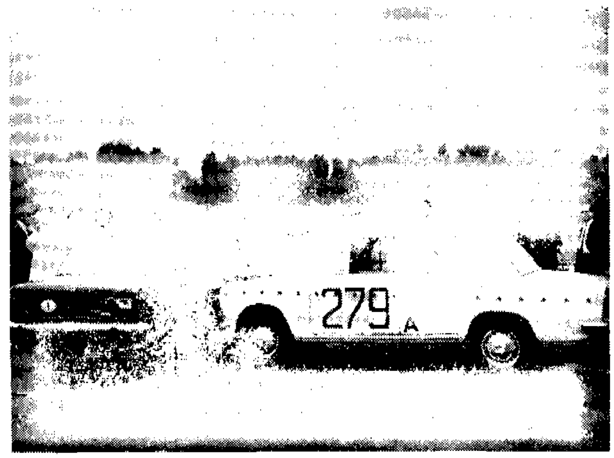


Figure 18

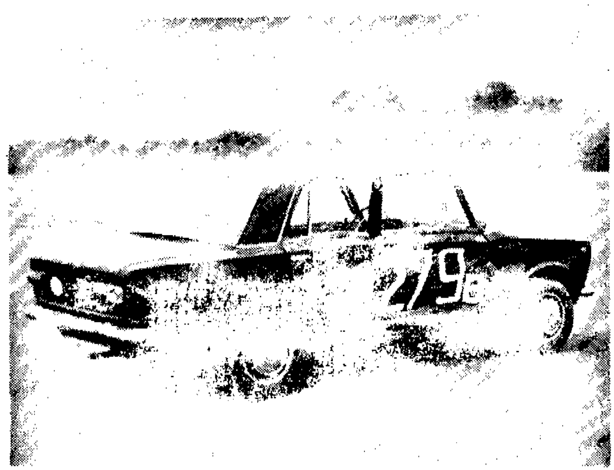


Figura 19

The normal version 1,200 lb. car was catapulted against a pole at 15 mph (Fig. 23), the results of which are here illustrated (Fig. 24). The addition of localised reinforcements, in order not to alter the architecture and, therefore, the max bodyshell cross section, has not brought significant advantages. It would seem that this type of test is excessively severe.

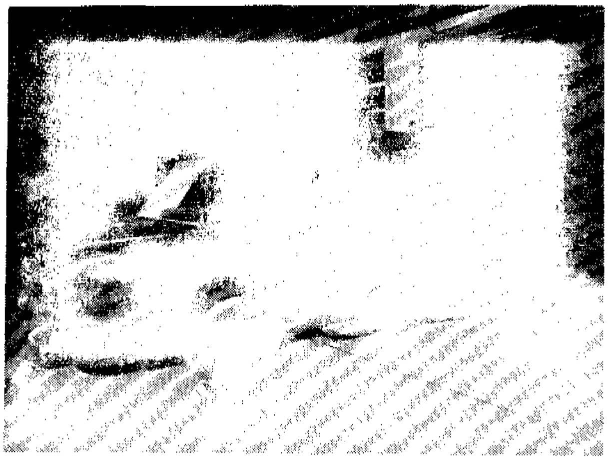


Figure 20

Figure 21

Figure 22

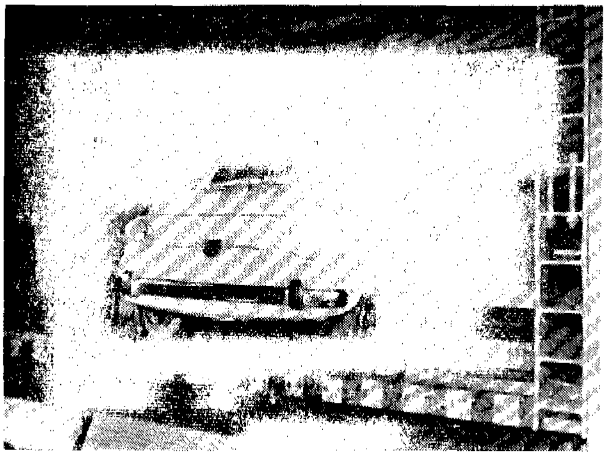


Figure 23

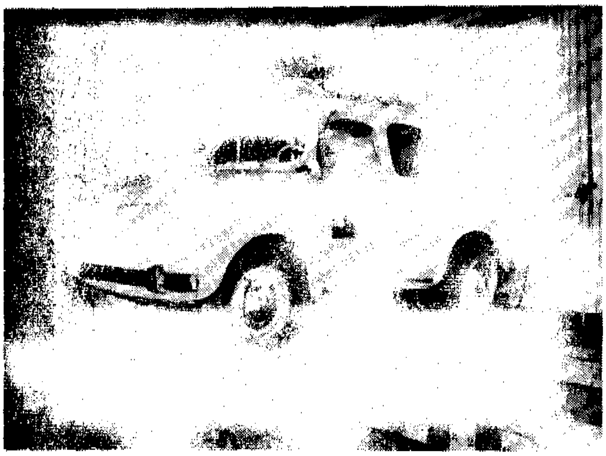


Figure 24

Rollover

The poor reproducibility of rollover tests whether by the ramps or abrupt off-steer method on radio-controlled cars, is a well known fact. In a simplified simulation of the rollover test, the pendulum may well be used.

An example is a roof panel impact test (Fig. 25) on a car secured with one side down and struck by a pendulum having a wider area than the roof (Figs. 26 and 27). A similar test may also be conducted under static conditions (Fig. 28) and in this test, again as before, the load may be applied perpendicularly (Fig. 29) or at an angle (Figs. 30 and 31) to the roof panel.

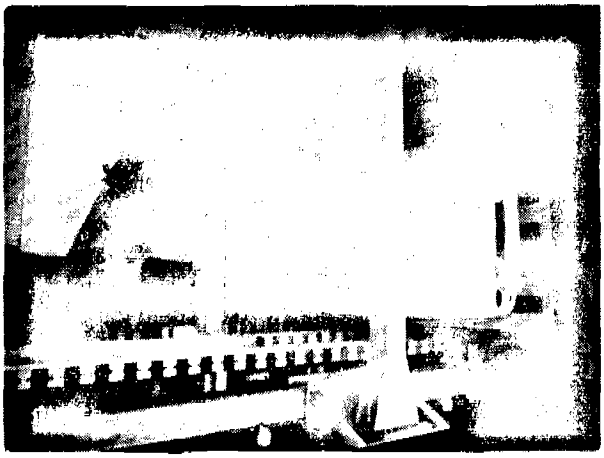


Figure 25

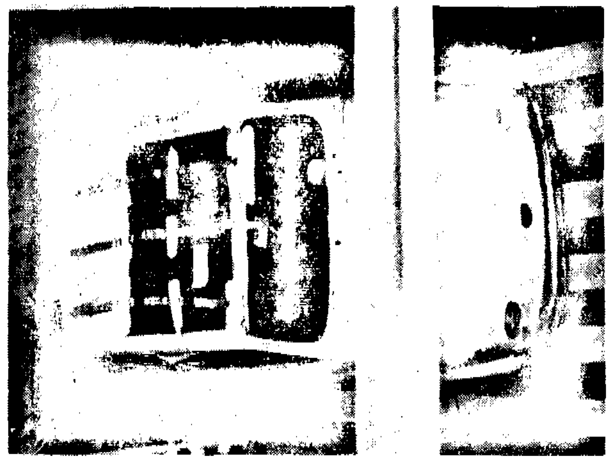


Figure 27

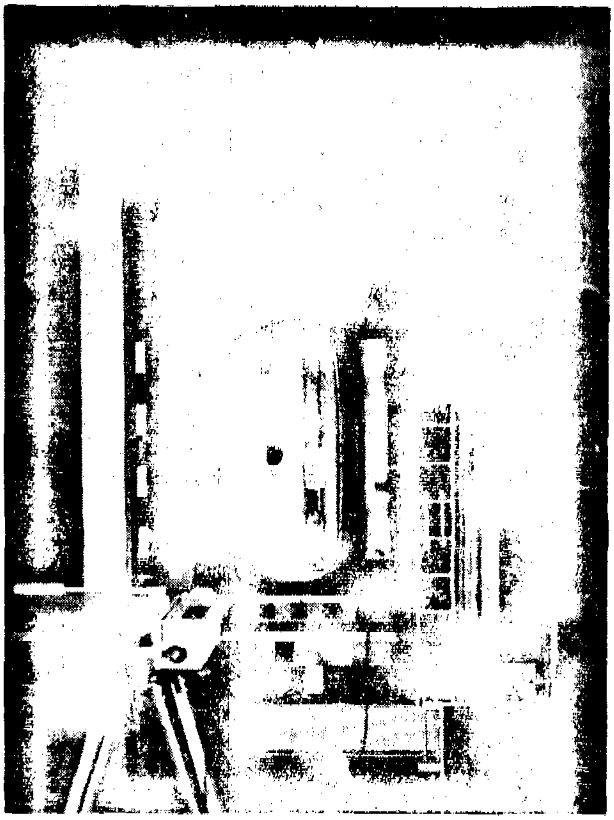


Figure 26

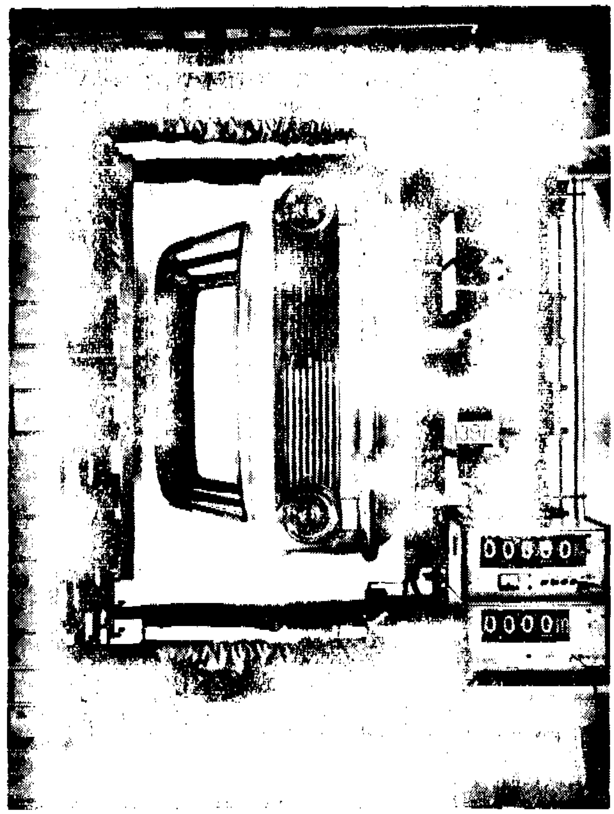


Figure 28

Such testing methods are both simple and reproducible. We are adding some information obtained during the development of the research program on *bumpers*.

The ESV is required to withstand impacts of up to 10 mph without body damage. Front-end barrier collision tests were run on the 1,800 lb. car, with standard bumpers, at increasingly higher speeds of 3 mph (Fig. 32), 6 mph (Fig. 33), and 10 mph (Fig. 34). While at 3 mph the body damage is practically nil, as impact velocity is increased they become evident on forebody front-end, even though all the lighting and signalling devices are still intact.

Experiments were made with a pneumatic bumper (Fig. 35) – on which a separate report will be made by Mr. Sapper – consisting of an air cushion inflated to 4 atm with compressed air, and provided with inertial device which, upon reaching a pre-set deceleration of 5g, triggers the opening of exhausts for the compressed air.

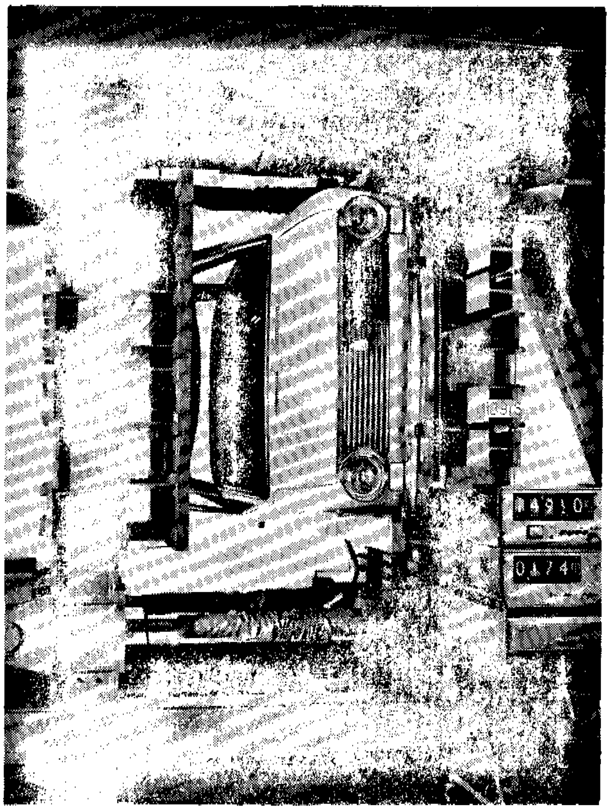


Figure 29

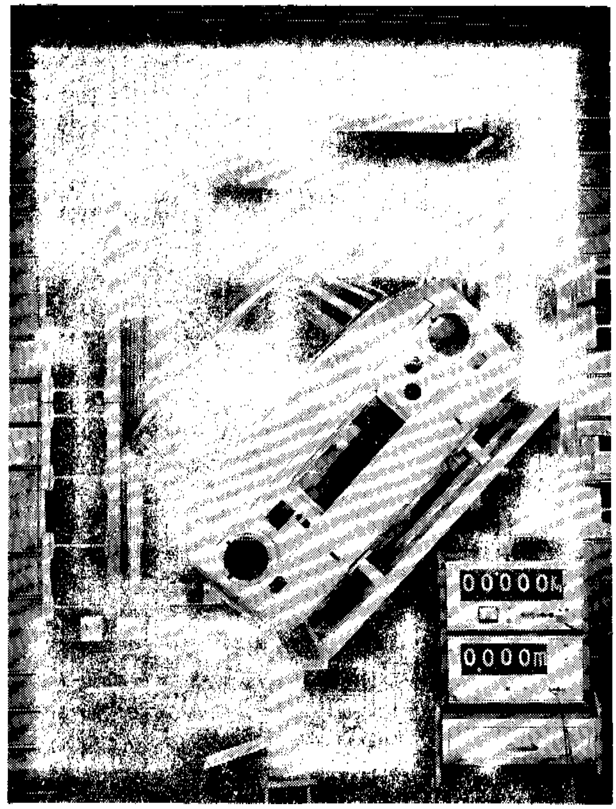


Figure 30

Figure 31

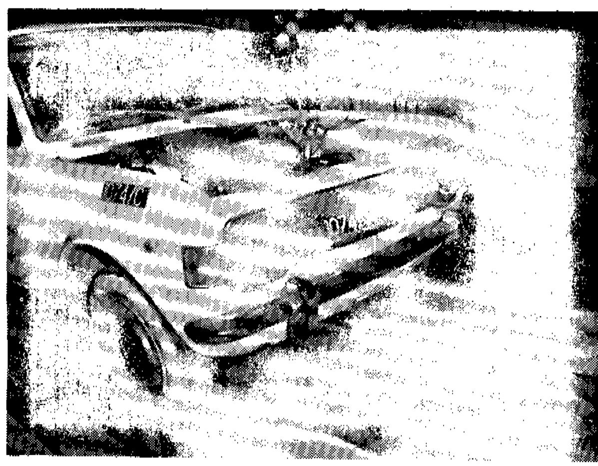


Figure 32

Earlier tests against barrier were repeated and (Fig. 36) no damage to body was found up to 10 mph.

Another series of tests was conducted with pole impact; with the standard bumper car (Fig. 37), again the body damage increased (Fig. 38) as impact speed was increased (Fig. 39), while with the pneumatic bumper car (Fig. 40) no damage was found (Fig. 41) up to 10 mph (Figs. 42 and 43). Tests are in course, using different inflation pressures and inertial device settings.

As regards the bumper problem we are against the proposed imposition of deceleration values to be measured on the structure not only because of the reasons mentioned earlier but also for the fact that it prompts the adoption of bumpers protruding noticeably from the front-end, thus making the car highly aggressive for pedestrians.

In fact, note (Fig. 44) how first contact between the front-end of a normal car and the dummy, simulating a

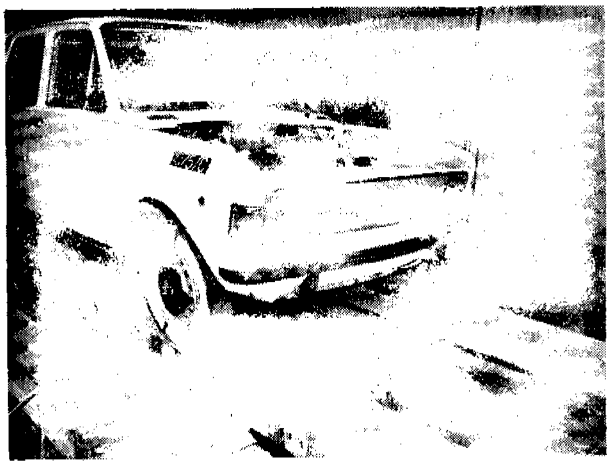


Figure 33

Figure 34

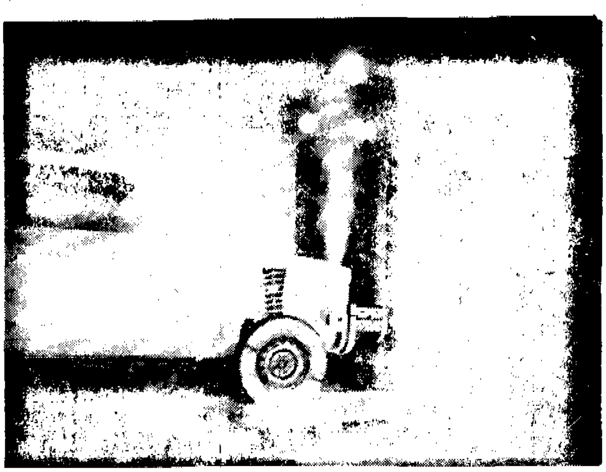


Figure 35

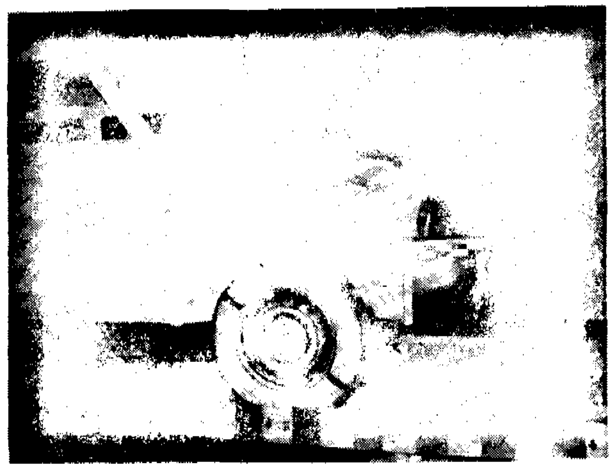


Figure 36

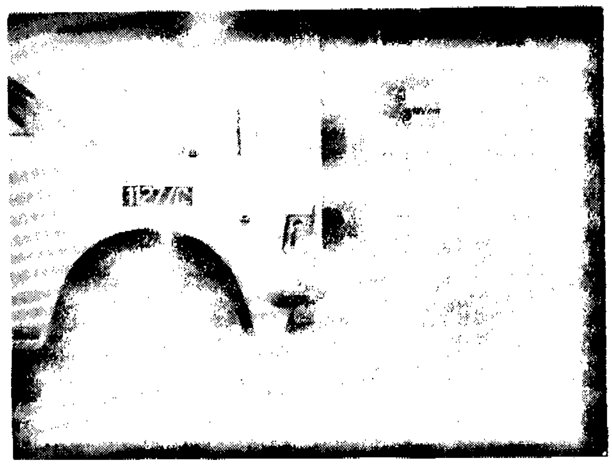


Figure 37

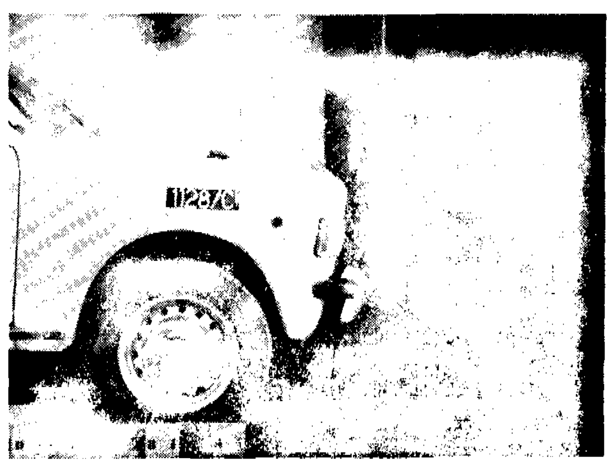


Figure 38

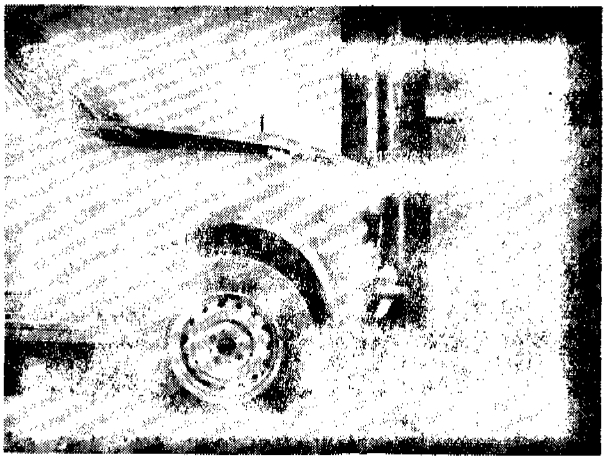


Figure 39

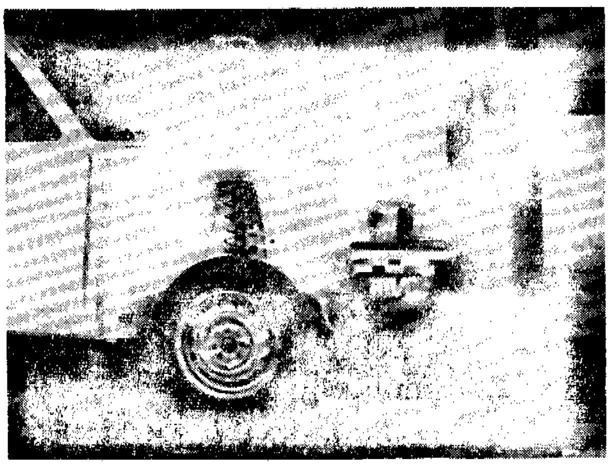


Figure 40

Figure 41

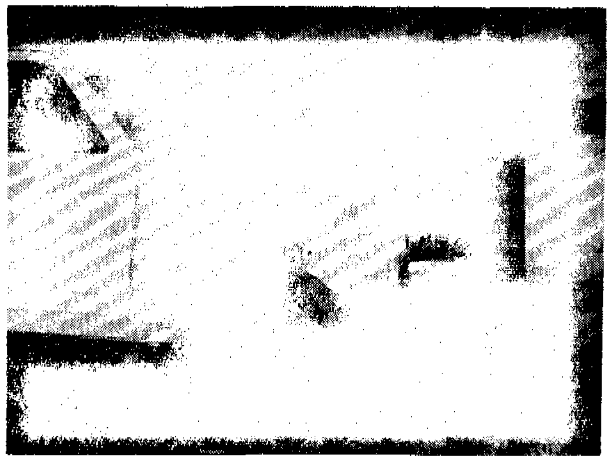


Figure 42

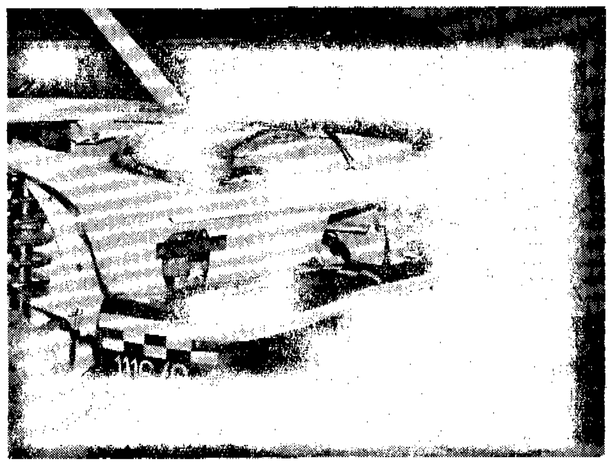


Figure 43

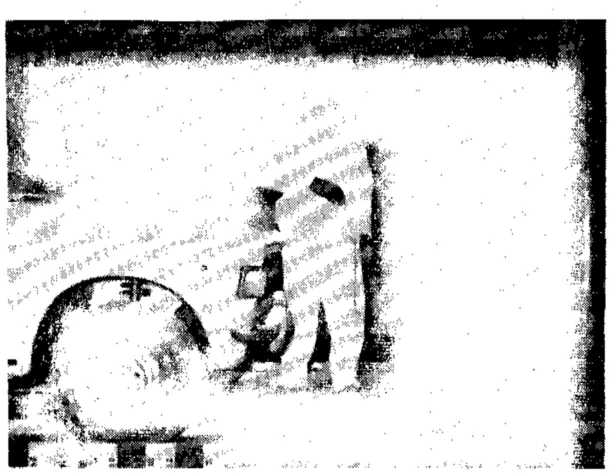


Figure 44

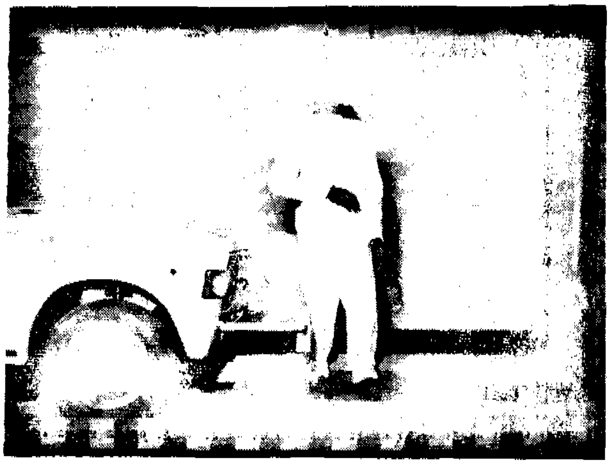


Figure 45

pedestrian, occurs at two different heights above ground – bumper and hood edge – that is, with loads distributed in two areas of the leg. The standard 215 already requires that the bumper must protrude so that no contact whatsoever shall take place with the pendulum top block, which means that the body fore-section must be located noticeably backward in relation to the bumper. The ESV requirements impose an even more marked protrusion of the bumper and in this case (Fig. 45) the first contact with the dummy occurs at bumper level only, hence, with load concentrated on only one spot of the leg. It seems to us that a higher safety level for car occupants should not be achieved at the expense of the pedestrian being run over by a "safe" car.

CONSEQUENCES ON THE DESIGN OF AN ECONOMY CAR

Dr. Ing. G. Puleo, Fiat

The results you have been shown, recorded from the tests run by our Safety Laboratory on a series of suitably modified cars, seem to support a rather optimistic view on the actual possibilities of solving one of the basic problems arising particularly in the design of a safe car belonging to the weight class of about 1,200 pounds. Namely, the problem of providing the vehicle structure with those features which are essential to ensure, through suitable restraining devices, the survival of occupants in the different types of collisions likely to occur on the road.

