DOT HS-805-301

;PAN CHRYSLER RESEARCH SAFETY VEHICLE PHASE III FINAL DESIGN REPORT

Volume I: Technical Report

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Contract No. DOT HS-7-01551
Contract Amt. $7,083,931

DECEMBER 1979
FINAL REPORT

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National Technical Information Service,
Springfield, Virginia 22161

Prepared For
U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Washington, D.C. 20590

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT-HS-805-301		

4. Title and Subtitle	5. Report Date
RESEARCH SAFETY VEHICLE PHASE III FINAL DESIGN REPORT Volume I: Technical Report	December 1979
	6. Performing Organization Code
7. Author(s) EDITORS: G.J. Fabian and G.E. Frig	8. Performing Organization Report No. ZN-6069-V-23 (Volume I)
9. Performing Organization Name and Address Calspan Corporation Advanced Technology Center P.O. Box 400 Buffalo, New York 14225	10. Work Unit No. W90 Series 11. Contract or Grant No. DOT-HS-7-01551
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration 400 Seventh Street, S.W. Washington, D.C. 20590	13. Type of Report and Period Covered Final Design Report 1/26/77 to 1/31/80 14. Sponsoring Agency Code

15. Supplementary Notes

APPENDICES INCLUDED AS VOLUME II.

16. Abstract

A comprehensive summary of the final design of the Calspan/Chrysler RSV is presented. Reference is made to earlier studies in which the design goals were established. Details of the design tradeoff analyses and the final design decisions which culminated in the cars built for the fourth, or final, phase of the six-year program are given. These vehicles are based on a modern-high production car design which was modified to achieve the resistance to damage in low speed collisions, pedestrian safeguards and occupant protection characteristics which were desired. Subsequent testing in various types of impacts at Calspan and elsewhere demonstrated these qualities. Analytical development and testing activities supporting the evolution and improvement of the individual body and chassis components are discussed and the final parts are illustrated with photos and drawings. The documentation includes a bill of materials from which the actual automobiles were fabricated.

17. Key Words	18. Distribution Statement
Automobile handling, economy, safety, crashworthiness, occupant restraints, pedestrian safety, bumpers, structures, chassis, body design, styling	This document is available to the public through the National Technical Information Service, Springfield,VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	256	

Form DOT F 1700.7 (8-69)

METRIC CONVERSION FACTORS

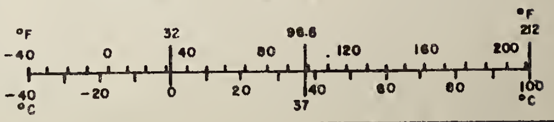
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FOREWORD

This Final Design Report on the Calspan/Chrysler Research Safety Vehicle has been prepared by the combined efforts of program staff members at both organizations. Much of the information has previously appeared in correspondence, internal memos, and progress reports, as well as in the documents cited in the references. It is the intention of the editors to combine that information into a complete and comprehensive summary of design decisions which were made during the course of the RSV program, culminating in the configuration of the final vehicles built for Phase IV.

The Phase I reports (Reference 1) document the original definition of the program. A preliminary design review data package (Reference 2) was published during Phase II on 16 March 1976. It describes program philosophy, program constraints, technical approach and the design details of the vehicle that had evolved to that date. Because the basic program objectives remain the same, the reader is encouraged to refer to that document. Additional information on the Phase II vehicle is presented in the final reports on the Phase II program (Reference 3). This report will concentrate on documentation of the final design, including revisions accomplished during Phase III. The documentation is presented in Volume I. The appendices in Volume II include exploded views and drawings of the entire car and various body and chassis components, as well as significant tabular data such as the engine family description and the bill of materials from which the vehicles were built. A complete bill of materials which provides an index to part numbers of the components as well as the bases for their design is included. Frequent reference to the appendices is suggested during reading of this report.