However, before drawing hasty conclusions, it would be well to proceed with a critical analysis not so much of the results but, rather, of the means used to obtain the results and in the light of the assumptions and aims of the investigation in question.

The fundamental objective which Fiat purports to reach on completion of the specific research and test program on collision behavior is the acquirement of all the informative elements needed to provide positive answers to the following questions:

1. What is the highest safety level thought to be reasonably attainable for a car having the characteristics typical of those in the class considered here?
2. What technical provisions are necessary to reach said maximum safety level and lower levels.
3. What cost increases are involved by each of the different safety levels considered.
4. What is the limit beyond which the joint safety and cost levels become practically incompatible with the class of car considered?

As is readily apparent, the search for possible solutions to the numerous safety problems is in our case not a matter of purely theoretical approaches, but is conducted with the specific aim of ascertaining the real limits of the improvements obtainable. The possible provisions and means intended for vehicle safety improvements cannot in fact be conceived without due consideration of the basic technical, economical and commercial requirements of mass production at industrial levels.

For this reason, after having concluded the first stage of our research work with extremely positive results – from a strictly technical angle – it seems we have now come to the point where the first economical facts must be faced. That is to say, in line with the aims of our program, we wish to proceed with a preliminary verification of the true validity of the technical solutions tested and try to convert into cost terms the direct and indirect consequences of the possible adoption of said solutions in the realisation of a hypothetical car as a future substitute for the present model being investigated. In drawing this preliminary cost account we shall limit our considerations to the influence on car cost exerted only by the provisions aimed at ensuring the passive safety primary requisite, namely, the "occupants' survival space."

The comparative table in Figure 1 shows, for the vehicle outfits relevant to the different front- and rear-end impact velocity levels, the weight increases ascribable to the new elements fitted additionally onto the original structure. Also given in the same table are the presumable weight increases resulting from the satisfaction of the side and rollover impact safety requirements, these being types of collisions on which a research and test program is now in course at our plant. Taking into account the latter requirements, and with reference to the outfit prepared for the 50 mph impact

GROUP	WEIGHT INCREASE		COST INCREASE	
	kg	lb	lire	$
BODYWORK	110	242	115'000	188
ENGINE	5	11		
POWER TRAIN	7	15,4		
SUSPENSION	9	19,8	65'000	107
STEERING	3	6,6		
TYRES AND WHEELS	10	22		
BRAKES	6	13,2		
TOTAL	150	330	180'000	295

CAR OF THE NOMINAL CLASS OF 550 KG (1,200 LB) - EXPECTED WEIGHT AND COST INCREASE TO MEET SAFETY REQUIREMENTS FOR SURVIVAL SPACE

Figure 1

velocity tests, the total weight increase estimated for body structural reinforcements alone amounts to about 240 pounds which raises the 1150 lb. curb weight of the present car to about 1390 lbs. and the gross weight from 1860 to 2100 lbs. Now, it is all too evident that a weight increase of this order – that is, approximately 21% and 13% over the curb and gross weights, respectively – cannot but deeply modify the delicate conditions of balance existing between the different technical, economical and commercial features of the original car, especially when the attainment of said balance, as is the case of the model being considered, has called for the solution of exceptional design difficulties.

Let's examine in detail the practical consequences that said weight increase would originate in the new project, starting firstly with the modifications that would have to be introduced in the mechanics of the car.

- Increased engine displacement, from present 500 cc to about 650 cc, and power, from 18 to about 23 HP (DIN), to retain the same performance of the original car (top speed, pick up and gradeability).
- Re-design of power train components (clutch, transmission, final drive bevel gear and differential, axle shafts and joints) to cope with increased engine torque and load on ground.
- Stronger suspension components (swinging arms, springs, shock absorbers, wheel hubs and bearings) as a result of increased axle loading.
- Stronger steering gear components because of increased load on front axle.
- Higher tire and rim loading capacity, with consequent larger size, 125-12 to 135-13 and 3½-12 to 4-13, respectively.
- More effective braking power, by adequately increased size of brakes on wheels, as a result of higher vehicle gross weight.

But the consequences of the practical introduction of the foregoing structural improvements would not be confined to vehicle mechanics alone. In fact, the obtainment of truly acceptable results as regards passenger compartment protection would inevitably involve the introduction of the new structural elements we have tested in a body outline having larger dimensions than the body of the original car. Figure 2 compares the

CAR OF THE NOMINAL CLASS OF 550 kg (1,200 lb) EXPECTED INCREASE OF BODYWORK OVERALL DIMENSIONS AS A RESULT OF IMPROVED CRASHWORTHINESS

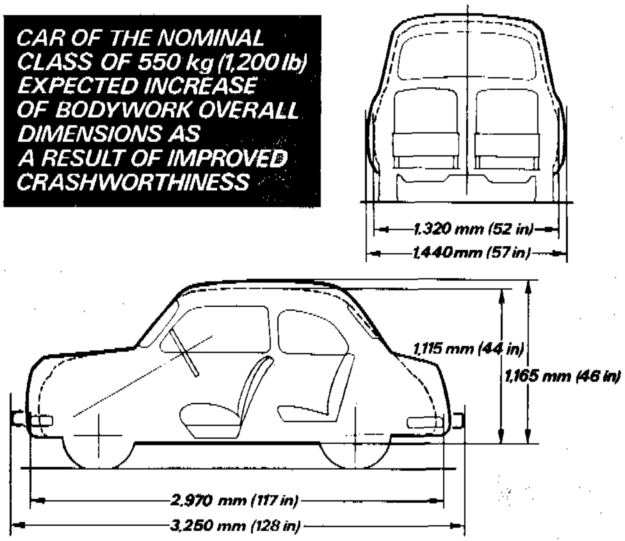


Figure 2

probable dimensional configuration of this hypothetical new car with the current 500 Sedan configuration.

The summary table in Figure 3, instead, gives for each one of the modifications examined the corresponding weight and cost increases, the latter being already converted into customer costs.

The final outcome of the entire operation would eventually be:

- About 20% larger car bulk surface area.
- About 330 lbs. added weight, i.e., 29% of curb weight.
- About $295 sales price increase, i.e., 31% of the initial price.

But the item in the red which is not considered above and which to us seems more important than the indicated items, is the fact that in reality the car so redesigned would no longer offer any of the features consistent with the class to which it is supposed to belong.

In other words, no valid reasons would be left to justify its existence, unless it is subjected to a more

TYPE OF COLLISION	SPEED		WEIGHT	
	kph	mph	kg	lb
HEAD-ON COLLISION	48 64 80	30 40 50	- 20 45	- 44 99
REAR COLLISION	48 64 80	30 40 50	- 15 30	- 33 66
SIDE COLLISION	24	15	20	44
ROLL-OVER	96	60	15	33

CAR OF THE NOMINAL CLASS OF 550 KG (1,200 LB) EXPECTED WEIGHT INCREASE TO IMPROVE CRASHWORTHINESS

Figure 3

radical upgrading revision so that it may more properly belong to the next higher class into which it has inevitably trespassed.

The above percentage increases in overall bulk, weight and cost estimated for this hypothetical new car still represent, in our view, the maximum limit beyond which it would not seem logical to go for the sake of offering occupants the only benefit of "survival space."

Much severer consequences on car design – body length in particular – would have to be expected, however, in case the "survival space" requirement were to be met in the respect of possible restrictive conditions for passenger compartment decelerations at different impact velocities. This is a problem that was ignored during the first stage of our research work as it will be the theme of a future test cycle.

From the foregoing, the conclusions that can be drawn are extremely pessimistic with regard to the possibility of building in the future a safe car having such features as to remain within the economy class so far considered.

One thing is certan: if some day the small economy car were sacrificed, millions of potential motorists belonging to the low-income bracket would be unjustly deprived of the possibility of using a means of transportation which, perhaps more than any other, has contributed to improve the living standard of mankind. And this multitude of disappointed would-be motorists would then have no other choice but go back to other less costly means of transportation, whose presence on the roads would inevitably lead to a revival of the safety problem and, what is worse, in even more dramatic terms than at present.

Even though the mass production of cars capable of meeting the safety requirements laid down for the ESVs at present appears to be far from forthcoming, our research work is continued with sincerity of purpose and with confidence in the fact that the work done will soon yield its first fruits. The cars we will produce in coming years will surely already benefit from the partial findings that will be accomplished from time to time and that the state-of-the-art will allow to transform into industrially feasible constructional provisions.

We are aware that the road to safety is long and rough; it will certainly not be possible to come to its end in just one non-stop lap and at every fork on the way it will not be easy to choose the right direction.

One thing is sure: come what may, we shall go all the way to destination.

ANALYSIS OF STATISTICAL DATA ON ROAD ACCIDENTS IN ITALY 1969-1970

Mr. Alfredo Margara, Fiat

From the report made previously by Mr. Puleo we have seen that safety may affect the weight, size and costs of a small car to such an extent as to change its nature.

It is a serious problem which, if not suitably solved, would create a series of new problems; social and economic in particular.

It is therefore right that the study of any solution be conducted on the grounds of an accurate analysis of the motor vehicle safety situation in the complex framework of road traffic.

In the course of the "Multidisciplinary Road Accident Investigation Conference" held by NATO-CCMS on July 1-2, 1971 in Turin, Fiat had submitted an investigation on the degree of dangerousness of cars during road accidents in Italy. The conclusions were quite surprising as it was found that, during an accident, the dangerousness of a small car was not greater than for a larger class car.

We are going back to those investigations to let you know some data which we think worth considering.

The data was obtained from the official statistical information published by the Italian State Central Institute of Statistics.

To this end we have plotted a series of histograms showing the death figures provided by the Central Institute of Statistics for the various classes of cars involved in accidents on the Italian roads.

The death figures are related both to the cars on the road and to the kilometers covered.

Figure 1 shows, for the years 1969 and 1970:

- The total number of deaths in road accidents.
- The number of deaths in accidents involving at least one motor vehicle.
- The number of deaths in accidents involving at least one car.

		1969	1970
	TOTALS	NO. 9891	NO. 10208
DEATHS IN ACCIDENTS INVOLVING AT LEAST ONE MOTOR VEHICLE		NO. 8809	NO. 9137
DEATHS IN ACCIDENTS INVOLVING AT LEAST ONE PASSENGER CAR		NO. 7422	NO. 7771

Figure 1

In Figure 2 is illustrated how the Central Institute of Statistics has split up the total cars on the Italian roads. There are five classes – A, B, C, D, and E – each referring to a given engine displacement group.

CLASS	DISPLACEMENT cm^3
A	< 750
B	750 ⟶ 1000
C	1000 ⟶ 1300
D	1300 ⟶ 1500
E	>1500

Figure 2

Histogram in Figure 3 shows the total cars on the road in 1969 and 1970, and the relevant subdivision into the five classes illustrated in Figure 2. For 1970, also the percentages of cars in the various classes have been indicated.

The division in engine displacement classes nearly corresponds to the weight and size class split-up.

In the following histograms we have indicated the number of deaths – recorded in the accidents involving at least one car – divided according to car class. For a detailed investigation we have again divided the number of deaths in two separate histograms:

- Number of deaths inside cars, namely occupants in the cars of that class, involved in the accidents.
- Number of deaths outside cars (third parties), i.e., occupants of other vehicles involved in the accident, pedestrians, cyclists, motorcyclists or any other road user.

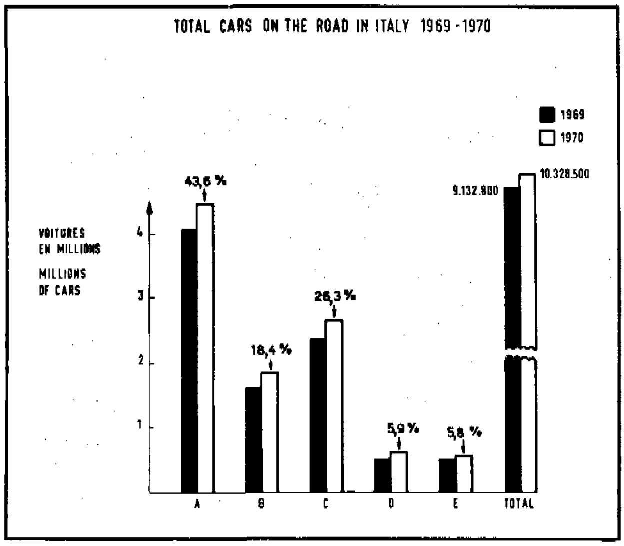


Figure 3

In the next three histograms of Figure 4, the number of deaths is related to the number of cars on the road and is referred to 1,000 cars of each class on the road.

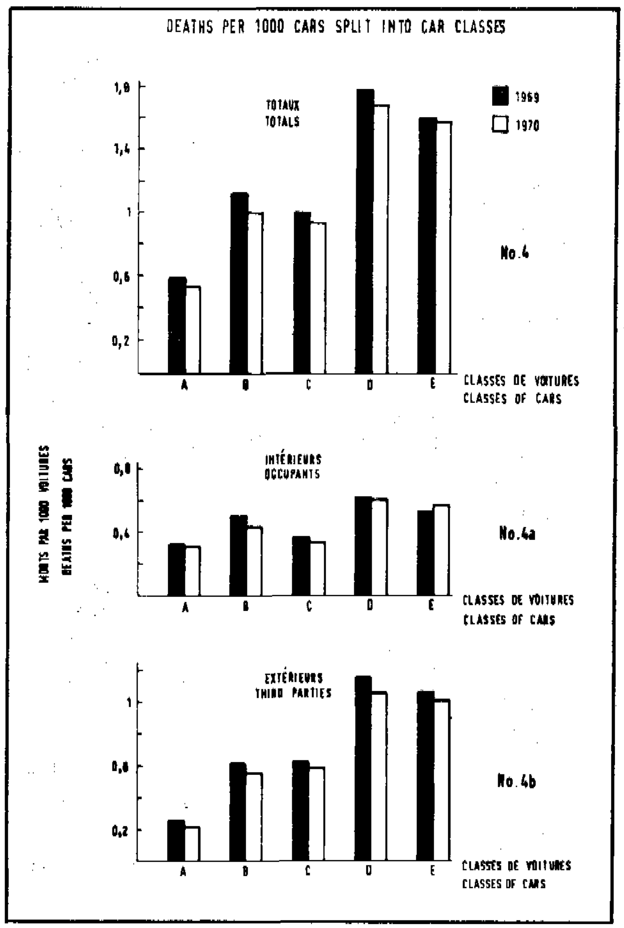


Figure 4

Histogram 4a covers deaths of car occupants.

The histogram shows the trend to a lower number of deaths in small cars.

Finally histogram 4b gives the number of deaths outside cars (third parties).

The trend towards a lower number of deaths in small cars, for this type of selection, is very strong.

Figure 4 does not, alone, give a clear picture of the situation in that kilometers covered are not kept into account. We have therefore thought it more significant to relate the number of deaths to the kilometers covered yearly by the cars in each class rather than to the total number of the cars on the road.

Figure 5 gives the average of the kilometers covered. These figures have not been provided by the Italian Central Institute of Statistics but are the result of Fiat investigations.

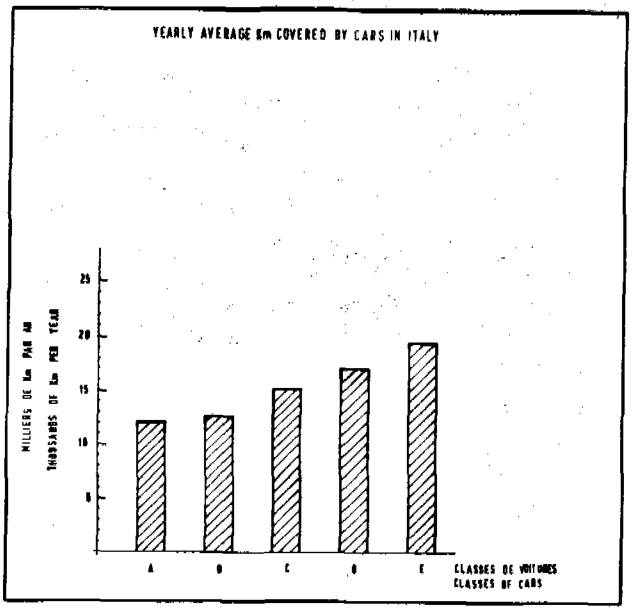


Figure 5

In Figure 6 histogram 6 indicates the distribution of deaths in each class versus the number of kilometers run. In this and in the following histograms is shown the number of deaths per 100 million kilometers covered.

Histogram 6a gives the number of car occupant deaths.

The sub-division of deaths outside cars are shown in histogram 6b.

Histograms in Figure 6 also show an average increase in car casualties as engine displacement increases.

In particular, histogram 6b on third party deaths shows that small class A cars cause less deaths than any other class of cars.

At this point it may be of interest to analyze third party deaths caused by cars in the various classes,

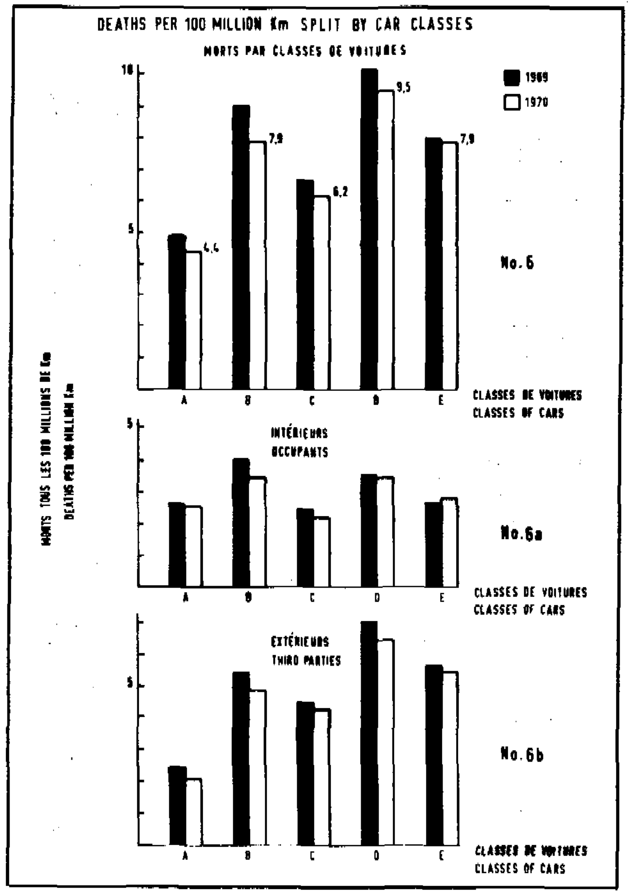


Figure 6

divided as follows: pedestrians, riders of motorcycles, mopeds, bicycles, wagons and other users, among whom are included also the occupants of other cars involved in the accident.

Figure 7 illustrates the deathly consequences for third parties in accidents against cars in the various classes. Class A cars are less dangerous than cars in the higher class to pedestrians, cyclists and motorcyclists and cause very few casualties in the cars against which they crash.

One objection to this could be that the cars with larger engine displacements are responsible for a proportionally higher number of deaths because they usually travel at higher speeds.

Let's then analyze the urban area traffic factor and examine the case history of casualties occurring in traffic conditions at a speed as uniform as possible; in Italian cities the maximum speed limit is 50 km/h.

The investigation method relating the number of deaths to every 100 million km covered by cars in the different classes cannot however be applied to distances travelled in town where, evidently, the distances totalled do not increase proportionally to the class of cars.

We have therefore prepared histogram 8 where, neglecting the average distances covered, the number of

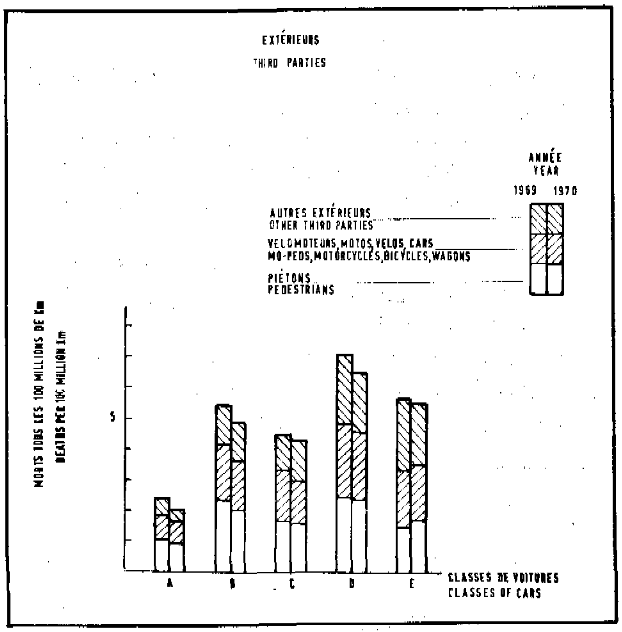


Figure 7

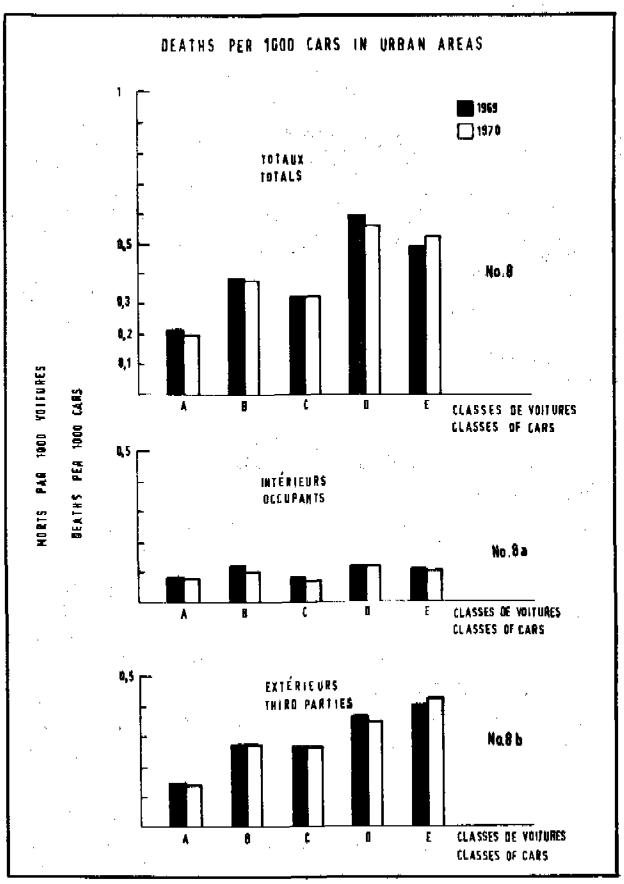


Figure 8

deaths is related to the number of cars on the road. Here again, statistical data is dealt with separately: the number of car occupant deaths in 8a shows an almost level pattern and the number of third party deaths in 8b once more evidences the low dangerousness of the small class A cars.

This chart clearly proves that the large size cars are responsible for a larger number of deaths though it is quite right to presume that in town they circulate less than the smaller cars.

However, data of Figure 9 provide the most convincing evidence. For each 1,000 cars of class A on the road, the number of casualties in accidents in urban areas and on open roads, involving small cars of this class, corresponds to the deaths caused by large cars (classes D and E) in urban areas alone.

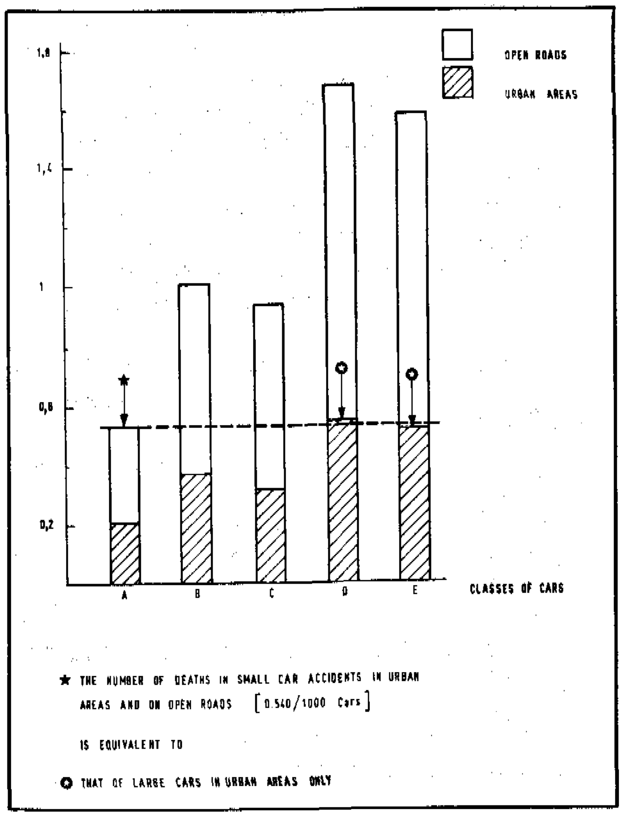


Figure 9

All the histograms we have so far examined prove that the mass of the car – which supposedly is the fundamental factor in passive safety – does not play a determinant role even when the case history of car occupant deaths is taken into consideration. It is then inevitable to admit that there must be other factors, belonging evidently to active safety, that exert a much more incisive influence also on the picture of car occupant deaths.

Our feeling is that it is hardly possible to deny that the ease-of-handling and limited bulk of small cars represent a determinant factor in accident avoidance and, consequently, that their influence on active safety is much stronger than the influence which a large mass may have on passive safety.

All these factors contribute to give small cars a low death rate and cannot be transferred to large cars.

We wish to end with some considerations. Total deaths in accidents on the Italian roads in 1970 were 10,208. Of these, as many as 1,071 were due to accidents in which motor vehicles were not involved.

It is clear that no ESV or subsystem safety improvement would have contributed a pennyworth in the avoidance of these 1,071 casualties which account for 10% of the road victims total.

One more piece of information. Of 7,771 deaths in accidents involving cars, as many as 3,802 deaths, namely 50% of the total, were represented by pedestrians, motorcyclists, cyclists or other road users less protected than the occupants of a car. Passive safety as a whole will in no way lower this high percentage.

On the contrary, there is the risk that by making a driver feel safer in his "armour" he may be led, perhaps unconsciously, to be more reckless, with the sad, but not unlikely, result of an increase in the already heavy 50% toll which will hardly be compensated for by the reduction of deaths inside the car afforded by passive safety.

We can conclude by admitting that it may be true that the small car is more dangerous once it crashes, but undeniable data show that even in a highly diversified traffic such as in Italy, it is less dangerous than any other car.

Shall small cars therefore be banished?

Do we really want to increase the 50% death rate of the less protected third parties?

It is better to think it over.

PNEUMATIC BUMPER PROTECTION SYSTEM FOR PASSENGER CARS

Dr. Richard Sapper, Fiat-Pirelli Consultant

This project, conducted as a joint effort with Pirelli and Fiat, aims at the reduction of the consequences of low speed collisions.

Among the new utilizable systems of energy-absorbing bumpers we examined the features of the following:

1. Elastic metal elements
2. Hydraulic systems
3. Water bumpers
4. Foam structures
5. Pneumatic elements

We have concentrated on the latter system as long earlier we had been working on a similar element surrounding the whole car to limit bodywork damage following minor impacts or swiping.

We had noticed that pneumatic elements could provide considerable car protection with negligible penalty on weight and, besides, they could be manufactured so as to ensure good abrasion resistance.