All Phase III design revisions have been based upon static crush tests, dynamic impact tests, and evaluations of RSV components using special equipment like the HYGE sled. The static crush test report is listed as Reference 4. References 5 and 6 are the final reports on the development of the air belt and the driver air bag. The reports on the Phase III crash tests are included in References 7 through 16. Research Safety Vehicle handling is discussed in References 17 and 18, while its compliance with Federal Motor Vehicle Safety Standards is assessed in Reference 19. References 20, 21 and 22 document segments of the development and Reference 23 is the Final Technical Report on Phase III.

The Final Design Report is submitted in partial fulfillment of the requirements of Paragraph 3.4 of the Statement of Work of Contract No. DOT-HS-7-01551. The Contract Technical Manager for the program is Frank G. Richardson of DOT/NHTSA. The contents of this publication reflect the views of the members of the Calspan and Chrysler RSV staffs and are not necessarily those of the National Highway Traffic Safety Administration.

The report has been reviewed and is approved by:

G. J. Fabian
RSV Program Manager

ACKNOWLEDGMENTS

In addition to the RSV staffs at Chrysler and Calspan, a large number of other groups and personnel in both organizations have given unstintingly of their time and effort to the development of the RSV. The editors wish to acknowledge the complete support of both organizations. We are similarly indebted to many NHTSA personnel within the Office of Passenger Vehicle Research for their support, but particularly wish to identify the efforts of Frank G. Richardson, who has been the Contract Technical Monitor since the start of Phase II.

A development program of this magnitude could not have been achieved without complete support from a number of our supplier companies who have contributed their engineering talent, facilities, and special components to the Calspan/Chrysler RSV program. The following organizations and their contributions deserve recognition.

Alderson Research Laboratories, Inc. - Anthropomorphic Dummies
Allied Chemical Corporation - Restraint Components
Rita Amabile - Air Bag and Air Belt Fabrication
Amanda Bent Bolt - Hood Latch Components
Ast Servo Systems, Inc. - Rate Gyro
Atwood Vacuum Machine - Seat Tracks
Bell & Howell - Strain Gauge Accelerometers
Bendix Corporation, Auto. Control Systems Group - Anti-Skid Brakes
Buffalo Insulation Distributors - Styrofoam
Capitol Plastics - Plastics
Chrysler/France - Simca Components
CIBIE Corporation - Headlamps and High Level Tail Lamps
George W. Colburn Lab., Inc. - Reproducible Film and Masters
Conwed Corporation - Headliners

Cranz Co., J.M. - Ensolite Material

Creative Industries of Detroit - Engineering Services and Fabrication of Vehicles

Custom Trim Products - Molding

Davidson Rubber Compnay - Soft Bumper Systems

Dynamic Sciences, Inc. - Rental of Test Facilities and Measurements of Parameters on the RSV

Empire Volvo - Volvo Steering Wheels and Miscellaneous Volvo Parts

Essex Chemical Corporation - Windshield Adhesives

Essex Group, Inc. - Wiring Harnesses

General Electric Company - Plastics

Goodyear Tire and Rubber Company - Flatproof Tires

Grand Rapids Smelting - Remelt Zinc to Zinc Alloy

Great Lakes Steel - High Strength Low Alloy Steel

Harris Hill Heating Company - Air Bag Manifold Assemblies

Hexcell Corporation - Aluminum Honeycomb Energy Absorbing Material

Irvin Industries - Air Belts and Air Bags

ITT, Auto, Electrical Products - Wiring Harnesses

J.R. Products, Inc. - Air Bag Covers

J.W. Lewis Company - Adhesive, Cleaner and Wax Remover, Stikit Pads, etc.