Some pilot solutions were realized and tested during the last four years and were used to study a new type of bumper – to be fitted at car front and rear – which was capable of performances similar to those required by the ESV program low speed collision specifications.

It consists essentially of three parts (see Fig. 1):

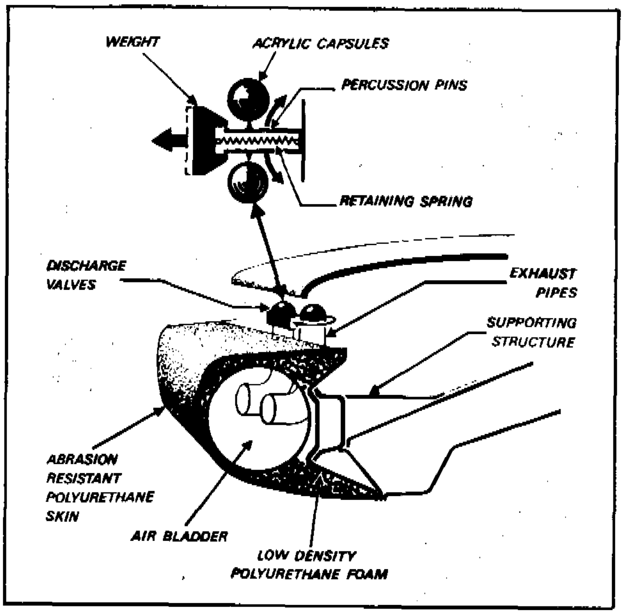


Figure 1

- A cylindrical rubber air cushion diagonally and longitudinally reinforced to make its surface inextensible. The two ends are hemispherical and provided with exhaust tubes.
- A polyurethane foam protection, lined with an abrasion resistant skin – enveloping the air cushion.
- Two exhaust tubes whose ends are connected to inertial decelerometer actuated valves. They consist of two thin diaphragms blanking the exhaust tube ends and of two percussion pins, held at a distance from the diaphragms by a hook connected to the decelerometer mass. When deceleration exceeds a pre-fixed limit, the diaphragms are perforated by the pins and air escapes from the cushions.

Design and dimensions of the elements were determined by the following specifications:

- Vehicle weight: 800 kg
- Type of collision: head on against vertical barrier

• Impact speed: 15 km/h
• Maximum tolerable deceleration: 10g
• Maximum diameter of the cushion: 200 mm

The optimum values for diameter, initial pressure, exhaust section and critical deceleration for valve opening were calculated making the following hypotheses:

• The discharge of the gas was considered without losses of any kind; whereas two different equations were used depending on the pressure ratios being higher or lower than the critical state.
• The cylindrical cushion was considered inextensible and infinitely flexible. The influence of the hemispherical ends on the behaviour of the cushion was neglected; it was considered as a cylinder with a horizontal, straight axis whereas in reality its axis is slightly curved with about 25 mm camber.
• The structure of the car was considered non-deformable during collision and deceleration was supposed to result exclusively from the pneumatic element applied forces.
• The opening of the valves and the discharge of the gas was considered instantaneous as soon as an established deceleration value was reached.

Based on these considerations, the equations simulating the vehicle motion during collision against barrier were introduced into Pirelli IBM 360/44 computer and the optimum dimensions investigated by the trial and error method.

Some results of these calculations can be seen on the following diagrams.

They show clearly how the discharge of gas through the exhaust valves lowers considerably the maximum deceleration as compared to an element without valves.

In Diagram A, which shows a collision at 15 km/h, with opening of the valves at a deceleration of 6.3 g, maximum deceleration is lowered from 23 to 9 g.

Diagram B shows the progression of deceleration during the collision versus time, with and without opening of the discharge valves.

Diagram C shows the maximal values of deceleration in function of impact speed, with and without gas discharge.

In all these diagrams, the comparison between the behaviour of the two types of pneumatic elements, with or without valves, has been made not only with equal quantities of energy, but also with the same amount of deflection of the pneumatic element; for this purpose it was necessary to establish different initial pressures: in the case of the element with valves, this initial pressure is considerably higher.

The calculations resulted in the following optimum dimensions:

• Cushion diameter: 200 mm

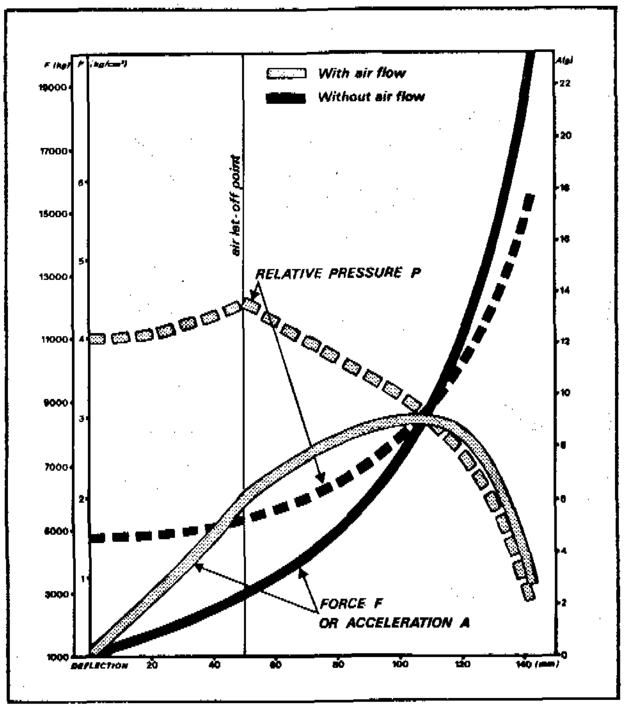


Diagram A

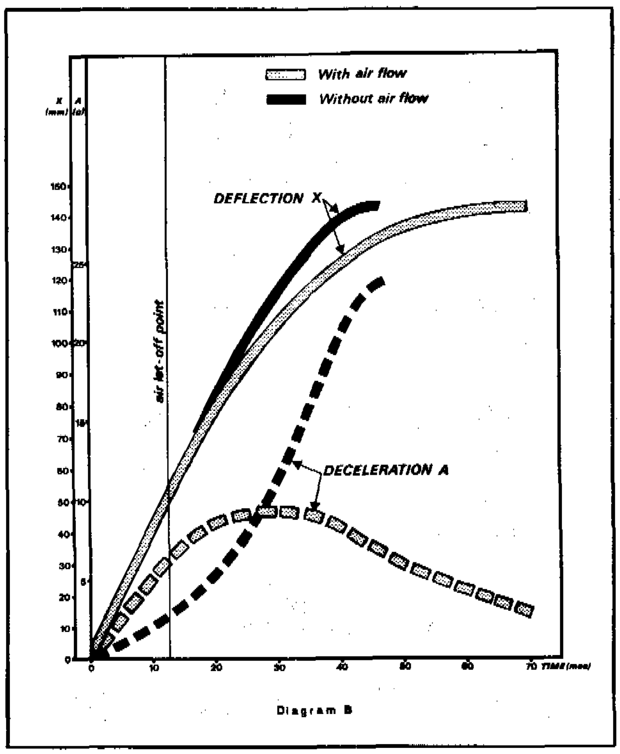


Diagram B

• Initial pressure: 4 atmopheres (gauge)
• Discharge section: 0.0048 sgm
• Critical deflection for valve opening: 50 mm – corresponding to 6.3 g

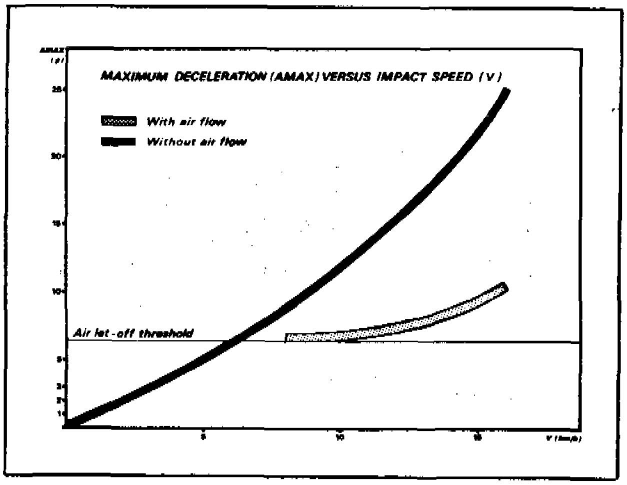


Diagram C

As a next step, a series of prototype bumpers was built and fitted to modified Fiat 128 bodies. This pneumatic bumper protection system, the test results of which have been illustrated in Mr. Franchini's report, represents the present state of the project. We are now analyzing these test results in order to go on with the development.

NOTES ON VEHICLE STABILITY PARAMETERS WITH RESPECT TO ACTIVE SAFETY

Mr. Angelo Schiepatti, Alfa-Romeo

1. Introduction.

It is well known that the optimisation of the single parameters which determine vehicle handling and stability is a difficult problem, not only because the physical laws controlling vehicle motion sometimes give difficultly foreseen results, but also (and especially) because these parameters interact in rather a complex way with each other.

However, there is no doubt that the greatest obstacle in defining a safe vehicle is the present uncertainty which surrounds the essential characteristics of such a vehicle. In turn, this is due to the fact that the dynamic behaviour of a vehicle is strongly influenced by its driver's behaviour which is still, in our opinion, not sufficiently known.

For our purposes, then, a classical definition of vehicle stability will not suffice, but what is needed is a deeper understanding of the driver-vehicle system, and of handling itself. To overcome these difficulties, Alfa Romeo has started a research program, on both the theoretical and experimental aspects of the driver-vehicle system behaviour, with the aim of satisfactorily defining the essential response characteristics of a normal driver, and hence establish the limits of acceptability of the dynamic characteristics of the vehicle.

It is then our opinion that only when the definition of these limits has been achieved, through the study of the above mentioned driver-vehicle system, we will be able to establish an objective definition of active safety tests.

2. Driver-Vehicle System Research.*

The research is carried out on a track, with vehicles having different and well - defined dynamic characteristics, and with drivers of varying ability.

The processing of the first experimental results has allowed us to prepare a mathematical model of the driver-vehicle system. This model, rather complex but undoubtedly effective, represents the vehicle in the now traditional scheme, with 3 or more degrees of freedom, according to the type of problem to be solved. More particularly, the non-linear representation takes into account the actual behaviour of tires, of aerodynamic effects, of tractive and braking actions, etc. The driver's reaction, manifesting itself mainly as a steering input, is based on a continuous comparison between a predetermined trajectory and that extrapolated starting from the position at each particular instant (i.e.: a step by step process). The extrapolation gap is linked with the vehicle time constants, and the driver's reaction time. The comparison between the 2 trajectories obviously involves an error, the probability distribution of which is assumed to follow Gauss's law. The driver's steering action, in his effort to bring the vehicle back on the pre-determined path, is affected by the above named error distribution in such a way that it will undergo an attenuation (with respect to the ideal condition) which will increase with the mean square difference of the distribution. This difference is linked with the extrapolation step, the path curvature, and to a parameter pertaining to the driver's ability.

Moreover, the steering action is conditioned by the presence of curbs and possible obstacles, in a similar way to that used for the pre-determined path.

To sum up, this scheme has the advantage of taking into account the driver's characteristics in quite a realistic manner, using only two parameters:

a) the driver's reaction time

b) the accuracy of the extrapolation estimate.

It may however become necessary, in the course of the present work for the improvement of this model, to accept further complication. The following are some of the results obtained with the above method.

2.1. Behaviour Of A Vehicle Travelling On A Bend At Various Speeds

The vehicle travels on the centreline of a 90° bend joining two straight roads (Fig. 1). This centreline is the reference trajectory we will use. The vehicle considered here is one having average dynamic parameters and neutral behaviour. Figs. 2, 3, 4, 5 show the trajectories,

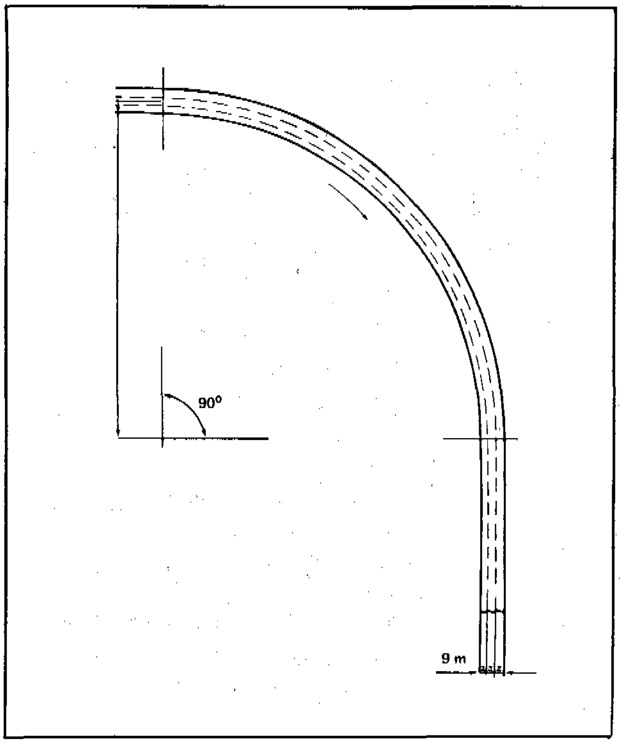


Figure 1

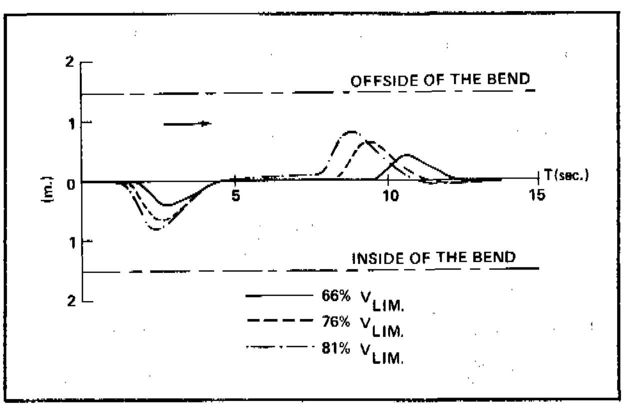


Figure 2

the lateral accelerations and the steering angles at the wheels for three different speeds, and for two driver reaction times.

For each of these reaction times, as the speed increases, so does driving difficulty; at the maximum velocity considered, substantial "opposite lock" was necessary.

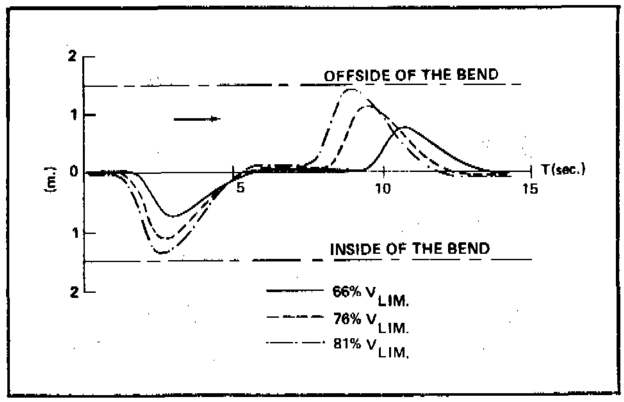


Figure 3

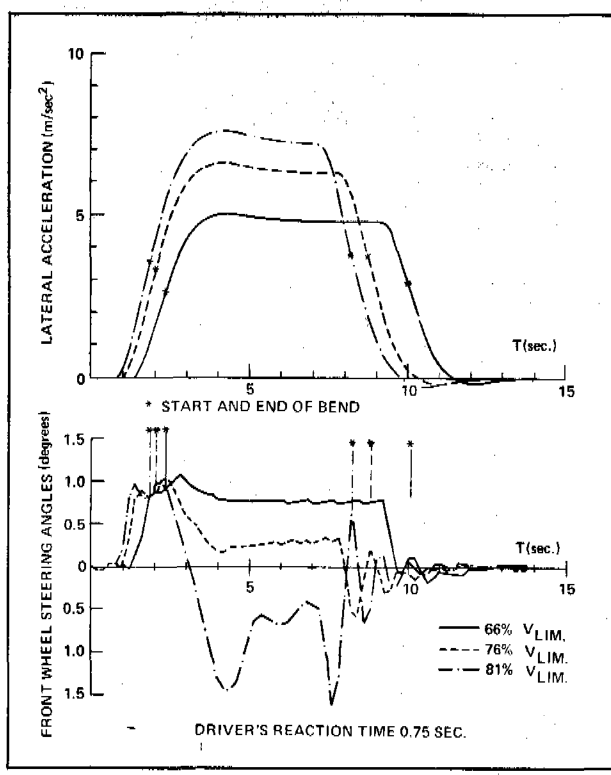


Figure 4

As the reaction times increase, the deviations from the reference trajectory become greater; when at the maximum velocity considered, with a 1.25 second reaction time, at the end of the bend the vehicle leaves its lane and enters the overtaking lane.

2.2. Lane Changing Maneuver On A Straight Road.

This maneuver (per se interesting in the study of the driver-vehicle system dynamic behaviour) can also be identified with the first part of an overtaking maneuver.

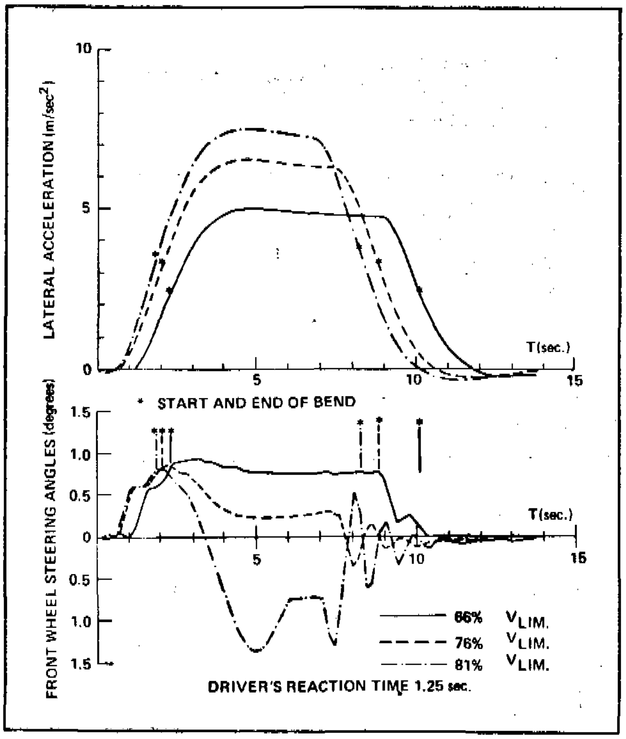


Figure 5

The vehicle, travelling at 40 m/sec., has characteristic dynamic parameters as in the previous case. The driver's reaction time is 1 second.

Under the test conditions used, roll oversteer made the vehicle obviously unstable. The effect of understeering, instead, is strongly stabilizing (Fig. 6).

3. Active Safety Tests

These must satisfy the following requirements:

1. Be safe in their actuation
2. Emphasize those dynamic characteristics shown by driver-vehicle system analysis to be the most important for safety
3. Have a sufficient degree of repeatibility
4. Be, if possible, easy to perform.

The requirements mentioned in 3 and 4 can be met with tests using an actual driver, who will perform simple and previously well defined maneuvers, as long as point 1 is conformed to. We note that the proposed American ESV requirements generally satisfy the four points mentioned above.

As far as we are concerned, we are utilizing the results of the above described theoretical and experimental research to define a series of tests to be incorporated in the classification of Fig. 7. The blank squares may be occupied by further definitions.

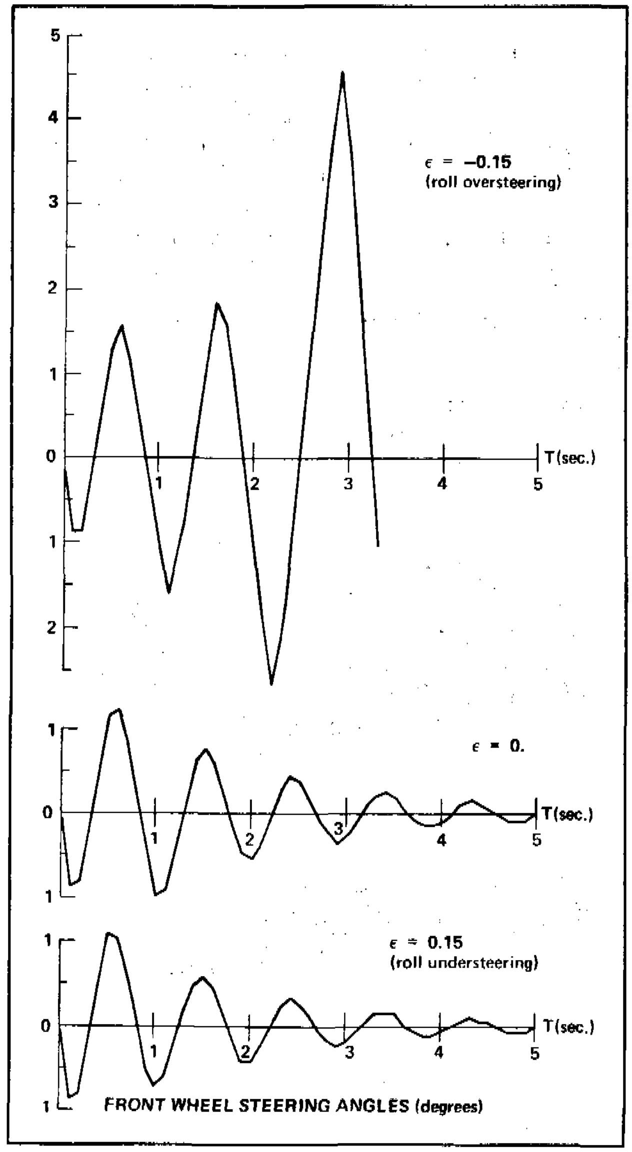


Figure 6

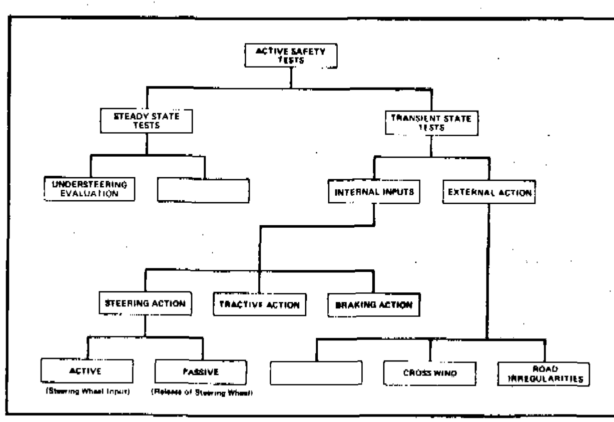


Figure 7

In what follows we will illustrate the simulations of some of these tests comparing them, whenever possible, with the active safety requirements contained in the American proposal. The simulations were based on the configuration of an average European car with good road-holding and varying, when necessary, the most significant parameters.

It may be interesting to show the data which more closely characterizes the vehicle under consideration:

Total mass = 113 kg. sec^2/m

Sprung mass = 101 kg.sec^2/m

Principal moment of inertia of the total mass with respect to the yaw axis = 160 kg. sec^2 m

Distance of the center of gravity from the front axle = 1.05 m

Distance of the centre of gravity from the rear axle = 1.40 m

Height of the centre of gravity = 0.47 m

Height of the front roll centre = 0.106 m

Height of the rear roll centre = 0.23 m

Front track = 1.38 m

Rear track = 1.35 m

The tires have non-linear characteristics, of the average European type.

3.1. Steady State Tests

3.1.1. Evaluation Of The Degree Of Understeering

The behaviour of the basic vehicle was compared with the American proposal limits, concerning the relationship between steady state yaw velocity and steering angle at the front wheels, with a lateral acceleration of 0.4 g. The test speeds specified are 40, 80 and 112 km/h.

The results obtained are shown in Fig. 8: this diagram is derived from the original American proposal, with the difference that the ordinate was multiplied by the vehicle wheel base, to extend the application of this diagram to vehicles having different dimensions.

The diagram was completed with curves for fixed degrees of understeering, defined by the following expressions:

$$\frac{\omega L}{\delta} = \frac{V}{1 + K V^2}$$

$$K = \frac{\Delta}{A_m g L}$$

$$\Delta = \frac{A_p - A_a}{A_m}$$

where

ω = steady state yaw velocity

L = Wheel base

δ = front wheels steering angle

A_m = average dimensionless cornering stiffness of the vehicle = $\sqrt{A_a / A_p}$

A_a = front dimensionless cornering stiffness

A_p = rear dimensionless cornering stiffness

g = gravitational acceleration

The curves were traced for a value $A_m g L$ = 240 m^2/sec^2, which may be considered valid for an average vehicle with generous tire equipment undergoing 0.4 g. lateral acceleration.

The vehicle examined, as shown in Fig. 8, falls outside the imposed limits, even if it is characterized by substantial understeering and considered having a good road-holding standard.

We are of the opinion that the USA proposal expects rather strong understeering characteristics.

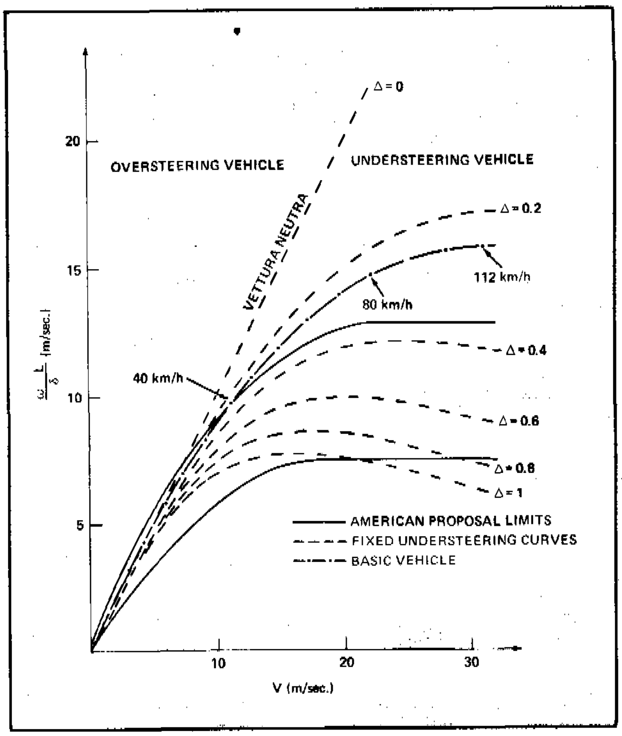


Figure 8

3.2. Transient State Tests

3.2.1. Active Internal Steering Action – Step Function Steering Input

It is assumed that, when the vehicle travels at constant velocity in a straight line, an instantaneous steering input is applied, so as to achieve a fixed value of steady state lateral acceleration.

In actual practice, the time taken to rotate the steering must be negligible with respect to the lowest of the time constants related to this phenomenon, for the particular vehicle. This requirement is due to the aim of making the test result independent of maneuvering speed.

For comparison, we will show the simulations results on the basic vehicle in accordance with the American proposal on this maneuver.

The test conditions are as follows:

velocity of rotation of the steering wheel: V500°/sec.
test speed: 40-11 = km/h
steady state lateral acceleration: 0.4 g.

The curves of yaw velocity against time must be contained within the limits shown in Figs. 9 and 10; in these diagrams appear also the transient state curves for the same vehicle and various degrees of understeer, as defined in the previous case.

The same considerations as the ones in paragraph 3.1.1. can be made by examining Fig. 10, concerning the high speed test.

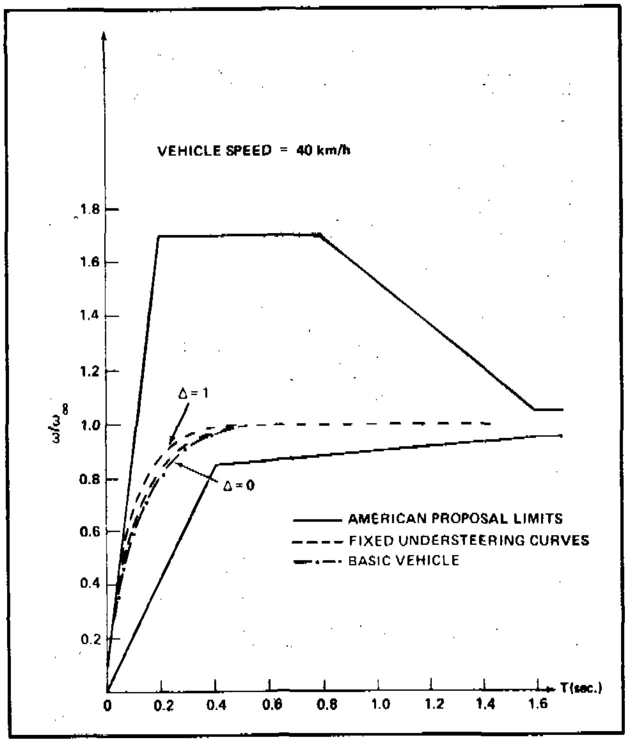


Figure 9

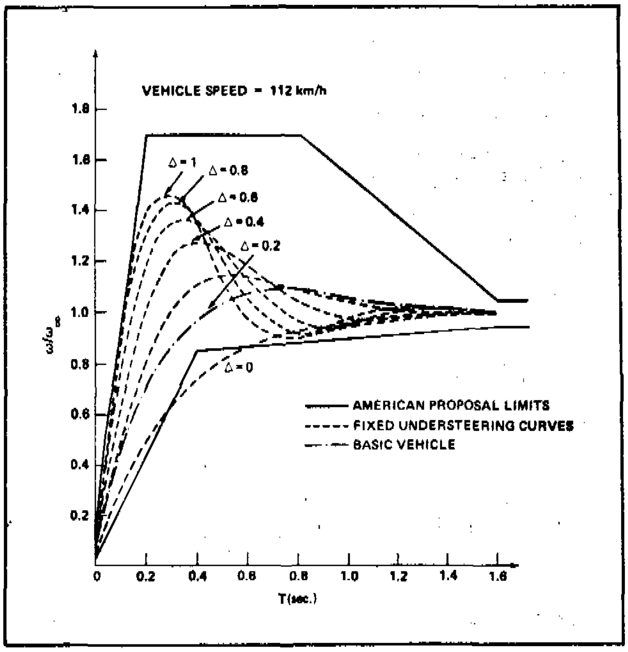


Figure 10

3.2.2. Passive Internal Steering Action – Influence Of Steering Dynamics On Vehicle Control And Stability

The treatment of the present problem is referred to a vehicle with three degrees of freedom (lateral displacement, yaw angle and roll angle) and to a steering system with two degrees of freedom (front wheels steering angle and steering wheel angle). As far as the steering system is concerned, not only its inertial characteristics are taken into account, but also its damping (assumed to follow Coulomb's law), roll understeer and characteristic wheel angles.

The vehicle starts the bend with a pre-determined forward speed and lateral acceleration. The steering wheel is suddenly released at a point on the trajectory which then becomes the initial reference point.

The test conditions suggested by the American proposal are analogous to the ones described above, but are characterized by the requirement of running the vehicle on circular trajectories of such radii that the lateral acceleration achieved is 0.4 g, for both 40 km/h and 80 km/h.

The principal reason for this test is to evaluate steering returnability and damping. Hence, after releasing the steering wheel, yaw angles (referred to the initial angular position of the vehicle) and yaw velocities are measured as a function of time.

With reference to the American proposal, the yaw angles response curves for 40 km/h and 80 km/h must be within the limits shown in Fig. 11. In addition, two seconds after the start of the test, the yaw velocities must be within the following limits (Fig. 12):

$\geqslant 4°$/sec. at 80 km/h
0°/sec. at 40 km/h

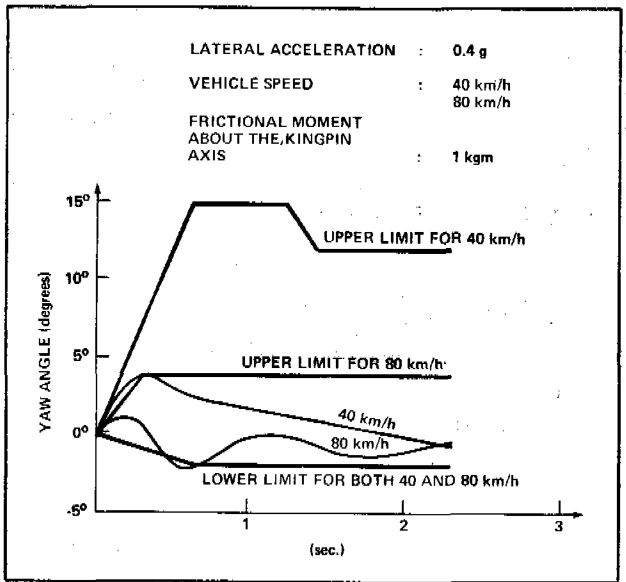


Figure 11

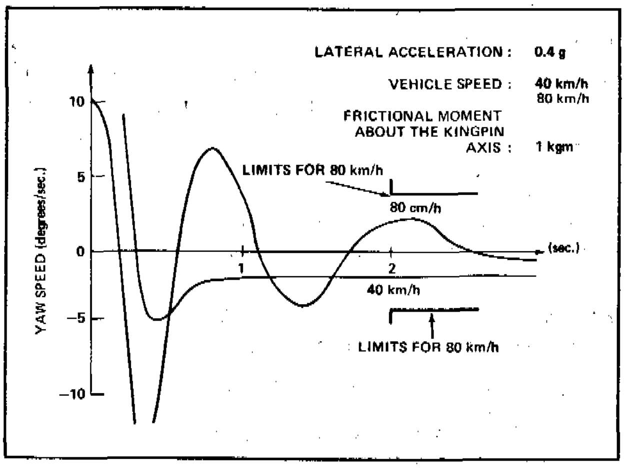


Figure 12

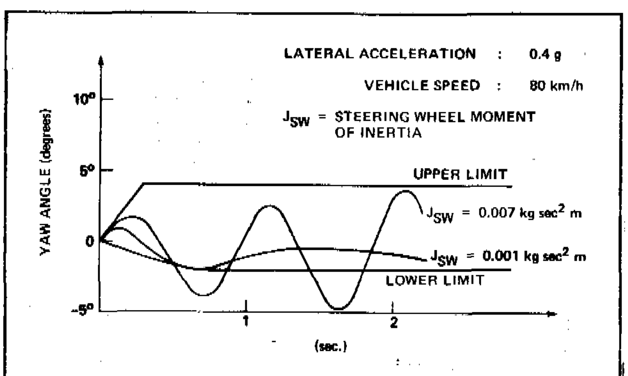


Figure 13

It can be seen from Figure 11 that the curve pertaining to the speed of 40 km/h is wholly inside the ESV limits, while the one drawn for 80 km/h is substantially outside those limits for a small time interval.

The curves shown in Figure 13 are deduced from the basic conditions, increasing the steering wheel moment of inertia from 0.00297 kg.sec^2.m to 0.007 kg.sec^2.m, then decreasing it to 0.01 kg.sec^2.m. It can be noted that an increase in the steering wheel moment of inertia emphasizes the amplitudes of oscillations of yaw angles. Similar effects are caused varying the steering ratio from 18 to 24 to 15 (Fig. 14).

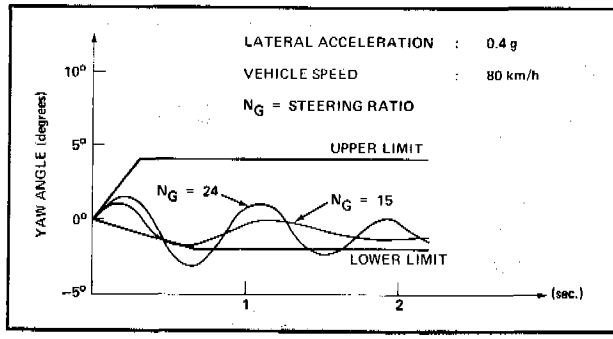


Figure 14

3.2.3. External Inputs – Wind – Vehicle Cross Wind Sensitivity

For uniformity with the American proposals, the vehicle was assumed subjected to a sudden cross wind having a velocity of 80 km/h. The total course deviation, for a wind exposure of 6.1 m, must be less than the values specified in Figure 15, when measured two

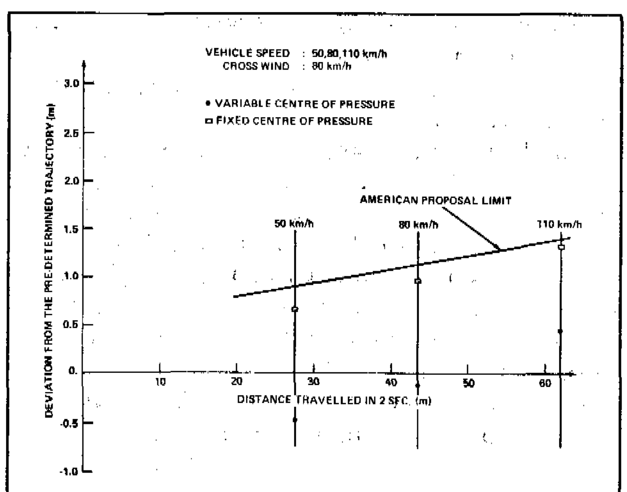


Figure 15

seconds after the start of this test. Vehicle speeds considered are 50, 80 and 110 km/h; the steering wheel is assumed locked in position.

Figure 15 shows the results for two different aerodynamic considerations: one with a fixed centre of pressure, located at a distance, from the front axle centre, equal to one quarter of the wheel base, and another with a variable centre of pressure (Fig. 16).

In this case the variable centre of pressure solution shows advantages over the other type. However, for small relative wind incidence angles, like the ones obtained, for instance, with high vehicle speeds and relatively low wind velocities, the fixed centre of pressure vehicle becomes more desirable.

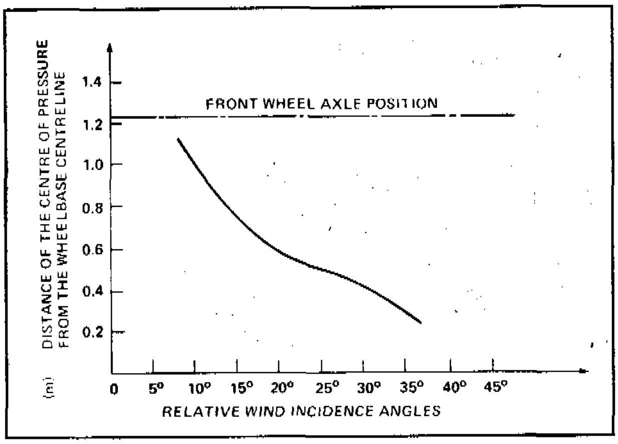


Figure 16

3.2.3. External Inputs – Road Irregularities – Roll Understeer Influence On Vehicle Stability

The vehicle is assumed to travel along a predetermined trajectory (e.g., rectilinear) with the steering wheel locked in position.

It is further assumed that the steering wheel and the front wheels are rigidly connected.

The investigation consists, for different speeds, in following the behaviour of the vehicle having various degrees of roll steering, and affected by an external input due, for example, to some road irregularity.

In this case the input is assumed to be applied at the centre of gravity of the basic vehicle (having neutral characteristics). Defining ϵ (the roll steering value) as the relationship between steering angle and roll angle (when ϵ is positive, it causes understeering), the effects of the following values of ϵ were considered:

0.15 (understeering)
0.03 (understeering)
-0.15 (oversteering)

Figure 17 gives the variations of lateral accelerations and lateral course deviation from the original path, relative to the time from the start of the test. The vehicle speed is 20 m/sec. The examination of Figure 17 shows that, at this speed, vehicle stability is not appreciably affected by roll steering. Figure 18 shows similar diagrams to the ones in Figure 17, but for a 50 m/sec. vehicle speed. In this case it can easily be observed that roll oversteering (-0.15) is such that it renders the vehicle unstable.

The example above shows the importance for active safety of perfecting a test to analyze, with the steering wheel locked in position, high speed vehicle stability, the lack of which creates the dangerous and well known phenomenon of high speed snaking.

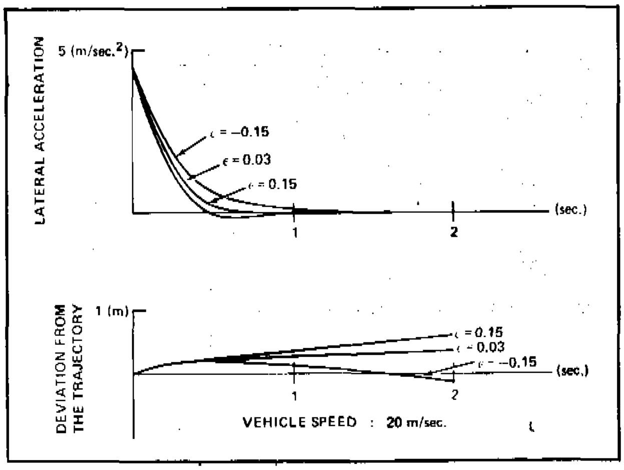


Figure 17

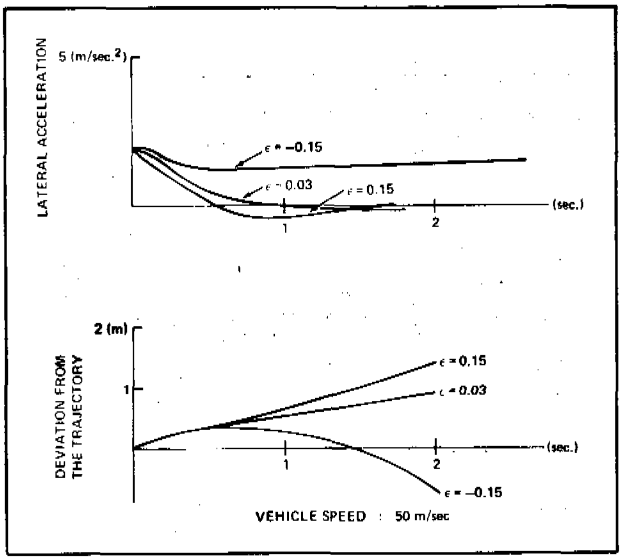


Figure 18

Conclusions

During our research we have compared, whenever possible, our results with the ones obtained using the American proposal: this suggests an undoubtedly interesting series of tests for the definition of the handling and road-holding characteristics of vehicles.

In our opinion it is probable that further tests will have to be introduced, that some parameters need to be more specifically defined and some limits reviewed, with the aim also of extending the applicability of such work to European type vehicles. We further believe that this analysis and problem penetration, to which we dedicate considerable efforts, can only advance through a study of the driver-vehicle system. Then we will obtain that knowledge of vehicle dynamics which, in the future will allow us to build safer vehicles.

References

Kyropoulous – Kelly – Tamer: Automobile Aerodynamics. Progress Report presented SAE SP180 (1960).

W. Bergman: Effect of Traction on Cornering Force. SAE Transactions (1961).

R. T. Bundorf – D. E. Pollok: Vehicle Handling Response to Aerodynamic Inputs – Paper presented at SAE Summer Meeting Montreal (1963).

R. T. Bundorf: The Variable Stability Automobile. Paper presented at SAE Meeting Detroit (1965).

L. Segel: On the Lateral Stability and Control of the Automobile as Influenced by the Dynamics of the Steering System. ASME Transactions (1965).

G. Toti: Aerodynamic Effects on Vehicle Moving in Stationary Air and their Influence on Stability and Steering Control. Paper presented at the SAE Meeting Detroit (1965).

E. Kikuchi: Mathematical model of man-automobile system. XII FISITA Congress Barcelona (1968).

G. Diana – F. Giordana: Modello analitic per lo studio del moto di un veicolo su strada. XIII FISITA Congress – Bruxelles 1970.

SUMMARY OF DEVELOPMENT WORK ON AUTOMOTIVE OPTICAL REAR VIEW DEVICES

Prof. Vasco Ronchi, Fiat Consultant

The problem of improving driver side and rear view has now been the object of investigations for some five years. In the course of these studies the complexity of the problem has come to full light, and to facilitate its solution, the relevant subject matter has been divided into three sectors as follows:

1. *Optical problems*, with a view to developing devices which afford a wide field of view, both in the horizontal and in the vertical planes, with clear and luminous and suitably magnified images.
2. *Mechanical problems*, involving installation on the vehicle so as to promote rapid, clear vision, at the same time meeting aesthetical requirements.
3. *Economic problems*, which drastically curtail the chances of using high-quality materials and semi-finished products and dictate the adoption of very simple devices.

In the programming of the work, optical problems have been given top priority.

The general approach and work schedule can best be summarised as follows:

a. It has been decided not to adopt separate devices for side and rear fields of view. Although flat or convex mirrors can be used for such devices, previous experience has shown that they are inadequate.

b. Accordingly, efforts have been channelled towards the development of a wide-field optical device capable of giving the driver simultaneous view of the rear and both sides.

The first approach in the development of a rear view device affording such features was to design a unit giving virtual images of 1/3 magnification. The original device (see Fig. 1a and 1b) comprised a negative lens on the

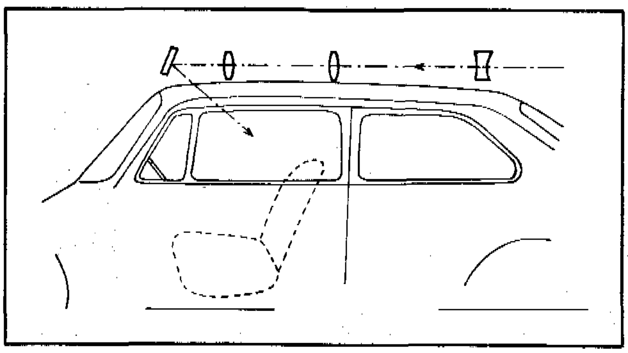


Figure 1A

rear of the car, followed by a system of lenses ending with a mirror similar to the currently used rear view mirror. A 160° external horizontal field contracted within a 60° apparent field, was visible all at once to the driver. The negative lens was approximately 20 centimetres wide.

When fitted on a car, the prototype gave encouraging results. A second prototype of different design but based on the same principle (see Figs. 2a and 2b), which was fitted on top of a fully closed van, again yielded

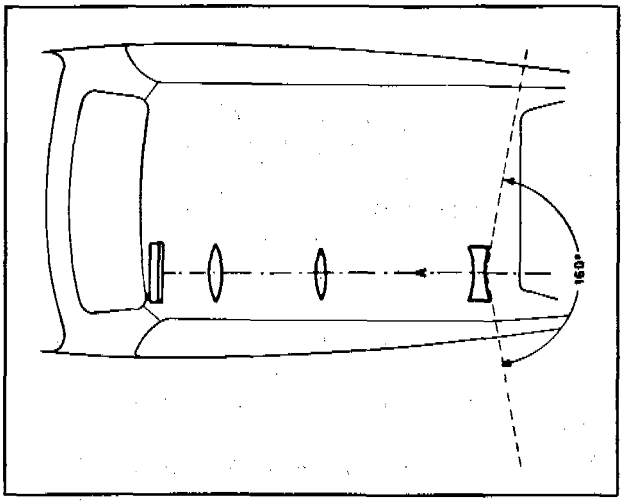


Figure 1B

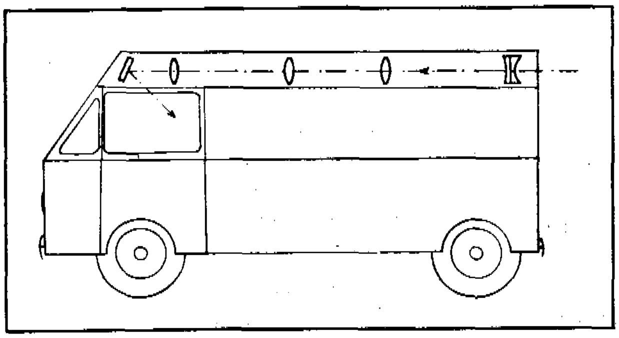


Figure 2A

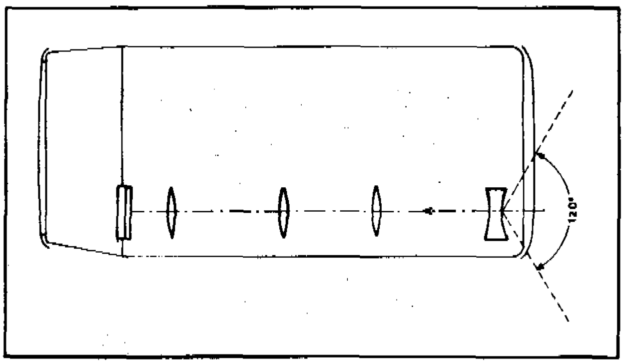


Figure 2B

interesting results. A third and more advanced prototype (see Figs. 3a and 3b), fitted to an 11 metre long urban bus confirmed that by following this approach it was possible to arrive at promising solutions.

Though offering the big advantage of a wide field viewed all at once, the adoption of an approximately 1/3 magnification gave a false impression as to the actual distance of the objects reflected as small images. This distance was reckoned three times as great. Initially, it

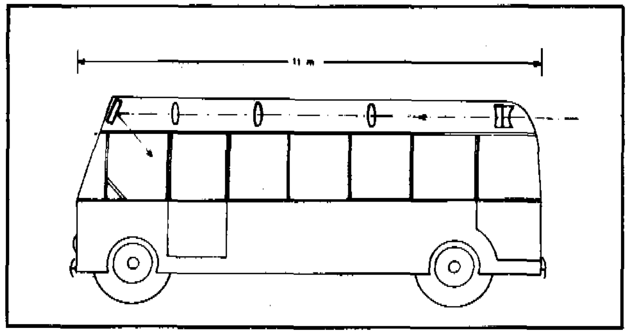


Figure 3A

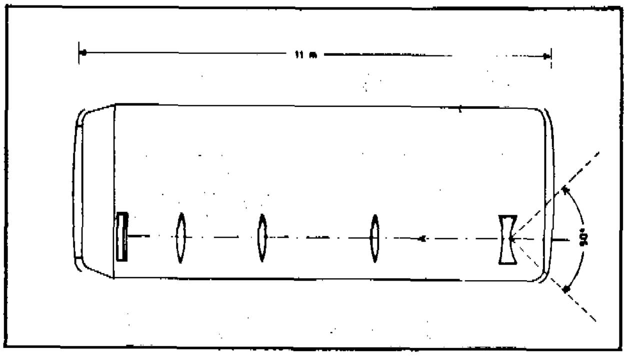


Figure 3B

was thought that the balance between the advantage of having a full view of the rear and sides including those areas which at present cannot be seen, and the drawback of a false judgment of the distance could turn out to be favourable and justified the investment in extensive trials to obtain confirmation. However, when the American proposed rule making irrevocably laid down that rear view magnification would not be permitted to differ from unity, the approach followed up to that time was dropped.

c. Thus the research effort was switched to wide-field unit-magnification rear-view devices. This meant foregoing the full-field vision feature, which it was decided to offset by allowing a limited sidewise head movement as contemplated in the American Standards.

The first car-mounted prototype featured a field of view of 90° in the horizontal and 30° in the vertical plane (see Figs. 4a and 4b), which is even greater than required by the American proposed rule making for the 1973 model year. This fairly uncomplicated device was housed in a 60 cm long, 30 cm wide and 15 cm high casing placed lengthwise on the roof of the car on the left-hand side above the driver's head, so that to look backwards from the straight-ahead posture, the driver only had to raise his eyes by approximately 30°.

However, investigations were continued with the aim of improving performance and further simplifying the device. In turn, this brought about a change in the concept of the optical system.

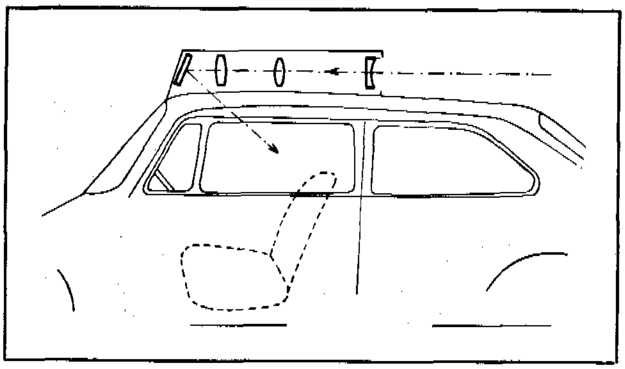


Figure 4A

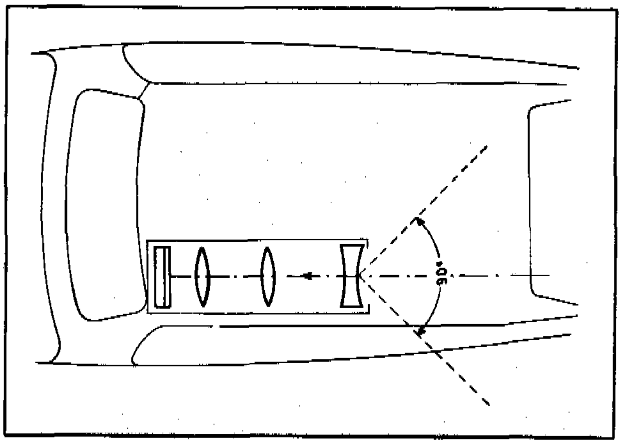


Figure 4B

In the latest type of device (see Figs. 5a and 5b) the wide range of divergent optical system and the magnification of the convergent systems was enhanced. The device simply consists of a divergent system (specular or dioptric) giving reduced size images but over a very wide field. These images are observed through a convergent optical system which acts as a magnifying lens and returns the magnification of the combination to the desired value giving suitable power ratings to the two systems. In particular, the degree of magnification of the system can be brought to unity with incredibly wide fields.

The description is rather vague, as this type of combination affords many degrees of freedom which have yet to be fully investigated. For example, one combination (see Fig. 6) is composed of only one convex mirror and a converging lens, both 30 cm wide, 8 cm high and 15 to 20 cm thick, and permits the observation of a horizontal 140° (approximately) field with a magnification of 1 and binocular vision over almost all the field; the images are optically well corrected and bright.