Lake Center Industries - Secondary Hood Latches

Lebow Associates, Inc. - Seat Belt Load Cell

Lone Star Manufacturing - Air Conditioning Condensers

Marui Industrial Company, Ltd. - Soft Emblems and Headlamp Bezels

Micro-Measurements - Strain Gages

Modern Engineering Service Company - Vehicle Parts and Engineering Services

R. Monahan/G.M. Fisher Body - Nylon Air Bag Material

Motor Insurance Repair Research Centre - Impact Tests and Engineering Services

Motor Wheel - Low Tire Pressure Warning System

Pittsburgh Plate Glass Industries - Front Door Glass

Rockwell International - Passive Belt Drive Mechanisms

Saint-Gobain Industries - Windshields

Saginaw Steering Gear Division - Air Cushion Slip Ring Assemblies

Sheller-Globe Corporation - Fabrication of Instrument Panel and Tooling

Sierra Engineering Company - Anthropomorphic Dummies

Standard Mirror Company - Convex Mirrors

Takata Kojyo, Company, Ltd. - Load Limiting Webbing

Thiokol/Wasatch Division - Inflators for Passive Restraints

Volvo of America Corporation - Steering Wheels for Air Bag Cars, Headrests

3M Company - Adhesives and Reflective Decals

METRIC CONVERSION FACTORS
U.S. TO METRIC MEASURES

QUANTITY	TO CONVERT FROM (U.S.)	TO CONVERT TO (METRIC)	MULTIPLY U.S. UNITS BY
AREA	SQUARE INCHES (in^2)	SQUARE CENTIMETERS (cm^2)	6.452
	SQUARE FEET (ft^2)	SQUARE METERS (m^2)	9.290×10^{-2}
DENSITY	POUND MASS PER CUBIC INCH (lb/in^3)	KILOGRAMS PER CUBIC CENTIMETER (kg/cm^3)	2.768×10^{-2}
	POUND MASS PER CUBIC FOOT (lb/ft^3)	KILOGRAMS PER CUBIC METER (kg/m^3)	1.602×10^{1}
FORCE	POUND FORCE (lbf)	NEWTON (N)	4.448
LENGTH	INCHES (in)	CENTIMETERS (cm)	2.540
	FEET (ft)	METER (m)	3.048×10^{-1}
	MILES	KILOMETERS (km)	1.609
MASS	POUND MASS (lb)	KILOGRAM (kg)	4.536×10^{-1}
POWER	HORSEPOWER (hp)	WATTS (W)	7.457×10^{2}
PRESSURE, STRESS	POUND FORCE PER SQUARE INCH (psi)	PASCAL (Pa)	6.895×10^{3}
	POUND FORCE PER SQUARE FEET (lbf/ft^2)	PASCAL (Pa)	4.788×10^{1}
TORQUE	FOOT POUND (lbf·ft)	NEWTON METERS (N.m)	1.356
	INCH POUND (lbf·in)	NEWTON METERS (N.m)	1.130×10^{-1}
VELOCITY	MILES PER HOUR (mph)	KILOMETERS PER HOUR (km/h)	1.609
VOLUME	CUBIC INCHES (in^3)	CUBIC CENTIMETERS (cm^3)	1.639×10^{1}
	CUBIC FEET (ft^3)	CUBIC METERS (m^3)	2.832×10^{-2}
	GALLONS (gal)	CUBIC METERS (m^3)	3.785×10^{-3}
	GALLONS (gal)	LITERS (ℓ)	3.785

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1.0 INTRODUCTION

The overall objective of the Research Safety Vehicle (RSV) program was to develop technological data applicable to automotive safety requirements for the mid-1980s for the National Highway Traffic Safety Administration and to evaluate the capability of achievement of such requirements with respect to environmental policies, energy utilization, and consumer economic considerations for that time period. So that information appropriate for the formulation of meaningful automotive standards for that era could be obtained by NHTSA, a multi-phase research program was undertaken at Calspan to develop a light-weight advanced safety vehicle (the RSV) suitable for family transportation. Current regulations were not to be a constraint on the RSV design (i.e., alternative safety features were to be explored).