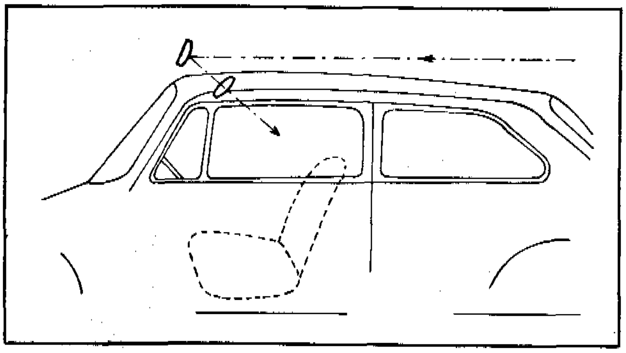


Figure 5A

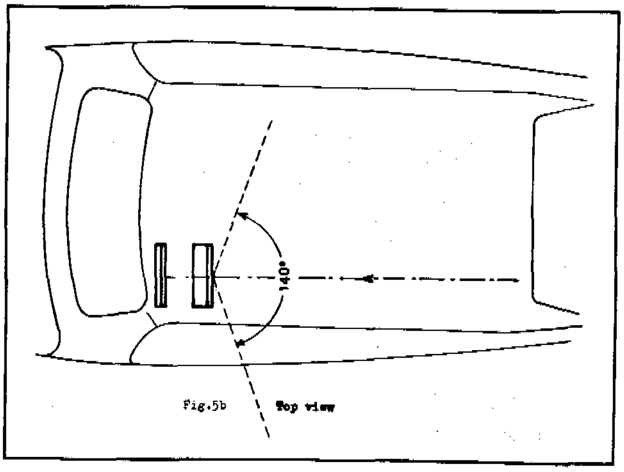


Figure 5B

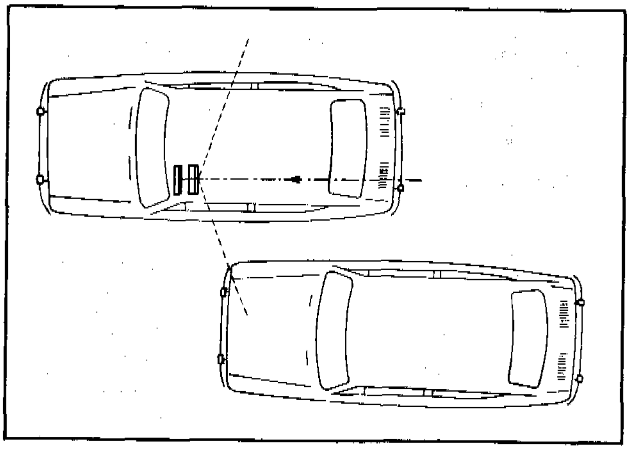


Figure 6

However, to observe the field boundary areas the head must be moved slightly to the right or to the left. However, the fact is that by moving his head and looking

SECTION 2

PART 6 THE FRENCH TECHNICAL PRESENTATION ON THE ESV PROGRAM

DISTRIBUTION AND GRAVITY OF COLLISIONS AS A FUNCTION OF THE DAMAGED PART OF THE VEHICLE AND THE OBSTACLE HIT

M. Claude Berlioz, O.N.S.E.R.

1. Object and Area of Study

The improvement of automobile crash qualities can involve many methods, not only by the nature of the planned technical improvements, but also by the type of collision where we try to minimize the consequences for the occupants. It is therefore important to define the priorities in these different situations in order to get the maximum improvement at the same cost. This choice calls for at least two criteria: the frequency and the gravity of different types of collisions. This study proposes to provide some comments on these ideas.

The study involves about 1/10th of the property damage accidents, involving at least one touring car, that occurred in France in 1968 (17,916) and not involving pedestrians, bicycles, nor a third vehicle (7,087).

2. Method

The facts were collected by police through their certified reports of accidents. On the form filled out for each accident, the officer indicates, for each vehicle, the damaged part by checking with the drawing on his form and reproduced here as Figure 1 (the angles shown on the form drawing). No other special instructions on this subject were given to the police. We must assume that in cases of multiple collisions, the damaged area indicated would represent the major crash.

However, it is interesting that a non-negligible number of officers had indicated the direction of the crash instead of the damaged part. The boundaries between the designated areas are most likely not interpreted in the same way by all the officers, but we can assume

TABLE 1

Using the Card Index of 1/10 of Accidents in 1968
Distribution of the Hit Part of Cars and Vans in Terms of The Type of Obstacle or Vehicle Hit

(7,087 Accidents)

	Front	Rear	Left Front	Left Center	Left Rear	Right Front	Right Center	Right Rear	No Answer	TOTAL
Post	45.9% 200 5.8%	0.7% 3 0.6%	13.1% 57 2.1%	4.1% 18 2.6%	1.6% 7 2.0%	16.1% 70 4.4%	5.0% 22 4.2%	1.8% 8 3.4%	11.7% 51 13.7%	100% 436 4.2%
Tree	40.8% 227 6.5%	1.3% 7 1.5%	14.4% 80 2.9%	6.8% 38 5.5%	2.1% 12 3.5%	14.0% 78 4.9%	10.0% 56 10.8%	1.4% 8 3.4%	9.2% 51 13.7%	100% 557 5.3%
Wall	39.2% 231 6.7%	0.8% 5 1.0%	16.3% 96 3.5%	3.6% 21 3.0%	1.0% 6 1.7%	18.3% 108 6.8%	5.1% 30 5.8%	1.0% 6 2.6%	14.7% 87 23.4%	100% 590 5.7%
Other Obstacles	39.0% 293 8.5%	0.7% 5 1.0%	11.8% 89 3.2%	8.5% 64 9.3%	1.5% 11 3.2%	14.9% 112 7.0%	7.0% 53 10.2%	2.1% 16 6.8%	14.5% 109 29.3%	100% 752 7.2%
Touring Car	29.9% 2011 58.1%	5.8% 388 80.8%	30.5% 2058 74.6%	6.7% 450 64.9%	4.0% 267 76.9%	15.3% 1032 64.7%	4.4% 299 57.6%	2.4% 166 70.9%	1.0% 65 17.5%	100% 6736 64.4%
Truck	35.5% 445 12.9%	5.2% 65 13.6%	28.4% 356 12.9%	7.2% 91 13.1%	3.3% 42 12.1%	13.6% 170 10.7%	4.3% 54 10.4%	1.9% 24 10.3%	0.6% 8 2.1%	100% 1255 12.0%
Other Vehicles	40.3% 52 1.5%	5.4% 7 1.5%	16.3% 21 0.8%	8.5% 11 1.6%	1.5% 2 0.6%	18.6% 24 1.5%	3.9% 5 1.0%	4.7% 6 2.6%	0.8% 1 0.3%	100% 129 1.2%
TOTAL	33.1% 3459 100%	4.6% 480 100%	26.4% 2757 100%	6.6% 693 100%	3.3% 347 100%	15.2% 1594 100%	5.0% 519 100%	2.2% 234 100%	3.6% 372 100%	100% 10455 100%

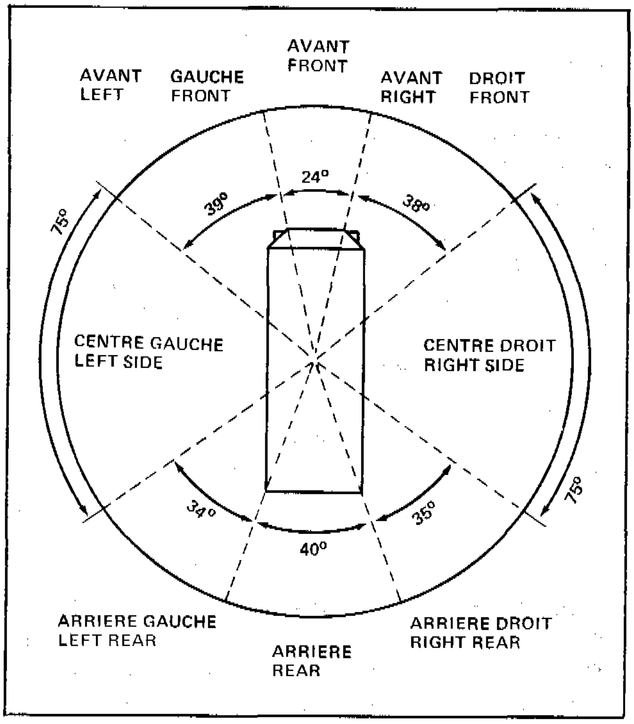


Figure 1

that on the average they correspond to the vertical joining of the fenders in the structure.

The obstacles hit as defined on the form are:

1. street lamp, post, milestone
2. tree
3. level crossing barrier
4. edge of a street island
5. safety guide-block (window guide)
6. animal, alone or many
7. wall, construction, various material

In view of the number of various objects, we have regrouped numbers 3-6 under the heading "other obstacles." For the sake of simplification, we will call the first heading "post" and the last one "wall" in the following text.

In the accidents involving only one vehicle, there is generally no question as to the obstacle hit (except in the exceptional case where many objects may have been hit but the form only allows for one case).

In accidents involving two vehicles, in about 4% of the cases an obstacle is hit, but we do not know if the main crash was against the other vehicle or against the obstacle. We will suppose, at least at first, that the main crash was against the other vehicle. For "other vehicle" we consider:

- touring car or van
- truck
- other vehicle with the exception of two wheelers

We generally include a distinction between the different trucks according to their total loaded weight for more detailed studies, but this distinction was not used here.

These facts are actually available for all property damage accidents in France, but we figured that one-tenth of the accidents would offer a precise enough measure, at least for the first step.

TABLE 2

Using Card Index of 1/10 of Accidents in 1968
State of Drivers of Touring Cars or Vans in Crashes Against An Obstacle or Another Vehicle According to the Hit Part

(7,087 Accidents)

	Front	Rear	Left Front	Left Center	Left Rear	Right Front	Right Center	Right Rear	No Answer	TOTAL
Killed	35.2% 114 3.3%	0.6% 2 0.4%	22.8% 74 2.7%	10.8% 35 5.1%	1.5% 5 1.4%	12.4% 40 2.5%	5.9% 19 3.7%	1.9% 6 2.6%	8.9% 29 7.8%	100% 324 3.1%
Serious Injuries	38.9% 648 18.7%	1.9% 32 6.7%	25.4% 422 15.3%	7.6% 127 18.3%	1.8% 30 8.7%	13.0% 217 13.6%	5.1% 85 16.4%	1.1% 18 7.6%	5.2% 86 23.1%	100% 1665 15.9%
Light Injuries	35.2% 1456 42.1%	3.8% 157 32.7%	26.7% 1105 40.1%	7.3% 300 43.3%	3.7% 152 43.8%	13.5% 558 35.0%	5.1% 209 40.3%	1.5% 63 26.9%	3.2% 135 36.3%	100% 4135 39.6%
Total Victims	36.2% 2218 64.1%	3.1% 191 39.8%	26.1% 1601 58.1%	7.5% 462 66.7%	3.1% 187 53.9%	13.3% 815 51.1%	5.1% 313 60.4%	1.4% 87 37.1%	4.2% 250 67.2%	100% 6124 58.6%
No Injuries	28.8% 1235 35.7%	6.4% 274 57.1%	26.9% 1151 41.7%	5.3% 228 32.9%	3.6% 154 44.4%	18.0% 771 48.4%	4.8% 205 39.5%	3.4% 145 62.0%	2.8% 120 32.3%	100% 4283 40.9%
No Response	12.5% 6 0.2%	31.3% 15 3.1%	10.4% 5 0.2%	6.3% 3 0.4%	12.5% 6 1.7%	16.7% 8 0.5%	2.1% 1 0.1%	4.2% 2 0.9%	4.0% 2 0.5%	100% 48 0.5%
TOTAL	33:1% 3459 100%	4.6% 480 100%	26.4% 2757 100%	6.6% 693 100%	3.3% 347 100%	15.3% 694 100%	5.0% 519 100%	2.2% 234 100%	3.5% 372 100%	100% 10455 100%

Only the state of driver and front seat passenger were studied, the number of rear seat passengers was much less. We first studied them as a function of the damaged part of the vehicle, as they were distributed among the four following situations:

- killed in the crash or dead within a week
- seriously injured, still in the hospital six days after the crash
- slightly injured–medical treatment or hospitalization for less than or equal to six days
- uninjured

We have analyzed the possible heterogeneity of these distributions by means of tests of X^2.

The same was done for the obstacle or vehicle hit, instead of the hit part of the first car.

We finally studied the distribution of the damaged part in terms of the obstacle or vehicle hit, in order to see if possible differences of gravity observed in the two first phases of the study could be explained by a non-independence of the damaged part and the damaged obstacle.

3. Chief results

a. Damaged part (Tables 2 and 4)

The most frequently damaged parts are, in order:

- the front: 33% of crashes and 35% of fatalities
- the left front: 26% of crashes and 20% of fatalities
- right front: 15% of crashes and 15% of fatalities

The distribution of occupants involved in fatalities, serious and slight injuries, and those unhurt differ significantly according to the damaged part, for the driver as well as the front seat passenger. We can make note of the seriousness of these types of crashes with the help of two indicators.

- the rate of mortality, ratio of the number killed to the number involved in crashes (3.1% for drivers and 2.8% for the front seat passenger)
- the rate of seriousness, ratio of the total killed and seriously injured to the number involved (19% for drivers and 22% for front seat passengers)

For the driver, the most serious crash corresponds to the left center crash for the two rates of 5% and 23%. Then come the right center and the front; the order depends on the indicator chosen. Rear collisions are the least serious.

For the front passenger the most serious crash is the center right side, for the two rates of 7% and 32%. Then come the right front and the front; the order depends on the indicator chosen. The rear crashes are the least serious.

TABLE 3

Using Card Index of 1/10 of Accidents in 1968
State of Drivers of Touring Cars or Vans as a Function of the Type of Obstacle or Vehicle Hit
(7,087 Accidents)

	Post	Tree	Wall	Other Obstacles	Touring Car	Truck	Other Vehicles	TOTAL
Killed	8.0% 26 6.0%	21.9% 71 12.7%	12.0% 39 6.6%	11.7% 38 5.1%	23.5% 76 1.1%	21.0% 68 5.4%	1.9% 6 4.8%	100% 324 3.1%
Serious Injuries	8.1% 135 31.0%	12.4% 207 37.2%	10.5% 175 29.7%	10.4% 174 23.1%	40.4% 673 10.0%	16.5% 274 21.8%	1.7% 27 20.9%	100% 1665 15.9%
Light Injuries	4.6% 190 43.5%	4.8% 200 36.0%	6.3% 259 43.9%	8.5% 350 46.5%	59.0% 2440 36.2%	15.2% 629 50.1%	1.6% 67 51.9%	100% 4135 39.5%
Total Victims	5.7% 351 80.5%	7.8% 478 85.8%	7.7% 473 80.2%	9.2% 562 74.7%	52.1% 3189 47.3%	15.9% 971 77.3%	1.6% 100 77.6%	100% 6124 58.5%
No Injuries	2.0% 85 19.5%	1.8% 79 14.2%	2.7% 117 19.8%	4.4% 190 25.3%	81.8% 3504 52.1%	6.5% 279 22.3%	0.8% 29 22.4%	100% 4283 41.0%
No Response	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	89.6% 43 0.6%	10.4% 5 0.4%	0 % 0 0 %	100% 48 0.5%
TOTAL	4.2% 436 100%	5.3% 557 100%	5.6% 590 100%	7.2% 752 100%	64.4% 6736 100%	12.0% 1255 100%	1.3% 129 100%	100% 10455 100%

The left collisions are significantly more serious for the driver than for the front passenger, no matter what indicator is used, and the roles are revised for right collisions.

But the results are not symmetrical.

- for the collisions on the side of the occupied seat, the front passenger is more seriously hurt than the driver, in a significant way, for both indicators (the difference is greater with the rate of seriousness)
- for collisions on the opposite place, the driver is more seriously hurt than the front passenger in terms of mortality rate, but not in terms of the rate of seriousness)

For the front seat passenger, the collision on the side of his seat is significantly more serious than the collision on the opposite side, for both indicators, while that is not true for the driver.

b. Obstacle hit (Tables 3 and 5)

The collisions against an obstacle are much more serious than against another vehicle: they represent 22% of the cases, and 51% of the fatalities

For the driver the most serious collisions are those against trees, for both indicators chosen (13% and 50%). Then come walls and posts, the order depends on the indicator, and followed by trucks. The least serious collisions are against another touring car, no matter which indicator you choose. (1.1% and 11%).

For the front passenger, the most serious collisions are also against trees, no matter which indicator you choose (8% and 50%). They are significantly less serious than for the driver in terms of rate of mortality, but not in terms of rate of seriousness. Then come walls, posts and trucks, in an order according to the indicator used. The least serious collisions are against another touring vehicle (1.4% and 14%).

c. Comparison of Obstacle Hit and Damaged Part (Table 1)

The distribution of the damaged parts differ significantly according to the obstacle hit.

The front strikes an obstacle more frequently than it hits another vehicle, which is an example of the high degree of seriousness of front collisions (proven in a).

The left front hits other vehicles about twice as often as the right front, although their frequency in striking obstacles is not significantly different, as shown in the great seriousness of right front collisions for the front seat passenger.

Trees are hit about twice as often as other obstacles by the right or left center, which is shown by the very grave results of side collisions and crashes into trees.

Conclusion

The seriousness of touring car collisions depends on the obstacle or vehicle hit and the point of impact. The latter is quite important. Therefore in matters of crashworthiness, we should associate the angles of impact with the corresponding obstacles. In particular,

TABLE 4

Using Card Index of 1/10 of Accidents in 1968
State of Front Passengers of Touring Cars or Vans in Collisions Against An Obstacle or Another Vehicle According to the Part Hit

(7,087 Accidents)

	Front	Rear	Left Front	Left Center	Left Rear	Right Front	Right Center	Right Rear	No Answer	TOTAL
Killed	33.9% 58 2.9%	0 % 0 0 %	14.0% 24 1.4%	7.0% 12 3.0%	1.8% 3 1.4%	18.7% 32 3.4%	13.5% 23 7.0%	2.9% 5 3.2%	8.2% 14 5.2%	100% 171 2.8%
Serious Injuries	39.9% 471 23.7%	1.3% 16 6.2%	19.7% 233 14.0%	5.6% 66 26.3%	1.3% 15 7.0%	15.5% 183 19.6%	6.9% 81 24.7%	1.9% 22 14.2%	7.9% 93 34.3%	100% 1180 19.0%
Light Injuries	32.5% 1022 51.6%	4.1% 130 50.6%	27.9% 879 53.1%	6.3% 198 48.9%	2.9% 93 43.4%	15.1% 475 50.9%	5.0% 158 48.2%	2.4% 75 48.4%	3.8% 120 44.6%	100% 3150 50.7%
Total Victims	34.5% 1551 78.2%	3.3% 146 56.8%	25.2% 1136 68.5%	6.1% 276 68.0%	2.5% 111 51.6%	15.3% 690 73.9%	5.8% 262 79.9%	2.3% 102 65.8%	5.0% 227 84.4%	100% 4501 72.5%
No Injuries	25.4% 432 21.8%	6.5% 111 43.2%	30.6% 522 31.5%	7.6% 130 32.0%	6.1% 104 48.4%	14.3% 244 26.1%	3.9% 66 20.1%	3.1% 53 34.2%	2.5% 42 15.6%	100% 1704 27.5%
No Response	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0% 0 0 %
TOTAL	32.0% 1983 100%	4.1% 257 100%	26.7% 1658 100%	6.5% 406 100%	3.5% 215 100%	15.1% 934 100%	5.3% 328 100%	2.5% 155 100%	4.3% 269 100%	100% 6205 100%

the front collision seems to be most often associated with the limited obstacles, and the off-center collision are most often associated with another vehicle (possibly simulated by a wall).

To be able to define priorities among the possible vehicle improvements, and more generally among the road safety measures, we must evaluate the gains in deaths and injuries for these different types of collisions. Then, thanks to the facts we are going to present, the total gains relative to the various improvements, that will be compared on a cost basis, will be evaluated. If we accept the criteria generally accepted in France for road safety investments, these extra costs should not exceed $500 per vehicle for an improvement of nearly 100%.

TABLE 5
Using Card Index of 1/10 of Accidents in 1968
State of Front Passengers in Touring Cars or Vans in Terms of the Type Of Obstacle or Vehicle Hit

(7,087 Accidents)

	Post	Tree	Wall	Other Obstacles	Touring Car	Truck	Other Vehicles	TOTAL
Killed	5.3% 9 2.8%	16.4% 28 7.7%	15.8% 27 6.1%	8.8% 15 2.7%	31.0% 53 1.4%	21.0% 36 5.1%	1.7% 3 6.5%	100% 171 2.7%
Serious Injuries	9.0% 106 33.2%	13.0% 154 42.3%	12.5% 148 33.6%	12.8% 151 27.0%	39.9% 471 12.5%	12.1% 142 20.1%	0.7% 8 17.4%	100% 1180 19.0%
Light Injuries	5.2% 163 51.1%	4.6% 146 40.1%	6.7% 211 47.8%	9.6% 304 54.4%	60.8% 1914 50.8%	12.4% 390 55.2%	0.7% 22 47.8%	100% 3150 50.8%
Total Victims	6.2% 278 87.1%	7.3% 328 90.1%	8.6% 386 87.5%	10.4% 470 84.1%	54.2% 2438 64.7%	12.6% 568 80.4%	0.7% 33 71.7%	100% 4501 72.5%
No Injuries	2.4% 41 12.0%	2.1% 36 9.9%	3.2% 55 12.5%	5.2% 89 15.9%	78.1% 1331 35.3%	8.2% 139 19.6%	0.8% 13 28.3%	100% 1704 27.5%
No Resonse	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0 % 0 0 %	0% 0 0 %
TOTAL	5.1% 319 100%	5.9% 354 100%	7.1% 441 100%	9.0% 559 100%	60.8% 3769 100%	11.4% 707 100%	0.7% 46 100%	100% 6205 100%

WHY CITROEN CHOSE 1500 LB. VEHICLE FOR ITS STUDIES AND EXPERIMENTS

M. Maurice Clavel, Citroen

After having conducted several hundred tests with impacts and collisions attaining speeds at impact of more than 70 kilometers an hour (or more than 45 mph) we have ascertained that the majority of the standards dictated by the Federal Administration, Standards 201, 204, 208, 214 and 215 for example, such as they are in application or in their short term development, unequivocably doom to the point of eliminating the small, low-range European car of about 1400-1600 pounds empty weight.

It is always possible and even easy by the addition of significant pounds or by the enlargement of the dimensions of a small vehicle to make it respond to the impact standards in force and even the more severe to come. But this increase in mass and volume which automatically causes a corresponding inflation of power, brings about a car with a weight, bulkiness and finally a cost price which pushes it definitively out of its category as a low-range European car, all the while risking a reduction of its fundamental qualities of active safety without, however, having attained the objective "effectiveness" desired in the matter of passive safety.

The "small car" is thus definitively eliminated, giving way to a hybrid vehicle of an experimental nature, but economically unacceptable by the user.

This serious outlook insofar as economical, ecological and social consequences can not be accepted and this for the obvious reasons which follow:

1. The small low-range European car is by its dimensions an essential factor for the fluidity of urban traffic.
2. The small, low-range European car, aside from not being aggressive, behaves just as well in the case of a

collision against or by a 4000 pound car as a 4000 pound car does in a collision against or by one of the trucks of more than 10 tons which plow our roads. Its turning qualities and its performance on the highway (holding of the road and braking ability of a high level) furthermore allow it unquestionably to avoid certain collisions better than a bulky car with less turning ability or inferior handling performance.

3. Inasmuch as the volume of pollutant gases emitted by the motors (carbon monoxide, hydrocarbon, nitrogen oxide, etc.) is roughly proportional to the mass of the vehicle, the use of a small car limits in some important degrees the pollution of cities by automobiles. It is among other things the reason that the pollution problem of big metropolises is less acute in France than in the United States.
4. Finally, "last but not least," in Europe, where the average individual income and the standard of living do not measure up to American levels, the small, low-range car is economical to buy and to use, and it is the sole means of access to motorization by the less affluent socio-professional categories. Unless they are eliminated through regulations, the European fleet of this type of vehicle will reach some twenty-three million units in 1976. In this regard, the elimination of this class of functional vehicles would not fail to provoke in a large segment of the population a feeling of frustration. The character of which no government would be able to accept. Under the effect of ill-adapted and discriminatory regulations, the automobile might undergo a backward evolution and once again become the prerogative of the few well-off classes.

In order to escape from this menacing impasse, all the while helping administrations to establish realistic safety regulations, and in order to save the little car and confer upon it effective safety/collision characteristics without, however, encumbering the weight, the road holding qualities and the cost price, our Society has undertaken a series of research and experiments which can be placed in the body of the program proposed by the French government, A Thematic Action for Secondary Safety by the study of structures and of components: in English, Experimental Safety Sub-System (E.S.S.S.).

Citroen's studies and experiments spaced out over a minimum of two years explore and will explore, for a small vehicle weighing 1500 pounds when empty, the development of classical structures and, still in matters of structures, diverse new orientations touching upon the capacity for absorption of energy, upon the formation of survival spaces after impacts and upon volumes and original arrangements in the seats which allow for a shifting of the driver and of the passengers equipped with restraining systems adapted to physiologically acceptable decelerations.

Mr. Bohers is going to report to you the main orientations of our research program in the light of experience gained during the course of already accomplished experiments on collisions at accelerating speed, with some experiments yet to be made.

You will note that in a Maoist fashion we don't hesitate to constantly question through analysis and comparison the results obtained in the course of this exploration of two years.

So, while pursuing the continual process of the perfecting of its effectiveness, "global safety," we are opposed to the elimination of the small vehicles, victims of regulations of rapid and unforeseen development. A number of these regulations aim to compensate in passive safety for the inperfections of certain vehicles awkward in active safety.

So doing, along the lines of our traditions, we will continue to work for the democratic diffusion of these small vehicles, of which the anti-inflationist and social impact, the road-handling qualities and the highly advanced technology are the long ripened fruit of an innovative European effort.

CITROEN'S PROGRAM OF THEMATIC ACTION FOR SECONDARY SAFETY OVER A PERIOD OF TWO YEARS

M. Serge Bohers, Citroen

CITROEN'S PROGRAM OF THEMATIC ACTION
SECONDARY SAFETY (ESSS) OVER TWO YEARS

1 – SUBJECTS CHOSEN BY CITROEN IN THE FRAMEWORK OF THEMATIC ACTION
2– REASONS FOR OUR CHOICE
3 – UNFOLDING OF THE STUDY
4 – ACCOMPLISHMENTS AND EXPERIMENTS ON PROTOTYPES

Slide 1

1. Subjects Chosen By Citroen Within The Framework of Thematic Programmed Action

Among the eleven topics of interest proposed by the Institute for Transportation Research, the Citroen Society has chosen, for small-range vehicles, the study of the three following points:

- Improvement of the survival space in case of front-end impact (code IRT 4.1)

- Study of new energy-absorbing structures (code IRT 5.4)
- Structure and interior arrangement (minimization of wounds in the case of a bump of the head on the vertical pieces, supports and forward cross pieces)

2. Reasons For Our Choice

As Mr. Clavel has reported, the growing severity of safety regulations, as much in the USA as in Europe, compromises the existence of the small vehicle, and it is necessary to know for this type of vehicle the limits of possible action in the matter of secondary safety, without, however, sacrificing primary safety and the price.

The three points mentioned in the preceding paragraph are those which *condition* the vehicle the most, and each one of them can not be studied independently of the two others, whether it be a question of a new vehicle or the adaption of existing vehicles.

It seems more easy to us to study *a posteriori* the other research subjects proposed by the IRT. Certain ones have long been in the process of being studied by our society and have already been the object of partial realizations (e.g. lighting from the SM – code IRT 4.10 – Lighting).