It is to be recognized that factors well beyond a strict safety consideration were also investigated. While reduction of highway losses, particularly human injuries and fatalities, was the major concern in the study, the design had to be compatible with mass production techniques, fuel economy, and emission requirements for the 1980s. The RSV had to be constructed of readily available materials. It had to be recyclable easily and require minimal energy in its manufacture. The purchase price, or consumer price, had to be reasonable, as did operating costs. In addition, the RSV had to have good consumer acceptance. Most importantly, however, it had to provide a high level of safety for its passengers as well as for the occupants of other vehicles or pedestrians.

The overall program was conducted in four phases as outlined below:

Phase I

a. Define program
b. Develop performance specification
c. Develop preliminary design

Phase II

a. Perform systems engineering and integration analyses
b. Develop total vehicle design

Phase III

a. Refine and optimize design
b. Fabricate test vehicles

Phase IV

a. Test and evaluate vehicles (by agencies other than the prime for Phases I, II, or III)

Although Chrysler's participation in the Phase I RSV was modest, it is important to note that it was involved almost from the inception of the project. Chrysler technical personnel provided inputs to a number of topics investigated during Phase I and helped to formulate the basic foundation of the program to meet NHTSA objectives as well as to provide detailed design embodiments for the RSV to demonstrate the desired performance.[1, 2*]

The initial activity at Calspan was aimed at identifying the ranges of vehicle characteristics suitable for an automobile that could be introduced in the mid-1980s. Data on injury-producing accidents (largely drawn from the Calspan files) were analyzed to discern accident configurations and the influence of vehicle weight. Information on accident causal factors was reviewed. Car damage information was obtained from insurance company and manufacturers' summaries. Auto usage trends were examined in the light of projected driver population development, perceived consumer needs, and economic and energy factors. It became clear that material shortages, in addition to fuel shortages, could well develop within the time span under

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*Superscripts refer to references in Section 7.

consideration. Therefore, extended resource recovery and fuel economy studies were utilized to augment and amplify the investigation of automobile usage. The foundation data were utilized to develop acceptable ranges for vehicle dimensional estimates, vehicle system characteristics, safety performance, and consideration of producibility factors. All aspects of safety performance were included: handling and stability, visibility, driver environmental systems, crash energy management, and occupant compartment systems.[3]

1.1 Design Specifications

Performance specifications were developed from the estimates produced in the early research. Motor vehicle injuries, fatalities, and victim lost time were viewed in the context of the national health/accident cost frame. Impact of existing regulations on car weight and cost was estimated, and Calspan's experience in crashworthiness guided the assessment of the costs for incorporating added weight to provide the desired structural performance and occupant protection.

A candidate vehicle was selected to provide a firm basis for evaluating the effects of safety-related modifications on operational characteristics. This base vehicle also provided a means for examining producibility questions on a realistic basis.

The preliminary design started at Calspan with a review of different concepts in the areas of pedestrian protection, compartment integrity, energy management and occupant restraints that previously had been advanced. Corresponding alternate subsystem installations were generated for the base vehicle. Energy management was investigated in some detail to insure effective utilization of any added weight. Experimental base vehicle crash response data and static crush data were used in conjunction with computer simulations to firm the initial estimate that an integrated structural system was feasible. Compatible padding and restraint alternatives were selected.

From the review of economic trends, it was apparent that automobiles have to undergo considerable changes in the next decade. The principal motivation, as evidenced in the current economy, was that automobile fuel efficiency had to be substantially improved. Although not yet receiving similar attention, there exist incipient domestic and worldwide shortages in other vital minerals such as manganese, chromium, nickel, lead, etc. Indeed, at the present rate of consumption, the U.S. known reserves of many of these materials will be exhausted by the end of this century. As conservation measures take effect, the excessive use of such materials in automobiles will be seriously questioned unless means are developed for their efficient recovery (recycling). Therefore, the design of motor vehicles to provide for a near total recovery and recycling of the basic materials was expected to be an important consideration for automobiles produced in the mid-1980s.[24,25]

Because of the anticipated greater emphasis on conservation and efficiency, it was believed that future automobiles would be designed with greater attention to mission than to appearance, style, status, etc. This trend was expected to result in essentially two basic automobile types: family cars and cars designed for specific purposes such as shopping, commuting, etc. In the context of the late 1980s, the former would be considered as "large" cars but have a mean curb weight near 3000 lbs. while the latter would likely be called "small" cars and have a mean curb weight near 2000 lbs. The development of either of these two basic vehicle types could have been pursued in RSV Phases II and III; it was believed, however, that greater benefit would result from development of the family car. That configuration was expected to serve the function of current cars in the compact to standard size because cars having four to five seating positions would probably have greater usage than small ones, which would be better-suited for the missions of current sub-compact cars.

To be viable and provide an impetus to automobile design, the RSV had to be basically compatible with automotive mass production methods. Calspan's partnership with Chrysler Corporation in this program assured proper focus on this aspect. It was well recognized that present cars for the most part represent evolutionary change from previous vehicles. Thus, cars carry over many components from previous designs. Principally, because of the producibility objective, it was believed that practice should be maintained to the greatest extent feasible in the RSV program.

It therefore became necessary to select a production car which represented a good candidate base vehicle for the RSV. Bearing in mind that the RSV must represent substantial departures from current automotive designs (at least as practiced in the U.S. for consumer tastes), consideration was given to both domestic and foreign vehicles. The major requirement for the base vehicle was that its weight not exceed 2500 lbs. and that it be adaptable to a five place seating arrangement (family and cargo). There was no American automobiles which met these basic requirements without drastic departures from the existing design.

Accordingly, the designs of all foreign vehicles imported to the U.S. were reviewed. Within that array, a number of vehicles seemed to conform - the Audi 100LS (2400 lbs.), Saab 9913 (2500 lbs.) and Volkswagen Dasher (2100 lbs.); all of which would be attractive possibilities for the program. These vehicles are mentioned here only to indicate the type of automobile believed appropriate as a base vehicle for the RSV program. It is noteworthy that all of these vehicles have characteristics distinctly different from typical American cars. That is, they are higher and have less vehicle length devoted to the hood and trunk with correspondingly less front and rear overhang. In addition, all of these vehicles employ front engine, front wheel drive systems. This latter factor has a major effect on vehicle weight, occupant packaging and vehicle crashworthiness. These investigations led to the choice of Simca 1308 as the base vehicle. It was a new car being developed by Chrysler/France with a curb weight of 2300 lbs., five passenger capacity, a transverse engine, and front wheel drive system.

Predicted future automobile usage and accident exposures have led to the conclusion that unless crashworthiness improvements are made, the loss in human injuries and property damage will grow to unacceptable levels in the late 1980s. Consequently, efforts to improve automobile safety had to continue, but the practice of recent times where safety has been essentially an add-on to the vehicle could no longer be tolerated. Instead, safety had to be integrated into the overall vehicular system. In this process, it is possible to trade the cost for such items as vehicle size (and related material bulk), luxury (e.g., power windows, steering, etc.) and excess performance for improved safety features. With this basic trade-off approach, it was felt that automobile safety performance levels could be greatly improved without increasing the cost presently allocated to family car transportation.

The major developmental effort in the RSV design was in the area of safety, particularly crashworthiness. This results because the philosophy of starting with a base car (to control the producibility aspect) guarantees that the vehicle will meet most of the non-safety requirements considered necessary within the context of U.S. near-future standards. Consequently, it was understood that changes in any candidate base vehicle were to be expected in order to provide the required greater crush distance. These would likely include increases in length and width. Even with these changes however, it was expected that the RSV would retain many of the basic characteristics of the selected car. Review of the Simca 1308 design revealed that fundamental changes in crashworthiness could be accommodated.