3. Framework Of The Action Of The Study

To reach our objectives, we believe that the framework of the action of the study should come about according to the following process:

3 – UNFOLDING OF THE STUDY
- 3.1. CONDUCTING OF COLLISION EXPERIMENTS AT THE WALL AND AT THE TESTING GROUND.
- 3.2. CARRYING OUT OF SEVERAL PROJECTS KEEPING IN MIND:
  - 3.2.1. THE POSITION OF THE SEATING AREA WITH RESPECT TO THE MECHANICAL WORKS
  - 3.2.2. THE SHAPE OF THE SEATING AREA
  - 3.2.3. THE PLACING OF THE PASSENGER INSIDE THE SEATING AREA
- 3.3 CRITICAL ANALYSIS OF THE PROJECTS IN THESE POINTS OF VIEW:
  - AUTOMOBILE QUALITY
  - WEIGHT AND PRICE

Slide 2

3.1 Procedure of the Collision Experiments

3.1.1 At the wall, of some existing vehicles with very diversified structures, at impact speeds comprising between 48 and 75 km/h

This, to try to extract information about:
- The influence of the relative positions of the "mechanics" and of the seating area.
- The advantages or inconveniences of certain particular devices, upon which we will enlarge further on.
- The pounds/performance yield as concerns the absorption of energy by typical structures (platform, box structure, body).

3.1.2 At the testing stand

Tests of impact at the wall at speeds progressively higher than 48 km/h give only an aggregate qualitative result of the behavior "in fine" of the vehicle and of its structure, but they don't supply the technician with the elements necessary to know what would be the most judicious thing to do; and the examination of the films,
- if it shows the general behavior of the structure as seen from the exterior
- if it allows for the following of the displacements of direction
- if it offers the possibility of establishing some curves: space/time, speed/time, acceleration/time

of the different parts of the seating area, it is insufficient for grasping the mechanism of the absorption of energy.

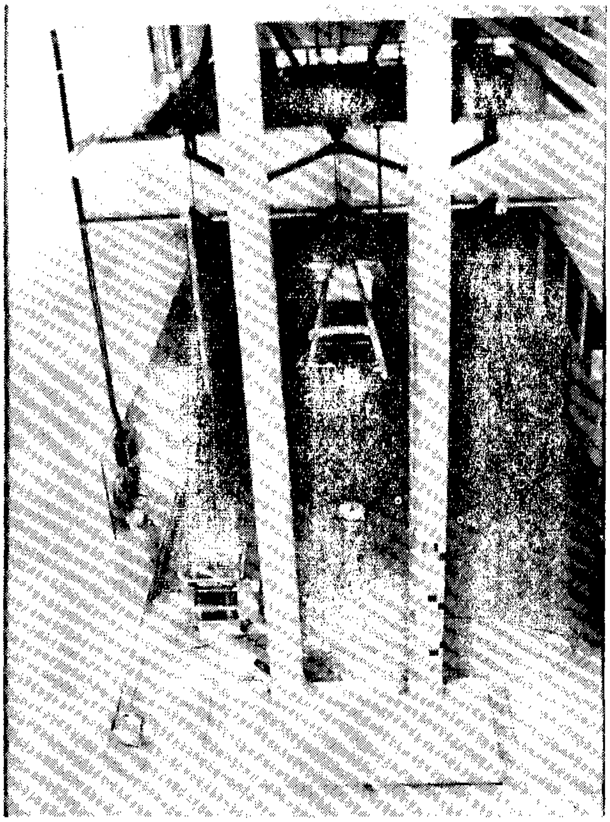
Of course, the examination of the deceleration curves draws attention on certain weaknesses if the curves don't have the purity that would be wanted for the exam, but again it is necessary to analyze the *why* in order to bring about the best adapted and most profitable remedies.

In an effort to understand, we have, since some time ago, begun to carry out, on a throwing tower installed in our technical center, a series of vertical drops at progressively higher speeds. This allows us to see in what order deformities occur (see Slide 3). This may be able to be done on entire vehicles, but also – and especially – on half-vehicles or even on partial systems.

This method, which necessitates a standardization with respect to the experiments at the wall and a certain habit on the part of the experimenter, is interesting because it allows the filming on top, underneath and along the sides (see Annex I and the slides).

3.2. The carrying out of several projects, while taking into special account the following remarks:

- The mechanical motor system and gear box is a non-compressible whole, representing an important part of the mass of the vehicle, and therefore of the kinetic energy. It seems therefore desirable to position it well in advance so that this energy can act



Slide 3

upon the structure during the least amount of time possible.

- The axles, the transmission and the suspension system are rigid elements which can favor the introduction of efforts in the structure, in zones not affecting the survival space, and eventually help this space in stemming or in transferring a part of these forces, or just the opposite, they can represent some dangerous protrusions.
- The steering wheel remains for the driver that which is the closest to his chest, and it is vital not only to limit the backwards movement of this but also the vertical trajectory, which presents a danger for the neck and head of the driver.

3.2.1. Position of the seating area in relation to the mechanics

The true problem seems to appear at this stage of the analysis and study, and our research as to the path to follow will continue without a doubt until the end of our work.

a) Is it necessary to be content with making timid developments yield to classic and familiar structure, example of which developments are reinforcements, adding of cross pieces, side pieces and arches?

b) Is it necessary to simply separate the seating area from some compact mechanical systems, in such a way as to arrange the free zones for the absorption of energy?

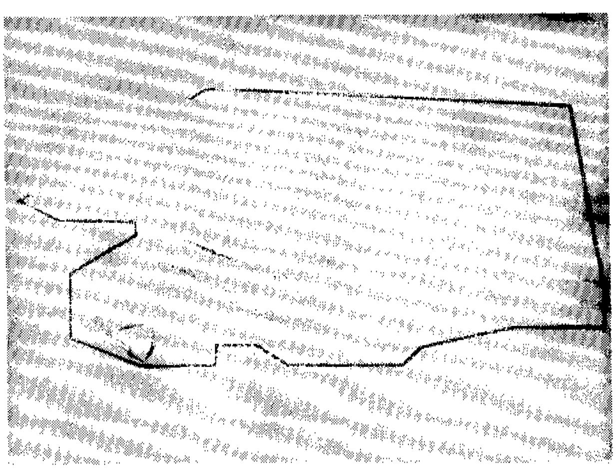
c) Or well, is it necessary to seek out other forms of cars and other devices for the occupants, while abandoning considerations linked to habits and to certain normalizations, which themselves have come out of statistical works performed on actual vehicles?

The first two paths seeming to *a priori* require us to weight down and lengthen a vehicle which we want small and light, we will endeavor to make our action more and more profound, and of a more free fashion while further exploring the third path.

Certain parts of the actual seating areas show a marked reticence for holding of a front-end impact (the front feet and all the higher portion of the vehicle in particular).

The position of the windshield, relatively close to the front occupants, can hamper these people in their displacement in the interior of the seating area, and sets itself up in opposition – out of lack of space – to the realization of new methods of restraint.

Slide 4 shows a picture of the front passengers retained by a three point belt and gives evidence of the importance of the position of the windshield.



Slide 4

3.2.2. Shape of the seating area

The general considerations previously reported, and in particular the "crankshaft" set up by the system of the wing, the wing sheathing, the wheel passage, and the front foot, that one finds in actual vehicles, have brought us to believe that a structure presenting a foot of windshield

- projected far forward
- in continuity with the shaft of the sedan

- bolstered by the forward post higher than the door entrance
- continuous in a geometrically simple surface being a part of a one-piece side panel

could give birth to a rigid and light seating area, our purpose being to make the whole of the structure participate in the absorption of energy. The reinforcements can only be justified when the normally used material has already brought its maximum contribution to the holding of a frontal impact.

3.2.3 Placement of the passengers in the interior of the seating area

We haven't yet spoken of the placing of the occupants in the interior of the structure which we have just sketched out and of which one of the main characteristics is to present a windshield and feet projected way out in front.

How can one position the driver and the passengers?

If we don't arrive, by a certain mental conception, at liberating ourselves from actual texts concerning the visibility through the windshield and the demands attached to its sweep, our first idea will be to position the occupants in classical style (2 and 2 abreast), making the driver the closest possible to the center, in order to assure him visibility in concordance with the SAE norms in force.

This first step, illustrated schematically (see Slide 5) stays very conformist. It offers, to our mind, the following apparent advantages:

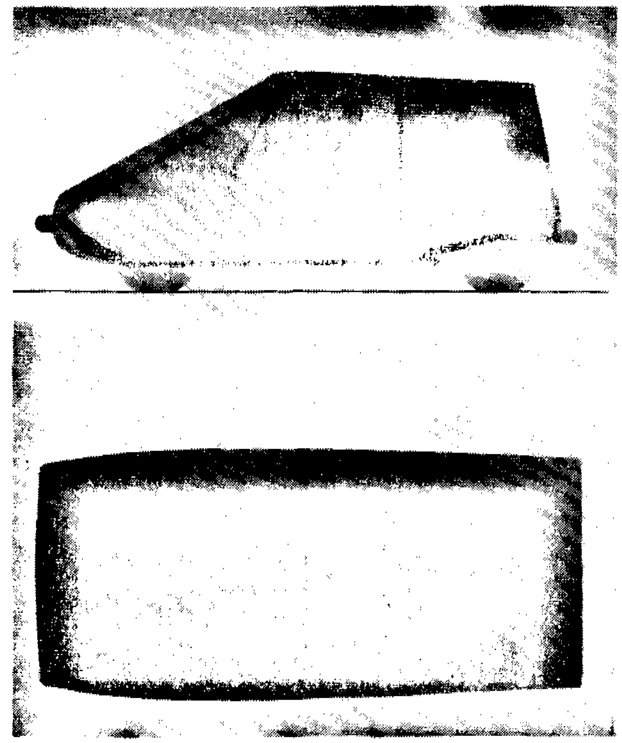
- doesn't upset the habits of the clientele
- larger space between the occupant and the sidewall

This notion is perhaps only suggestive, and it remains to be shown that the separation of the passenger in relation to the wall (independently of the penetration of an offending vehicle, which should be kept in mind) is the sole solution for resolving the whole of the problem for the secondary impact – dummy onto the seating area – is an important factor to be considered. The instant of deceleration in the dummy doesn't take place at the moment of impact, but when the dummy collides with the wall.

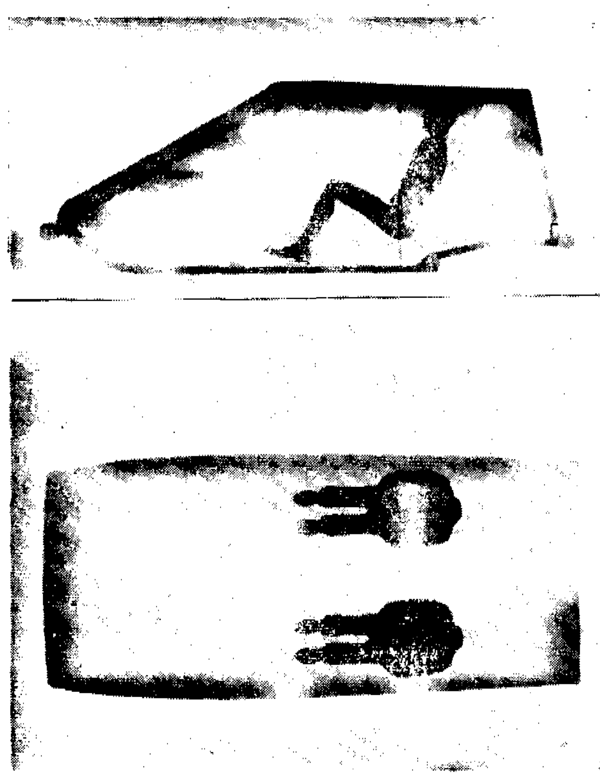
This also allows one to picture that the front seats having been separated from the wall, access to the back seats would be able to be accomplished without having recourse to tilting forward the front seats in a vehicle having only 2 side doors, one on the right and one on the left.

It is well known that having only one door on a side panel gives to this panel a rigidity superior to the two-door solution.

This always with the perspective of arriving at a safe structure and a structure with a reasonable cost.



Slide 5



Slide 6

If we will now free ourselves from "customs" and regulations, this same shape of the seating area allows us to imagine an unusual placement by which the driver would be over the center of the vehicle; two side passengers would be placed on one side and the other of the driver, a bit toward the rear of the latter, and a fourth passenger could place himself behind the driver in center of the vehicle, further back than the side passengers, thus forming that which we will call "the rhombus placement" (Slide 6).

We see therein the following advantages:

- the driver being in the center of the vehicle, the visibility becomes symmetrical rather than the practice now. For a vehicle with a size of between 1 meter 52 and 1 meter 62, the stipulated angles are respectively 17° to the left and 51° to the right.
- *the driver* is not hampered in lateral vision (crossroads) actually masked by the passenger.
- he is free in his movements, the side passengers having their breasts well behind his elbows.
- he can get out of the vehicle indifferently to the left or to the right without disturbing his passengers.
- the aggressiveness of the vehicle can be reduced to a minimum.
- *the side passengers* find themselves in a position allowing them to completely stretch out their legs (good support of footrests facilitating the supporting action).
- they are very far, at the same time, from the dashboard, from the windshield and its posts, and because of this fact, they have at their disposal some very important space for displacing themselves and deadening the front-end impact.
- they are bothered neither by the driver nor by arm movements nor by each other.
- In case of an impact from the side, they can move into the space toward the center of the vehicle.
- they have excellent visibility to the front and to the side.
- as far as the fourth occupant is concerned, one may consider, statistically speaking, that the total loading of a vehicle occurs less than ten percent of the time. It should be remarked that the highly reinforced structure to the level of the first foot allows us equally to believe that its behavior in a roll could be judged excellent.

A similar structure and rhombus-shaped placement of the passengers has not been manifestly envisioned by lawmakers; also, it appears necessary to us to await the results of diverse actions undertaken in the field of safety in order to promulgate new norms, and to be assured that governments will then modify regulations in force (field of vision of the driver in particular).

3.3. Critical analysis of projects, in these points of view

- *Automobile quality* – Primary safety remains for us a constant care and we cannot envision keeping solutions which would sacrifice the qualities of road holding, of comfort – whence the fatigue of the user – or of the behavior of the vehicle in braking (distribution of weight). So, the very heavy bumpers foreseen by the Federal Norm are of such a nature, while modifying the geometric center, as to influence the road holding of the vehicles.
- *Weight and Price* – The purpose of our action is to allow for the survival of the small car, economical to buy and to use.

4. Accomplishments and Experiments on Prototypes

4 – ACCOMPLISHMENTS AND EXPERIMENTS ON PROTOTYPES

4.1 FIRST STAGE
ADAPTATION ON EXISTING VEHICLES OF DEFINED AND TESTED ELEMENTS ACCORDING TO 3.

4.2 SECOND STAGE
PRODUCTION AND EXPERIMENTS WITH SEVERAL EXAMPLES OF THE DEFINITIVE PROTOTYPE.

Slide 7

4.1. First Step

After analysis of the diverse projects and orientations, among which can be found those which have just been reported, as regards:

- automobile quality
- weight and price

and some information garnered from the experiments at the wall and at the testing grounds, we will equip several existing vehicles with sub-systems seeming to us to be the best adapted, for the purpose of experiments against the wall and narrow obstacles, keeping a record of the precise weights.

In the course of these experiments there will be studied

- the behavior
- the trajectory

of dummies restrained in the seating area by safety belts, as well as the decelerations that they undergo.

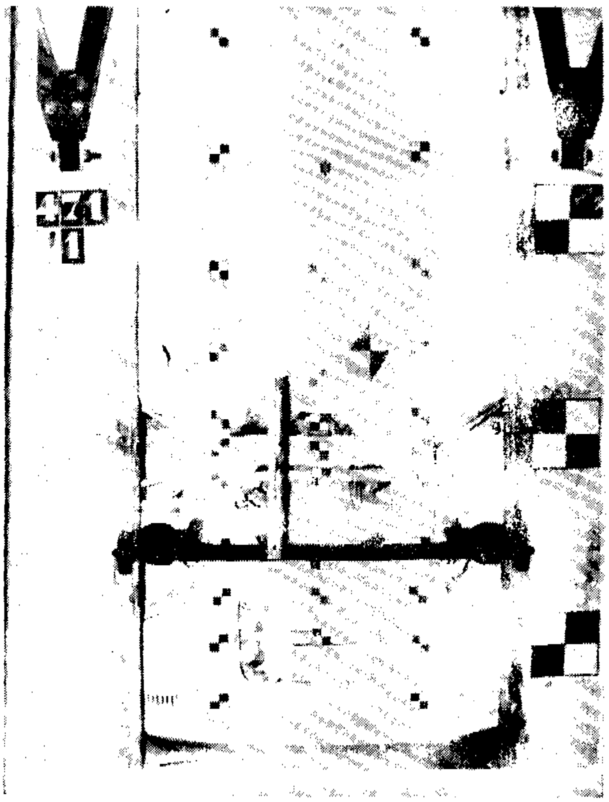
4.2. Second Step

This consists in the production of prototypes according to the information gathered in the preceding step, for the purpose of confirmation experiments.

Addition I

Slides illustrating collision experiments at the testing stand

Slide 8 – A vehicle GS before the test with the marks allowing one to note by particular points the displacements one wants to follow.



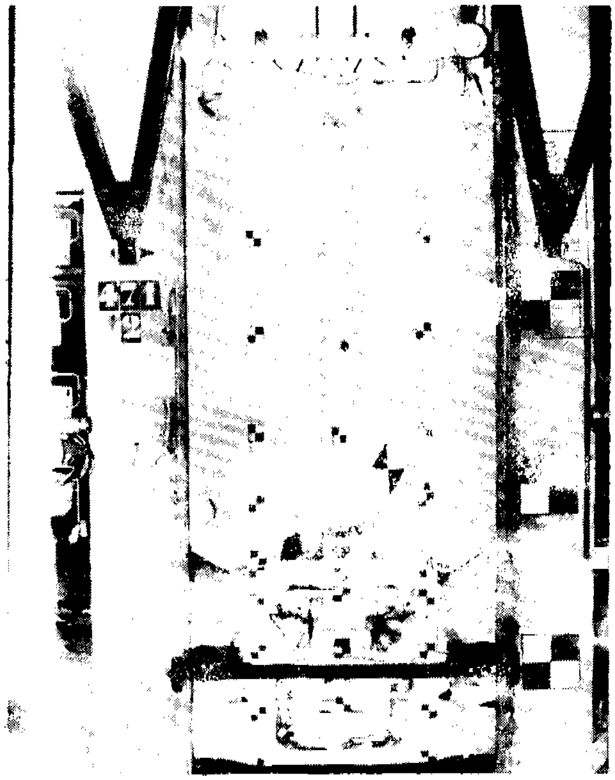
Slide 8

Slide 9 – The same vehicle after two successive falls at 23 and 40 km/h. One notes the relative displacement of the elements of the structure, and the analysis can be continued fall after fall.

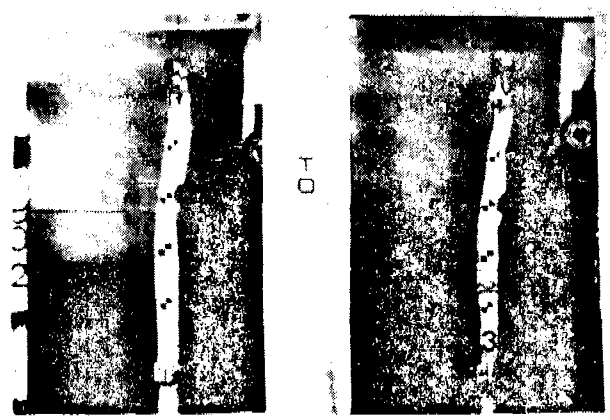
Slide 10 – A study concerning the platform of a 2.3 CV type vehicle. a) 0 time.

- The views on the left show an actual system, those on the right the same system with those particular structural elements designed to progressively absorb energy
- The two tests have been conducted under the same conditions, to wit: 500 kg burden, impact speed of about 20 km/h.

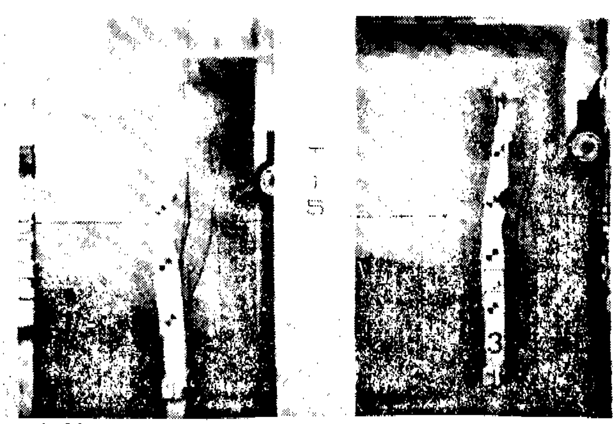
Slide 11 – b) 15 milliseconds time. One ascertains that the deformities of the system are starting on the manufactured system and that the second platform hasn't undergone any deformities.



Slide 9



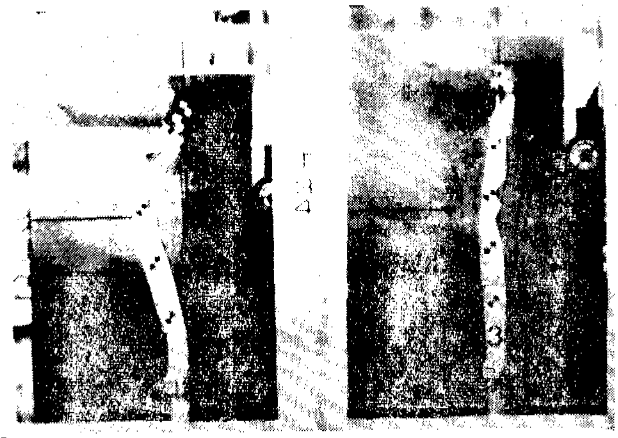
Slide 10



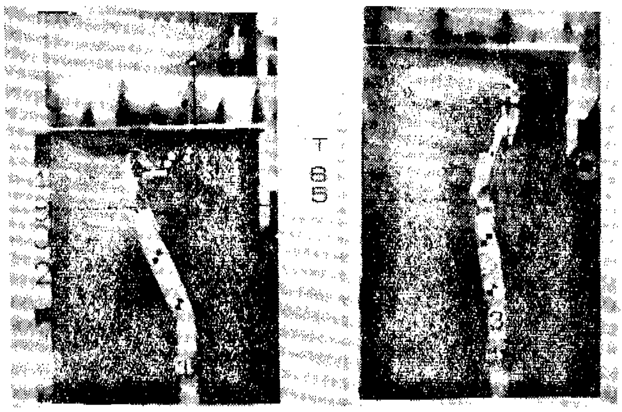
Slide 11

Slide 12 – c) 34 milliseconds time

- A double bending in the manufacturer's system
- Still nothing in the second



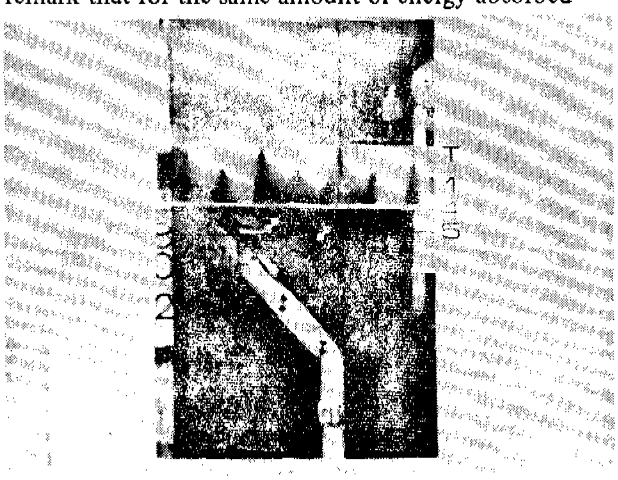
Slide 12



Slide 13

Slide 13 – d) 85 milliseconds time. The deformities grow greater in the system on the left. In the system on the right the deformities have ceased. The experiment is finished.

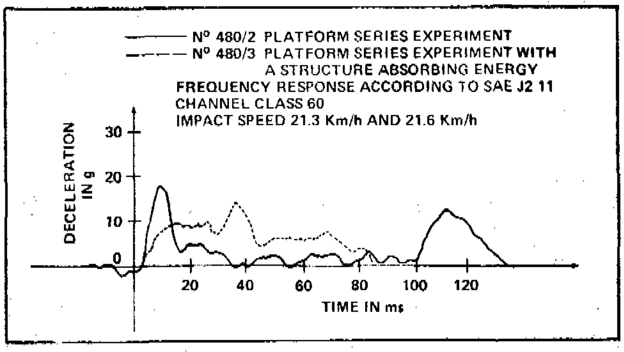
Slide 14 – e) 145 milliseconds. It is the picture of the original platform at the end of the experiment. One can remark that for the same amount of energy absorbed



Slide 14

- The experiments space out respectively at 85 and 145 milliseconds
- The destructions are very clearly different and the penetration remarkably improved in the second case.

Slide 15 – Decelerations as regards time in the two cases.



Slide 15

WORK PROGRAM OF THE RENAULT/ PEUGEOT PARTNERSHIP IN CONNECTION WITH IMPROVING VEHICLE BEHAVIOR IN FRONTAL COLLISIONS

Mr. Ventre

Introduction

Work carried out by the Renault-Peugeot partnership comes within the scope of the French Programmed Thematic Actions which deals with 11 points, and we intend illustrating the work method by an example, the first point of the French program – frontal collisions.

For a car manufacturer, solving frontal collision problems means defining, for a given objective, the most effective "protection yield," i.e., the best performance at the lowest price, at the same time having a non-aggressive car.

Our thoughts were directed in the following manner:

- Improving vehicle behavior during a frontal collision at high speed comes down basically to giving one's attention to saving the occupants. The final state of the vehicle will be conditioned only by what is necessary for protecting occupants.
- Saving the occupants, in the light of present day knowledge means complying with the injury criteria currently accepted, or at least imposed by the present American regulations and work statement of the ESV.

This objective being defined, it was important to know the mechanical, physical and reasonable chances we had of succeeding. To do this, if we assume the occupant to be a single mass, we can define a "performance index" for the combined vehicle-restraining device allowing the smallest possible average deceleration limit to be defined to which we should tend if this could be done so that:

$$\text{Average deceleration} \approx \frac{\text{square of the impact speed}}{2\,(\text{vehicle deformation} + \text{occupant travel inside vehicle})}$$

So, for example, if we take a vehicle which, in an 80 km/hr. collision with a fixed barrier is deformed by 50 cm., and if we assume that the occupant inside the vehicle can travel 30 cm., we can obtain, theoretically, an average deceleration of 30 g. This average deceleration has no physiological meaning but defines the ideal limit which we could not go beyond. This implies that we know how to completely use the deformation energy of the restraining devices in the vehicle as well as that engendered by such restraining means when travelling in relation to the ground; in other words, we have coupled occupant and vehicle. This thought shows that the restraining device must:

- Have little occupant play
- Be quite stiff, which is expressed by the rising distance of stress and the top limit of this stress so as to attain as quickly as possible, at beginning of collision, the top limit of restraining device.

We have considered a trapezoidal diagram for the restraining device, which means we have a limited-stress device that we can now bring into effect either by absorbers on the safety belt or by the air-bag.

From the moment we have a limited-stress restraining device and, consequently, limited decleration of the occupant it's restraining, the compartment deceleration is not entirely a requirement, which is a fundamental point for a manufacturer desirous of making small, but safe cars.

If we had to specify, in a statement of work, a maximum deceleration for a vehicle in a frontal collision, it should so be, not only as a function of impact speed, but mainly of its mass.

Our line of course has been, for a long time, to maintain the "survival space," i.e., to leave the maximum of available space for the highest possible impact speed so that the restraining device may function.

On a concrete basis, this is represented by:

- Maintaining passenger compartment non-deformed for the highest possible speed and, consequently, to do this, raise the deceleration levels so as to reduce deformation.
- Using limited-stress restraining devices so as not to go beyond accepted injury criteria.
- Improving the occupant-vehicle coupling by reducing play between occupant and restraining device, increasing stiffness of restraining device and by preloading occupant as soon as collision starts.

Analytical Phase

Once this philosophy at the outset was stated, we undertook the analytical study of structural behavior to impacts.

We wanted to find out the characteristics of energy dissipation in a mixed, complex structure made from thin sheet subjected to different types of impacts.

This analytical work can, in fact, become fundamental research work such as, for example, the study of the influence of deformation speed on the mechanical characteristics of a material or structure made from this material (Fig. 1 and 2).

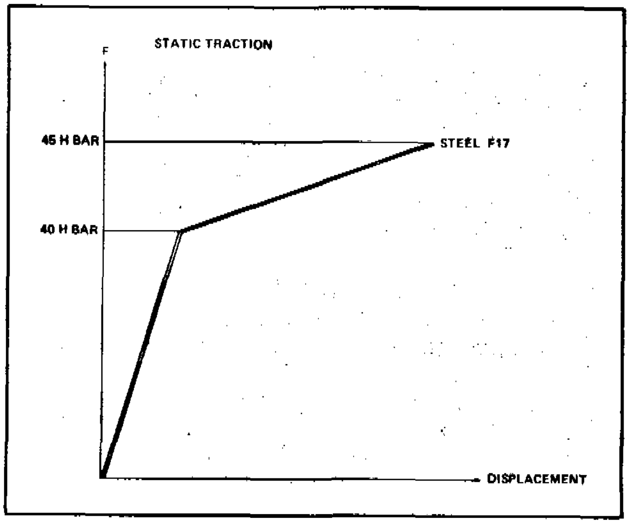


Figure 1

Indeed, this point is not to be neglected, for recent work has shown that the elastic limit of a given material can be almost doubled when passing from a deformation speed of a few millimeters per minute to several tens of meters per second.

In the case of the front unit of a car, the analytical problem is made difficult by the complexity of the structure and by the presence of incompressible parts such as the engine, gear box, etc.

The analytical method used consists, from information supplied by measurements made during impact tests, of a study as detailed as possible of energy dissipation during deformation, so allowing a precise knowledge to be obtained on the dynamic stiffness of the vehicle and of its capacity to dissipate the maximum energy per deformed unit of length.

Knowing the aspect of the "dissipated energy" diagram as a function of deformation, allows the zones where stresses in the structural members have gone

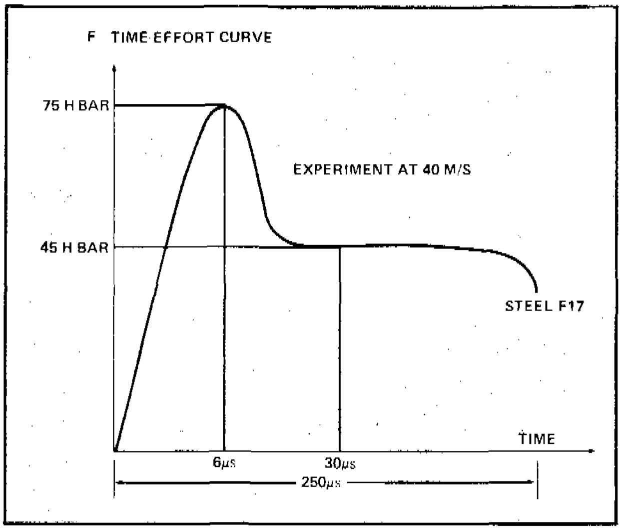


Figure 2

beyond local buckling limits and where deformation has taken place thus reducing its energy absorption capacity, to be shown. Cross checking of the calculations is now carried out, firstly on their own, then in comparison with high-speed films taken during impact, and finally using a dynamometrical buffer.

In the graph (Fig. 3), we can see that the R.12 Series

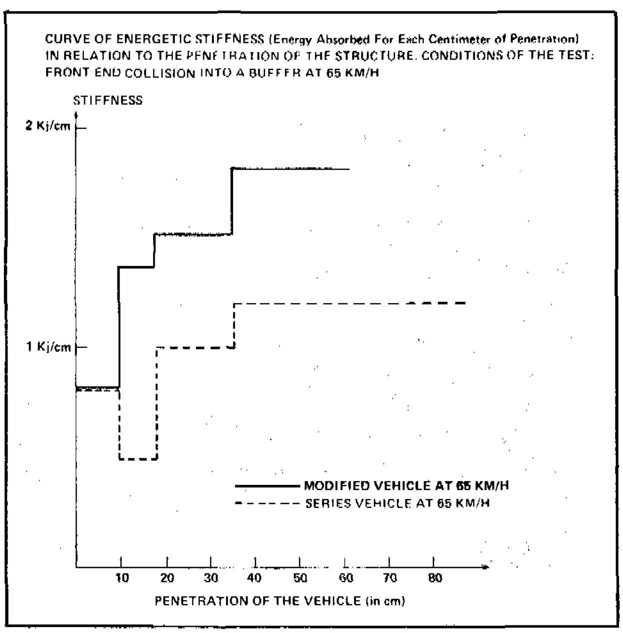


Figure 3

showed a weaker zone at approximately 10 cm. of deformation, which disappeared in the reinforced vehicle.

The dynamometrical buffer (Fig. 4) comprises 12 Kistler piezo-electric cells arranged on three blocks of wood 500 x 500 x 200 mm. thick, designed on one hand to protect the cells and on the other hand to filter the high frequencies of the impact. Connecting of the different cells is carried out as required depending on whether you want an overall value or a distributed value from top to bottom or from right to left.

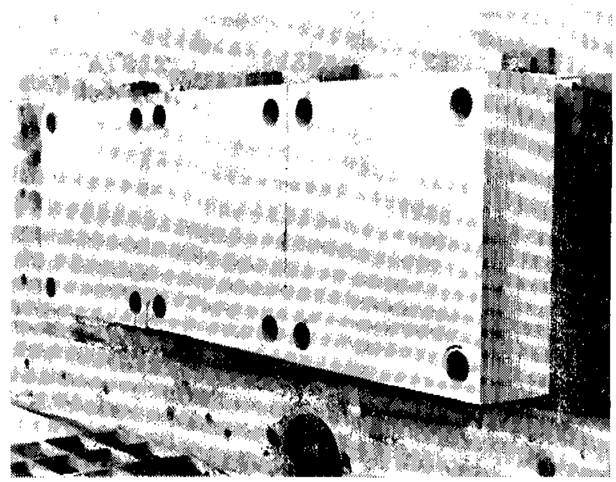


Figure 4

In Figure 5 can be seen the types of curves obtained with this measuring device.

In spite of practical difficulties, this curve allows the decelerated, effective, equivalent mass to be obtained at every moment of deformation. A calculating program

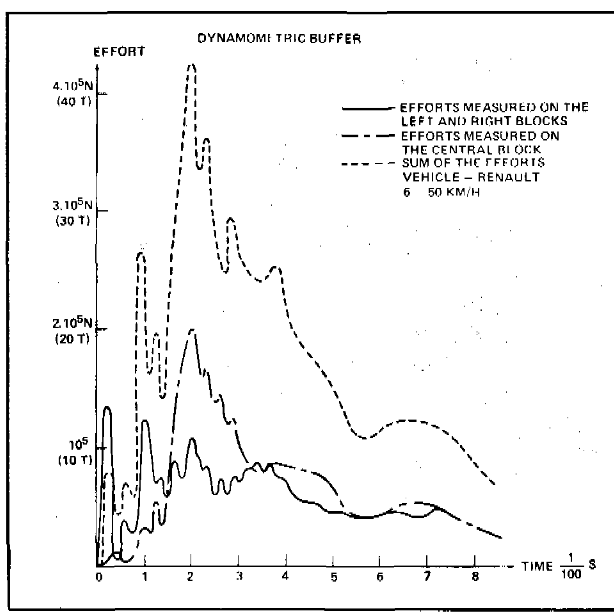


Figure 5

has been developped allowing the influence of the occupants on the energy dissipation in the structure as a function of their restraining devices to be defined. In actual fact, though it is easy to find the equivalence in terms of energy between an empty vehicle and a vehicle in which the occupant mass is an integral part of the vehicle mass, the problem is more complicated when some of the occupant energy is dissipated in the restraining devices.

Indeed, although the total energy dissipated is the same, the result is totally different, from the vehicle deformation point of view, depending on whether the structure stress and that of the additional masses are superimposed, or if the structure decelerates on its members and then the additional masses decelerate on their restraining devices by passing the stresses through the structure out of phase in comparison with those of the vehicle and modified by the restraining devices (Figs. 6, 6a, 6b).

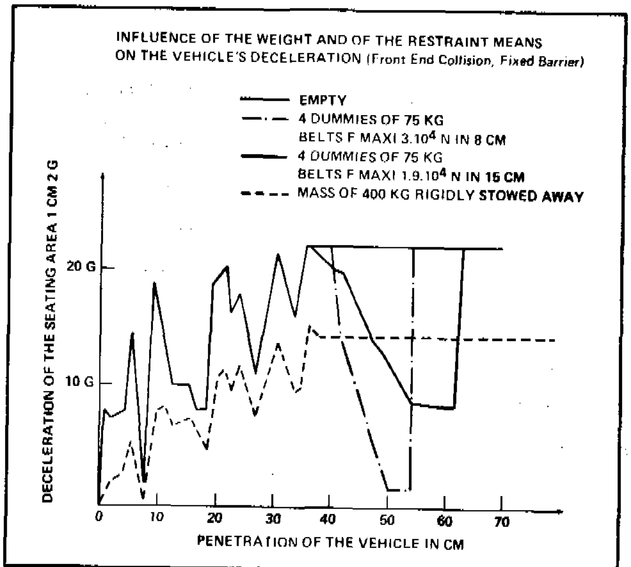


Figure 6

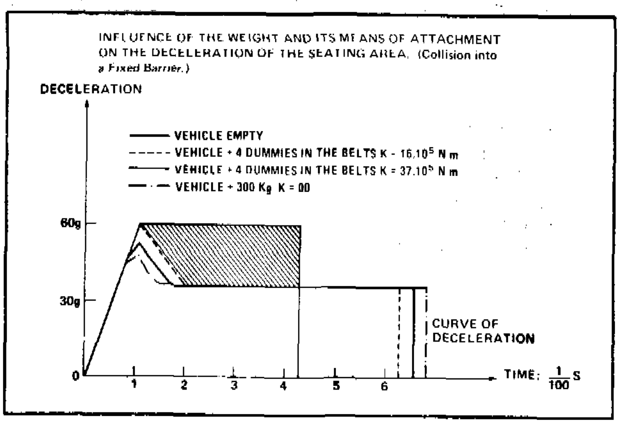


Figure 6a

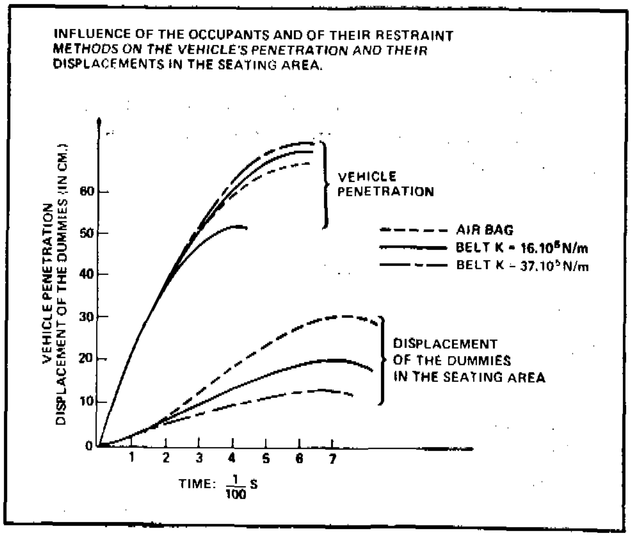


Figure 6b

This difference is shown in the table Figs. 7, 7a, 7b in which, so as to really materialize the influence of the restraining devices, we have, on one hand, characterized these devices by their strength, which is a little simplified, for one must take account of its energy absorbing

INFLUENCE OF THE ATTACHMENT OF THE WEIGHTS ON THE QUANTITY OF ENERGY DISSIPATED BY THE STRUCTURE

IMPACT SPEED	WEIGHT OF VEHICLE	RESTRAINT MEANS USED	SPEED WHEN EMPTY NECESSARY TO MAKE THE STRUCTURE ABSORB THE SAME QUANTITY OF ENERGY
48 km/h	EMPTY		48 km/h
48 km/h	4 DUMMIES AT 75 kg	BELTS OF A STIFFNESS $16\ 10^5$ N/m*	53 km/h
48 km/h	4 DUMMIES AT 75 kg	BELTS OF A STIFFNESS $37\ 10^5$ N/m*	56 km/h
48 km/h	MASS OF 300 kg	STIFFLY ATTACHED INFINITE STIFFNESS	61 km/h

*RAISED IN EFFORT BEGINNING WITH 5 cm DISPLACEMENT OF THE DUMMIES

Figure 7

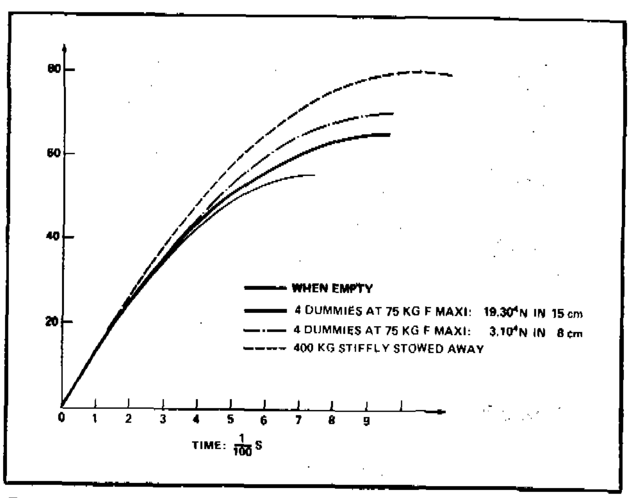


Figure 7a

capacity and, on the other hand, we have pointed out its influence by expressing it in terms of the impact speed of an empty vehicle so as to obtain an equal deformation. These calculations and measurements were carried out on a Renault 16.

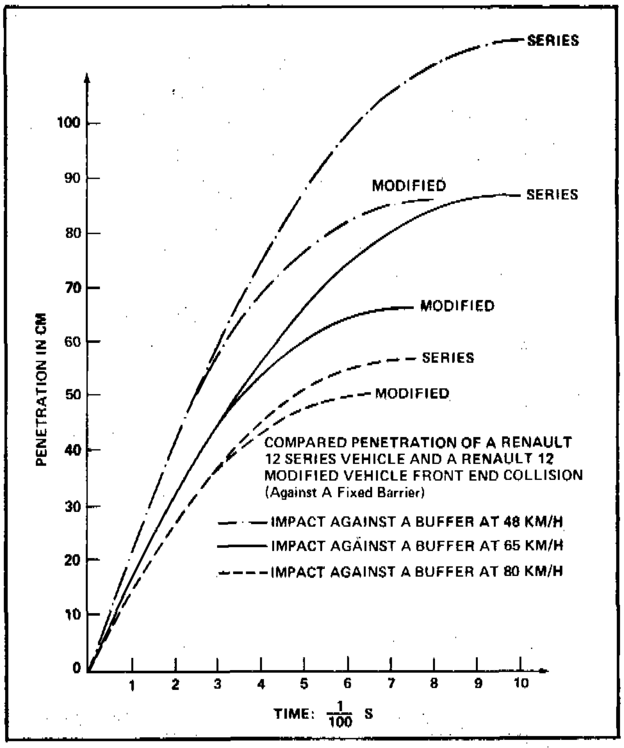


Figure 7b

It is to be noted in passing that it is an arbitrary act to impose a vehicle deceleration law for a frontal impact with a fixed barrier without taking account of the vehicle mass, the occupant mass and the characteristics of their restraining devices.

Experimental Phase

All these thoughts needed, and still do need, experimental support; neither ourselves, nor any other serious manufacturer has made a complete safety vehicle each time we have wanted to check such and such a point or reasoning.

The first theoretical tests were carried out on standard production vehicles on which the reinforcing principles were modelled by steel sections or thick steel plates. We quickly realized that this system, though having the advantage of simplicity and quickness, presented the following disadvantages:

1. Fastening is not carried out industrially and information gathered, consequently, is not complete.
2. Does not take account of methodical requirements.
3. Does not take account of architectural requirements (indispensable part openings, for example).

We have now passed to a more advanced stage consisting of modifying a standard production vehicle but incorporating structural variants taking all imperatives into account. This method has the disadvantage of necessitating more drawings and hours of fabrication but eliminates all the other faults stated, and the test results can be directly used, step by step, at any stage of the research. Furthermore, the vehicle remains standard.

This being the normal work of the design office, we will not go into further detail.

At the same time as the analytical tests on strength of structures as complex as the front part of a vehicle, we undertook work, as have done most of the other car manufacturers, to compare the advantages of the different types of architecture and positioning of mechanical parts. To do this, we proceed in the same way as above, i.e., working on existing vehicles but which do not all belong to the company's range, thus allowing the field of investigation to be widened. We are sure that in this field, an exchange of results between manufacturers would result in a saving of time and money.

It is in this spirit that we started modifying an R.12 according to the first method and soon passed to the second solution (Fig. 8 and 9).

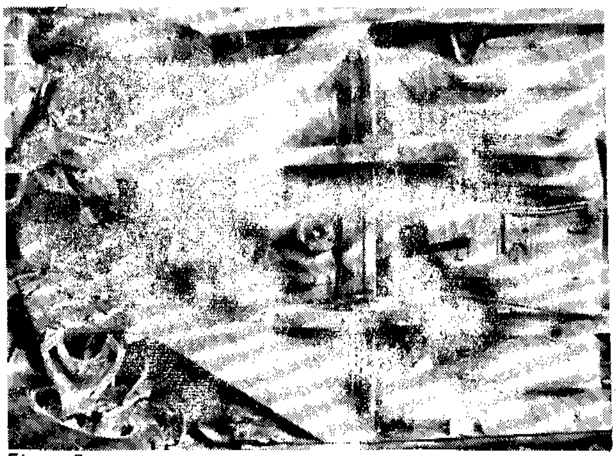


Figure 8

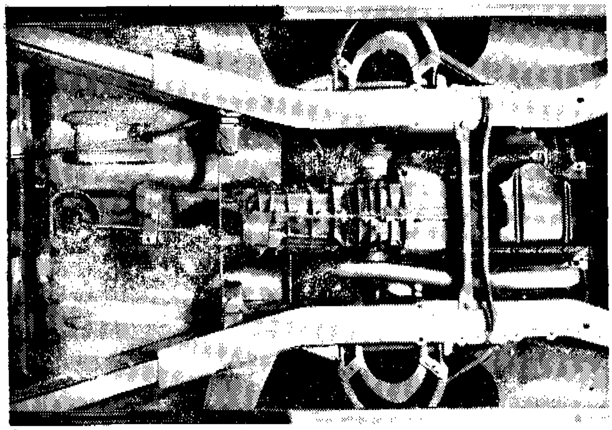


Figure 9

We are now going to show you the film of a test impact at 80 km/hr. of an R.12 thus modified on a fixed barrier.

(Film)

This film shows the enormous difference in difficulty in passing from 65 to 80 km/hr.

You are going to see a test at 85 km/hr. on a vehicle that looks like a Renault 12 but which has a modified structure and, so as to show up the influence of the extra energy to be dissipated between these two speeds, you will see the corresponding sequences, at 70 km/hr. of the same type of vehicle with roughly the same reinforcement although slightly lighter. For this investigation, the Renault 12 vehicle serves as a support for the tests because it is a standard production vehicle and is easy to obtain in large numbers, but the modifications carried out for testing purposes are, for the moment, far from industrial.

SIMPLIFIED COMPARISON
REINFORCED RENAULT 12, 70 KM/H
REINFORCED RENAULT 12, 85 KM/H
FRONT END COLLISION, FIXED BARRIER

TYPE	V	PENETRATION	AVERAGE G	WEIGHT OF STRIPPED BODY
REINFORCED RENAULT 12	70 KM/H	65 CM	23 G	275 KG
REINFORCED RENAULT 12	85 KM/H	95 CM	29.5 G	275 KG

Figure 10

The first view is a left-hand side view at 85 km/hr; the second view is a left-hand side view at 70 km/hr.; the third view is a top view of front unit at 85 km/hr. and the last view is a top view of front unit at 70 km/hr.

It is plain that the nature of the problem is different. Furthermore, we have no example at the present time of a real accident giving, on this type of vehicle, even non-reinforced, deformation levels of this importance.

As you have no doubt noticed, the test vehicle is not fitted with special bumpers for the "pole" collision, for these apparatuses are designed and calculated separately as they are part of the equipment, the weight and price of which are high, and for which the advantage of cost-efficiency remains to be proved.

Indeed, this requirement of the "pole" impact worries us, for at the present moment, we have no exact statistics clearly showing that in a frontal collision, this type of obstacle is a frequent cause of serious injury for occupants. Nonetheless, we set to work on tests and calculations which showed us that, depending on the architecture of the vehicle, engine length-wise or cross-wise for example, the result is quite different. The weight of the metal and, consequently, the price for this one case of impact, is in the same range as what has to be spent for the other cases of frontal collision.

Comparisons With Real Accidents

Detailed analysis of real accidents and vehicle/vehicle test impacts allows a comparison between accidents, standardized impacts and legal requirements to be made.

For example, in the barrier/frontal impact, a front wheel drive architecture with the engine behind the front axle is unfavorable, for the engine backward movements into the vehicle are quite considerable, although we have never found a real accident producing this phenomena. In a head-on frontal collision, the different vehicle heights, different front architectures and the relative strengths of the vehicles, are the reason for the engine not stopping as abruptly in a real accident as against an extremely rigid wall. On the other hand, an offset, frontal collision in a real accident, which is the most frequent, and is closely related to the 30° impact on a fixed barrier, creates problems that are completely different from those of the head-on collision with the wall:

1. Increased stresses in structure, which is deformed on one side only.
2. Wheel penetration not visible in frontal collision.
3. Compared with frontal impact at same speed, the severity of the impact is reduced for the occupant if the survival space is maintained, because:

   a. The speed variation of the passenger compartment is less, due to the existance of a residual speed instead of a rebound speed.
   In the case of impact at 13.3 m/sec., the speed variation for the occupant passes from 14.5 m/sec. in the frontal impact (initial V + rebound V) to 12.5 m/sec. in the impact at 30° (initial V – residual V). The energy to be dissipated in this restraining device is, in this case, reduced by 30%.

b. The greater deformation plus the longer impact time allow an extra gain to be had because of a better coupling.

This explains why, in accidents in which the vehicles appear to be badly deformed, the occupants who are not attached come out of it alive. But this assumes once again that the survival space has been maintained.

In the same spirit, it is possible to show up what may be called "the speed paradox." Let's take the case of a vehicle weighing one ton crashing into a rigid corner with little interference at high speed, 144 km/hr. for example. If we assume that the energy dissipated in cutting the vehicle is three times that dissipated in a frontal collision with a wall at 50 km/hr., we can calculate the residual speed of the vehicle after this terrible collision: 114 km/hr. The passengers on the side opposite the impact have undergone a speed variation equivalent to that in a collision with the wall at 30 km/hr., whereas the front, right-hand passenger risks touching a fixed obstacle at 140 km/hr.

Figure 11 shows a vehicle badly deformed in an offset, frontal collision, out of which the driver, who was not wearing safety belts, came unscratched.

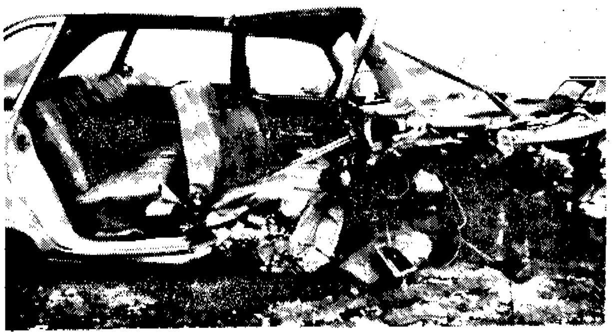


Figure 11

On the other hand, a thorough study of vehicles damaged in road accidents has shown us a certain number of very important points which are not visible in the standardized, frontal collision with a fixed barrier.

1. As many frontal collisions are offset, the impact points, more often than not, are near the front pillar. Our idea is now that the front pillar, side member and toe-board cross member assembly should be particularly strong and carefully made.

2. The compressive strength of body side and, consequently, of doors, is as important as its resistance to side impacts.

3. The interior sheet metal assemblies must be carefully designed and realized because many injuries are caused by more or less irregular sheet edges appearing when considerable deformation takes place.

Conclusions

The frontal collision with a fixed barrier at high speed does not seem to us the most representative of reality and rather than make tests more severe by increasing impact speed, it would seem to us wiser to try and find a more comparable and uniform test as, for example, the impact test at 30°, which would allow us to see more things in one, single test and, consequently, limit the different types and number.

The manufacturer must be left to choose the solutions and, so to do, must have to comply only with performance criteria to the occupants to ensure their protection and to give his attention only to stresses exerted by the vehicle so as to ensure uniformity of all vehicles made.

Careful work carried out on sub-assemblies should result in usable results, either for step by step use or for general research work on safety vehicles. This method allows requirements (for example in statement of work) to be fulfilled and details listed during real accidents to be improved. The safety vehicle should not be a dream car.

PEUGEOT/RENAULT ASSOCIATION PROGRAM ON LATERAL IMPACTS

M. Jean Hamon, *Peugeot*

General Statement – Importance of Aggressiveness

What we call aggressiveness is the action of a vehicle on other vehicles or on pedestrians, as opposed to protection which means the action of a structure on the occupants of the vehicle. It must be precised that aggressiveness has always undesirable effects in opposition to protection. Most of the tests performed till now to improve safety have actually been oriented only to protection, with no consideration for the risk of creating serious damages by increasing aggressiveness without any control.

At the first International Conference on ESV, this year in January, we already knew that aggressiveness plays its part in nearly the whole of the accidents (except those involving a vehicle traveling alone).

Aggressiveness has effects on:

- Non-protected persons (pedestrians, cyclists, motorcyclists).
- Vehicle occupants in multiple crashes.

In a *front crash* between two vehicles, any increase of the mass and structure stiffness of one of the vehicles supposes that the other vehicle will be absorbing a greater part of the kinetic energy of the impact, increasing sometimes considerably the crushing in of its front parts. In a front crash, a vehicle will be more *aggressive* as *the stiffness of its front parts and as its mass are increased* and more *vulnerable* as its stiffness and mass are decreased.

In a *rear impact*, the problem is similar but the consequences are increased owing to the fact that statistically the rear structures are less strong than those of the front end and that the petrol tank is frequently located in that part of the vehicle.

In *lateral impacts* aggressiveness is the most important factor owing to:

- The reduced thickness of lateral structures non-permitting the dispersion of a great part of the energy of the impact.
- The softness of the vehicle side which cannot resist to the intrusion of a more stiffened part.

Exploratory Stage Of The Program Description Of Lateral Impacts

We have conducted a great number of impact tests involving passenger cars within a range of velocity from 25 to 65 km/h. These tests have been performed either with an angle of direction of 45° or perpendicular to the impacted car, using vehicles with mass ranging from 1,000 kg to 2,000 kg.

We are going to see a film which is a retrospect of the most interesting impacts. All these tests show the same crushing in process.

- At first, the upper structure of the impacting vehicle penetrates in the door frame *with no displacement of the impacted vehicle*; the impacting vehicle not having any stiffened structure under its front bumper, the only forces involved are related to the door resistance in flexion these forces being unable to counterbalance the tire grip of the impacted vehicle.

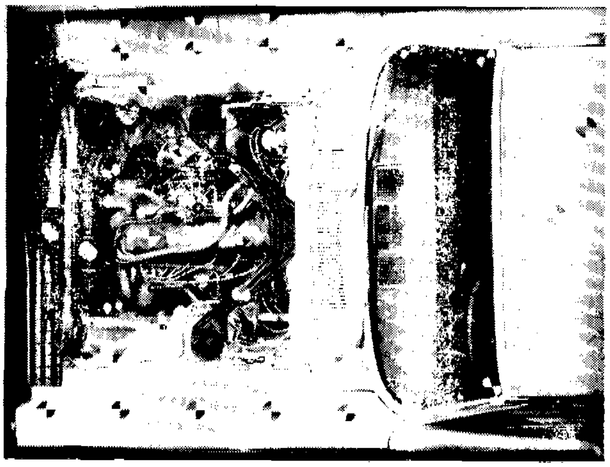


Figure 1

- At second, after the wheels have got in touch with the lower side member, the forces are quickly increasing and the impacted car starts moving. *The intrusion is by this time ranging from 30 to 40 cm*, in

Figure 2

a 50 km/h perpendicular impact, and the deformation is almost completed when the impacted vehicle starts moving. Moreover these preliminary tests have shown evidently the importance of the seats; we have observed that with no seat the intrusion of the door panel increases from 7 cm to 15 cm, in a 45° impact test at a velocity of 24 km/h.

Then, systematically a very low distortion of the impacting vehicle front end is observed, this involving that the greater part of the energy of distortion is abosrbed by the impacted vehicle side, which is the less resistant part of the car.

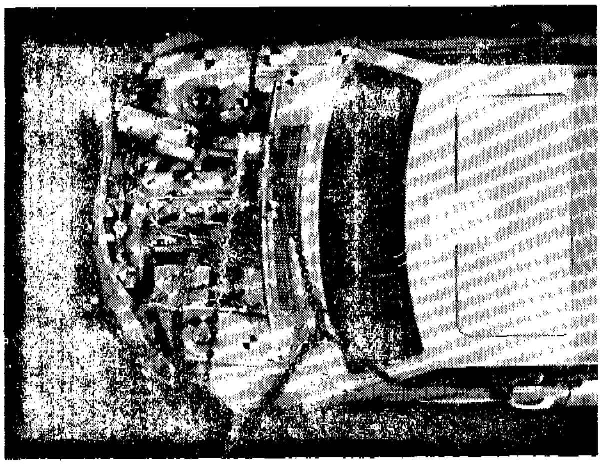


Figure 3

The figures 1 to 4 make a comparison between the distortions supported by the vehicle side and the impacting vehicle front end in a crash between two big vehicles (Fig. 1 and 2) and between two medium sized vehicles (Fig. 3 and 4).

Figure 4

Definition Of The ESSS For Lateral Impacts – Principles Of Reduction Of Aggressiveness

Theoretical Survey Of Aggressiveness

To describe and interpretate the distortions in lateral impacts, we have developed a calculation model (Fig. 5)

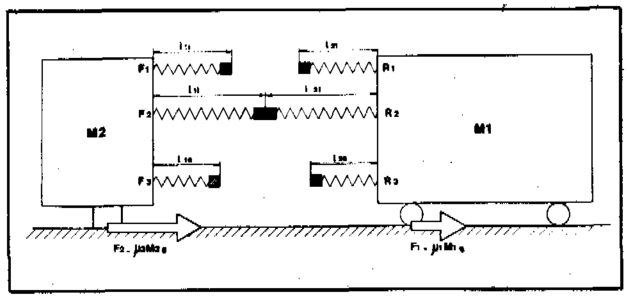


Figure 5

which will be explained with more details at the next Fisita Congress in June 1972. That model (Fig. 6) conforms to the level of experimental results, we therefore applied it to the study of the parameters on aggressiveness.

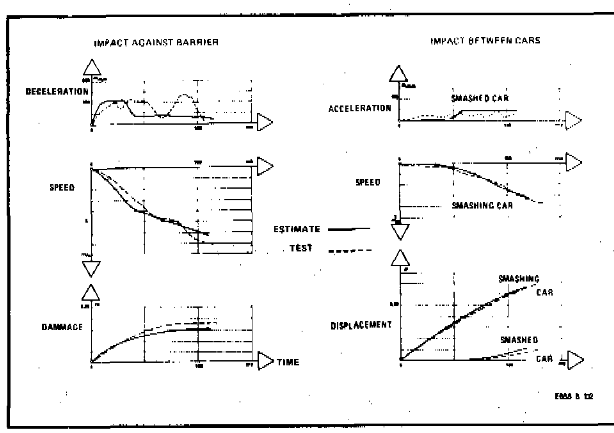


Figure 6

Survey Of parameters

The basic configuration of the calculation is corresponding to an actual 24 km/h lateral impact performed with two "404" model vehicles. The values of stiffness, introduced in the calculation, are directly deducted from experimental static constraint rules with a dynamical factor correction.

Using that model we considered the importance of the vehicle side and front end stiffness, the incidence of the geometrical configuration of the structure, and the consequences due to a variation of the mass of each one of the two vehicles.

Importance Of The Stiffness Factor

Indeed, strengthening of the vehicle side has a considerable influence (Fig. 7), however that possibility is limited owing that it is impossible to carry on boundless strengthening of doors.

On the other hand, an only 10 cm crushing in of the front end structure of the impacting vehicle leads nearly to the same results than doubling the door strength (Fig. 7). It involves that aggressive cars with a high front end structure having a great resistance in the first 10 cm crushing in, could cancel out the results obtained in strengthening the vehicle side.

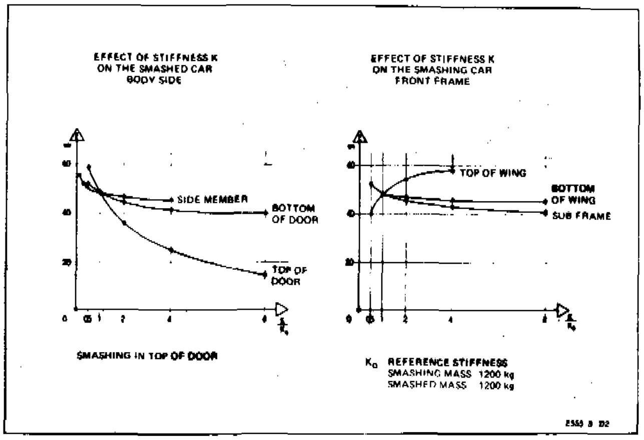


Figure 7

This is applicable to every part of the front end structure facing the impacted door frame and especially the bumper which, owing to aggressiveness, must not be too much stiffened.

Aggressiveness Due To The Geometrical Configuration Of The Impacting Structure

Referring to calculation, we can conclude that the relative positioning of stiffened elements in the vehicle front end is most important in relation with their aggressiveness. Particularly, a protruding stiffened upper structure with a recessed lower part is unfavourable. That protruding part is frequently corresponding to the distance between the bumper contact edge and the wheel, which is not usually protected by a strong structure. It may range about 40 to 50 cm.

The result obtained in decreasing the length of that protruding part is shown by Figure 8; it seems very efficient. On future models we must accordingly provide a stiffened structure at the very front and under the bumper, at the level of the impacted lower part.

Variation Of Vehicle Mass

Any increase of mass is at any case unfavourable, on both impacting or impacted vehicle (Fig. 9). It means that for an impacting vehicle at a fixed impact velocity, *the intrusion will be accordingly important as the impacted vehicle is heavy.*

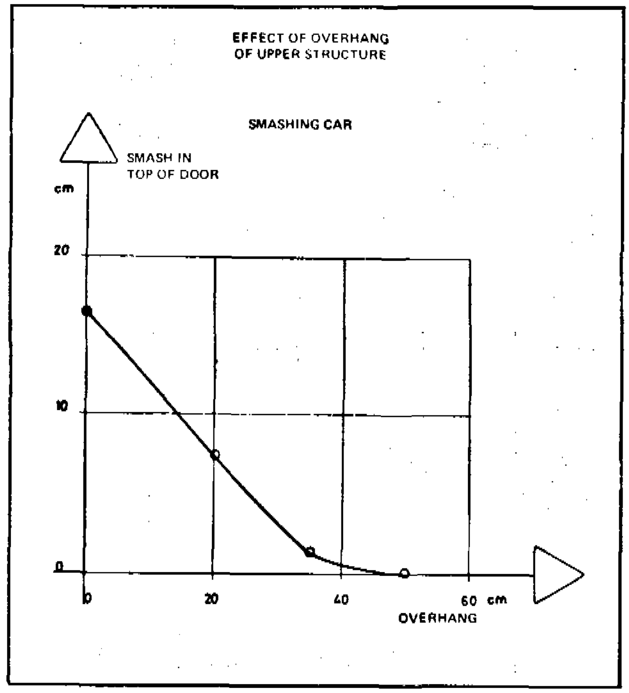


Figure 8

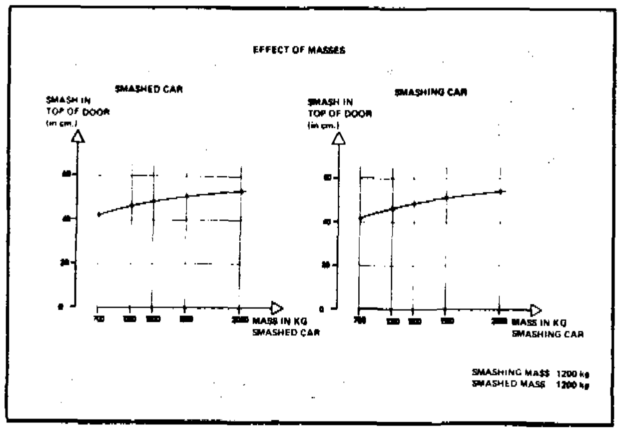


Figure 9

In this point of view the Figure 10 shows the similitude in the variations of the vehicle mass and the strengthening of the vehicle doors. In the case where a limitation of intrusion would be required, corresponding to a 1200 kg vehicle impacting a 2000 kg vehicle equipped with strengthened doors complying with U.S. Standard requirements, a reduction of the door strength corresponding to U.S. requirements x 0.8 is enough to obtain a similar intrusion when the impacted vehicle mass is decreased from 2000 to 1200 kg.

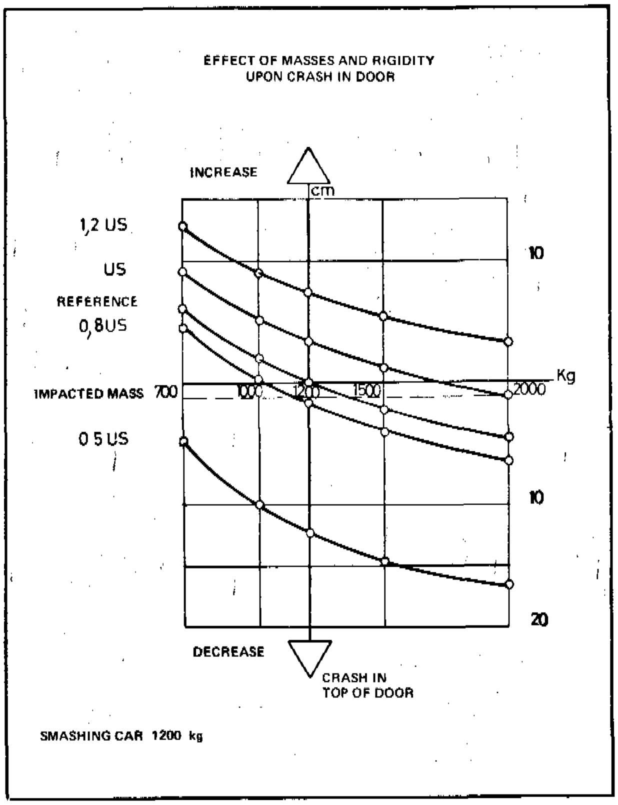


Figure 10

Principles For The Development of ESSS Lateral Impacts

Impacting Vehicle – Decrease In Aggressiveness (Fig. 11)

ESSS involving a reduced aggressiveness have been designed with low parts located as far as possible to the front, *under the level of bumpers* that are always facing impacted door frames while being aggressive according to their excessive strength. The upper part of the front structure is *soft on a 20 cm length*, then the structure is strengthened and shows a good resistance when impacting a wall.

It must be noticed (Fig. 12) that a reduction of the protruding parts of the upper structure improves the interest of strengthening the lower parts both on impacting and impacted vehicles.

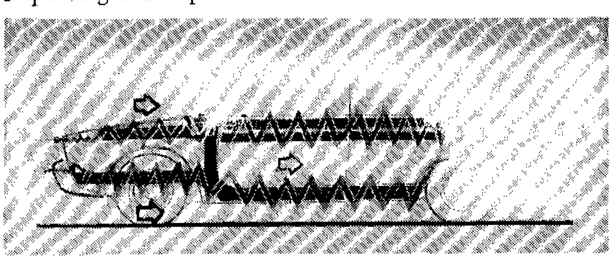


Figure 11

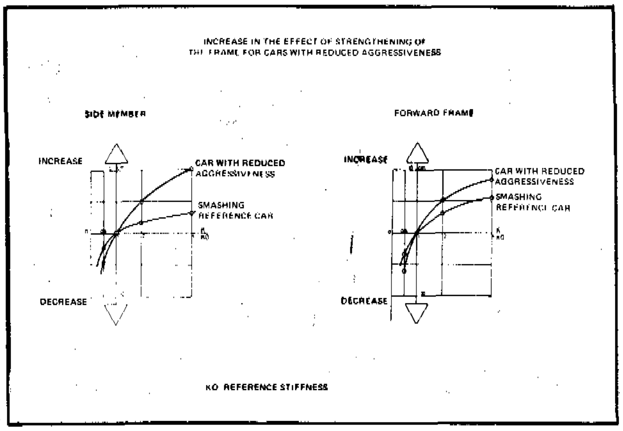


Figure 12

Impacted Vehicle – Strengthening The Vehicle Side (Fig. 13)

The strengthened lateral ESSS involves:

- door strengthening by members having a consequential effect to each other.
- Strengthened cross members near the cowl, the floor (lower part of the dash board, cross rails under the front and rear seats) and the backrest, intended to increase the transverse stiffness of the body by adding structures resisting by lateral flexion
- strengthened seats (Fig. 14) ensuring additional reinforcement of the body sides.

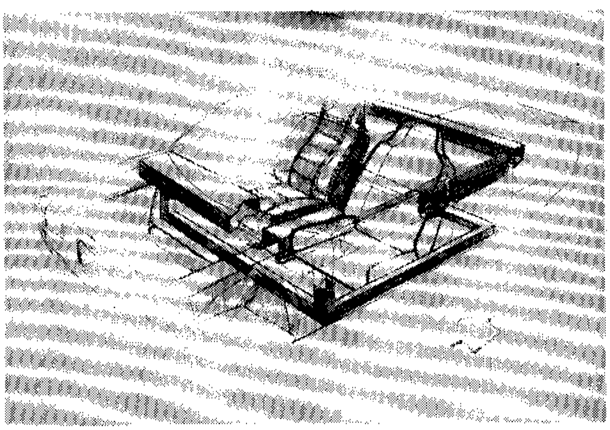


Figure 13

Testing The ESSS In Lateral Impacts

We performed a perpendicular lateral impact at a velocity of 50 km/h. The figures 16 and 17 show the condition of the two vehicles after the impact; they may be compared with Figures 1 to 4. We can see a considerable decrease of the distortions on the vehicle side related to an increased crushing in of the impacting vehicle front end.

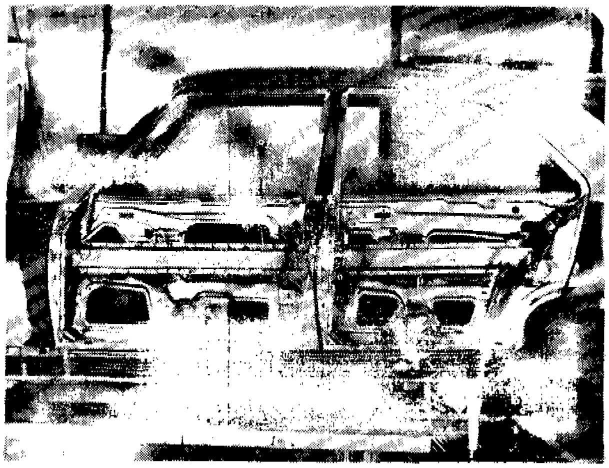


Figure 14

After seeing the film of the test, where the impact test with ESSS is compared with a crash between non-modified cars in the same test conditions, it is obvious that the lower part of the non-aggressive impacting vehicle starts pushing the strengthened impacted vehicle rather sooner than in the first case, reporting the greater part of the constraints on the side member. The wheel of the impacting vehicle no longer applies on the impacted member.

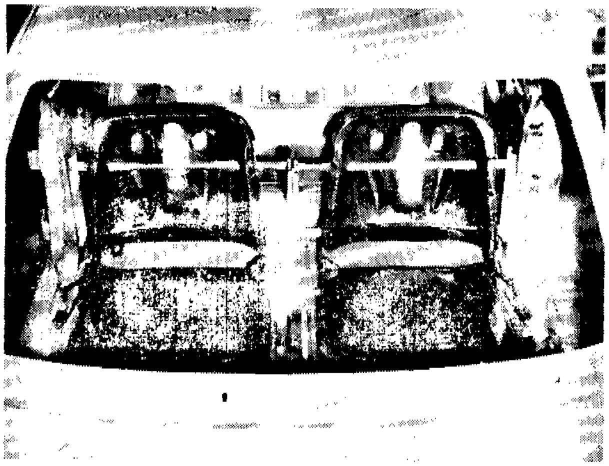


Figure 15

Figure 16

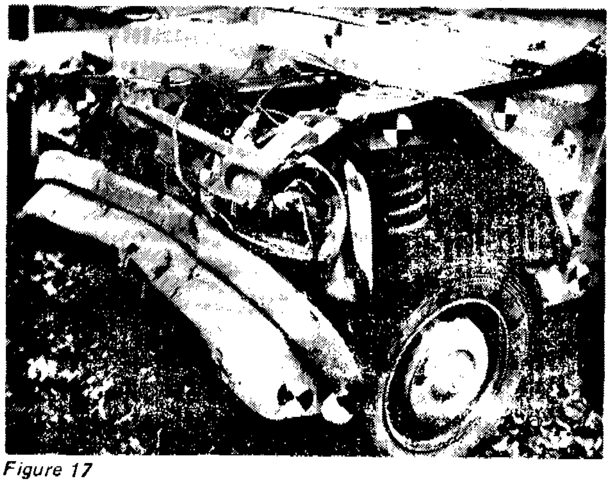


Figure 17

The door panel interior intrusion which ranges about 30 to 40 cm on most of non-modified cars is of 2 cm in the ESSS test.

Finally, the figure 18 shows that the acceleration of the impacted passenger compartment is not considerably increased, the maximum average value is about 20 to 30 g, the only difference is that it starts sooner after the impact.

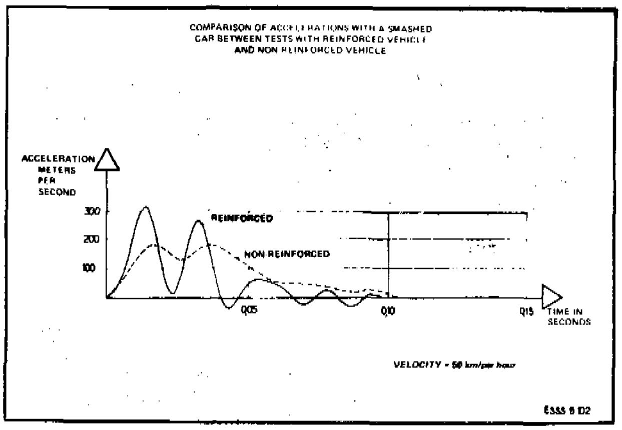


Figure 18

Conclusion

Reducing the aggressiveness of vehicle front ends and the body sides vulnerability, the principles to be applied seem to be the following:

a. On the impacting vehicle.

- Decrease the stiffness on a short length of the upper part of the structure.

- Adding a strengthened lower part leading as far as possible to the front and located under the door sill of all vehicles.

b. On the impacted vehicle.

- Reinforcement of the lower parts at the level of the floor.
- Strengthening with cross members the two sides of the body with structure elements or strengthened seats.
- Reinforcement of the door resistance to flexion.

Finally, it seems to us indispensable to investigate if any solution involving the structure and supposed to improve protection, would not increase the aggressiveness for the vehicle occupants.

REASONS FOR THE LINE TAKEN BY THE PEUGEOT/RENAULT ASSOCIATION IN STUDIES REGARDING SAFETY

M. Georges Boschetti, Peugeot

When safety research emerged from the secrecy of the laboratory and when study contracts were proposed by Governments, the Peugeot/Renault Association selected the following lines:

1. To first develop a free research program so as to experiment, and then, to gain better knowledge without, at first sight, laying down unnecessarily restrictive specifications.
2. To ascertain the relationship between cost and effectiveness by developing or examining the enquiries concerning real accidents and by carefully placing a figure on the cost of the solutions under consideration.
3. Attempt to apply, as soon as possible, the solutions that are partially advantageous on current models and more completely on future models with more integrated solutions.

Firstly, therefore, we wish to experiment, before deciding, and it is to remain faithful to this principle that we have, today, preferred to ask Mr. Ventre and Mr. Hamon to first present our studies on the front impact, the side impact and on aggressivity before explaining our main ideas.

You will then understand why we were spontaneously in agreement with the French Government who first proposed studies on safety cars in sub-assemblies with free specifications, since called ESSS by the NHTSA, by leaving everybody free to continue later with the ESV synthesis of the complete vehicle.

By this as it may, I believe that the two methods should not be artificially opposed. What we have seen over the last year in various publications and in the very work of this conference confirms this.

- The manufacturers that accepted ESV programs are, in actual fact, working on the ESSS to prepare their ESV.
- The manufacturers that accepted ESSS programs work in the same manner.

We so believe that the time has come to call for an armistice in this war of terminology.

For its proponents, the determination, at first sight, of specifications more rapidly mobilizes energies but, for us, it has the very great defect of fixing and, above all, crystallizing specifications that can sometimes be unnecessary or even be a concern.

For example:

- Mr. Ventre recalled that the mandatory requirement of a maximum driver/passenger compartment deceleration of 40 g. after a front impact is absolutely disastrous where the improvement of light cars is concerned and, in our opinion, unnecessary for heavier cars.
- Doctor Tarriere – Chief of our Physiological Laboratory – this afternoon, will explain that, out of 400 accidents analysed, the front crash as specified, very rarely exists.
- In the test against post, it is not evident that the very special solutions that it will require will be the best in the case of other impacts as in the optimum synthesis.
- Mr. Hamon has shown that the abnormal reinforcement of car front parts is very bad for protection in the case of side impacts.

I will insist on this side impact against which, as we have shown, large cars are no better protected than small cars. Door thicknesses do not enable, and this by far, structures that are as large as the deformable structures of the front and back parts of cars.

The important point is the lowering of the center line of the most aggressive rigidity.

Since it is fairly natural that the bumper be the most protruding component of this aggression center line, we insist on countering any policy of raising bumpers which is contrary to the sought-for aim.

We are pleased that the NHTSA has amended Standard No. 215 thereby making it possible not to aggravate this misunderstanding as was the case with the original standard which appeared, to us, to be a serious mistake.

This concept of aggressivity is not limited to the improvement of structures.

It is the entire behaviour of drivers that is in question. The latter are not the only ones, with their passengers, that must be protected. Third parties also have the right to this in the same manner and for the same reasons.

Furthermore, instead of seeing study programs developed concerning safety for oneself and, later, to see along the same lines safer cars praised, I would rather yet hear talk of cars that are less aggressive and less dangerous to others.

Our second aim is the study of the cost/effectiveness criterion.

For this, the Peugeot/Renault Physiological Laboratory works in relation with the hospital at Garches – near Paris – in collaboration with the local police, under the Patronage of the National Road Safety Office. It analyses the origins and true cause of accidents in relation with active safety but, above all, analyses for passive safety, the origins of characteristic injuries and the car components in question.

We thus hope to find truly useful solutions and then prepare good tests; because there are both good tests and bad tests.

It is most important to select the tests that result in the greatest effectiveness for a given cost meaning those that will best protect passengers in the greatest number of cases.

In actual fact, it must never be forgotten that safety solutions based on tests cannot protect occupants under all accident conditions.

It would be most serious for the public to believe, and it must not be led to believe that people will be protected in all cases because compliance with a test has been established. This would be a breach of trust.

To complete our cost/effectiveness studies it would be necessary to further improve the information for manufacturers on the statistical level.

We particularly request the insurance companies and the National Authorities to give us more, and, if necessary, confidential information concerning all the statistics which could lead to progress in our research work.

If we calculate, with the greatest possible accuracy, the extra cost of the solutions as such and the supplements due to weight and volume increases, it is absolutely necessary for us to have the information as to their true utility available.

Our third line of action is the application of the solutions retained.

Research work by component by taking, as a material basis, production cars that are more or less extensively modified, enables a faster application of solutions that could be found interesting whilst, more completely testing the audacious futuristic solutions.

For information purposes, the Peugeot/Renault Association has already destroyed 450 vehicles during impact tests and will probably destroy a further 200 next year.

We are attempting to well separate, in application, what can be done fast, what will require three or four years and the more ambitious solutions that prepare the cars of the future.

I will conclude by recalling that the consequences of all these studies, as you know, will be larger, heavier and more expensive cars and this is even truer to fight if anti-pollution solutions are added, which, as such, are rendered more difficult for heavier cars requiring higher powers.

Now, it is not unknown to you that the public, at least in France, and, I believe, in a large number of European countries, is clamouring for cheaper and smaller cars.

The laws of the market, alone, do not enable us to meet these contradictory requirements.

What, then, must European manufacturers do?

We do not believe that this is solely their problem since, with a sufficient delay, they can develop their production in the direction which they will be required to follow.

This is, above all, a problem of general policy which concerns, not only the price level but also town planning and the environment. This is why the question has been raised with all our Governments.

We are ready and I believe that our colleague manufacturers are also, to progressively develop all solutions leading to true progress in safety.

However, the public should be warned of the economic consequences of the choices that the Governments will make in their name.