The major changes intended to improve crashworthiness characteristics may not generally be evident except under careful inspection of the RSV structure.[26] A cutaway sketch showing the modified components of the RSV is included as Figure 109 in Volume II. A three-zone concept was developed at Calspan.[1] A soft face bumper, which will improve damageability as well as provide pedestrian protection, is Zone I at the front and rear of the vehicle.[27,28] The structure immediately behind the bumper, Zone II, is designed to provide energy dissipation during front-to-side and front-to-rear intervehicular collisions. Zone III, the remaining aft portion of the front structure, is designed to provide energy absorption during severe frontal collision. Likewise, the side structure, principally through redesign of the pillars and their attachment to the sills, will increase energy absorption as well as insure that front structures in other vehicles share in the energy dissipation during front-to-side collisions.

Rear structural changes do not significantly modify the base car. Alterations in this area, intended for the most part to provide greater protection of the fuel system during high speed rear collisions, include minor redesign of the fuel tank and elimination of the spare tire. Current progress in tire development suggests that "flatproof" tires will be available in the near future. The advantages of flatproof tires to an RSV type automobile are twofold: (1) elimination of tire failure and roadside repair is definitely in the interest of safety, and (2) elimination of the spare tire permits expanded cargo capacity. This latter factor has not been important in the large-sized American cars; but, as more efficient lightweight automobiles are developed, priority must be given to design innovations which increase cargo capacity (or reduce weight).

1.2 Basic Approach

Analyses and projections of availability of natural resources identified a need for reduced utilization of petroleum products.[25] A significant improvement in vehicle fuel economy was identified as an RSV requirement. The concern for overall energy consumption led to a decision to limit use of aluminum in spite of its weight and consequent gasoline consumption savings because of the larger amount of energy required in its refining and fabrication. Some potential trace element shortages could affect use of specialty alloys such as high strength low alloy steels (HSLA). The possibility of a "long-life", 20-year car design was examined (but was discarded) as a means of reducing energy usage. Since many advances in areas of fuel efficient engines, drivelines and automotive safety are likely to occur in the future, a long-life car would tend to delay their introduction and subsequent wide-spread use. Recycling was considered to be a better alternative but led to a restriction on the use of aluminum to only those areas where it could readily be removed prior to reclamation to prevent contamination of both the steel and the aluminum. Use of recycled plastics, as well as methods for subsequent use of scrap tires and other materials not currently widespread, was included where possible. Also, the compatibility of the various ferrous and non-ferrous alloys when mixed during recycling was considered in the selection of those materials.

Vehicle usage trends identified the continuing need for vehicles carrying five passengers and a rather large luggage capacity. The need to minimize use of energy and natural resources requires greater efficiency of the cars. This results in somewhat smaller, lighter cars having poorer acceleration but better fuel economy. Safety equipment and emissions control devices were identified as being contrary to these needs, but the goals seemed possible to achieve by advanced technology, albeit with added car cost. The convenience features of today's cars were shown to be desirable for consumer acceptability; however, some reduction of their installation rate would be anticipated to result from owner concern for operating costs. Also, changes in the mix of vehicle sizes indicated a requirement for the RSV to withstand impacts with cars over at least as broad a size spectrum as today's cars. It was shown that the planned size of the RSV, less than 3000 lbs., would probably represent the median vehicle size in the mid-1980s.

The accident statistics review provided data to establish meaningful impact performance specifications. Improvements in frontal impact protection could yield the greatest reduction of injuries and fatalities. Side impact mitigation retains a high priority but as secondary to frontal crashes. Rear impacts have an even lower frequency of injury or fatality and rollovers produced the lowest occupant injury risk. One interesting concept brought out in the study was that injury in single vehicle accidents appeared to have little or no dependency on vehicle weight (and, thereby, size). However, occupants of smaller cars, when struck by larger ones, tended to suffer greater injury than when struck by equal or smaller ones. Also, since ejection was identified as a major cause of injury, a need was indicated for some type of belt to keep the occupant inside the vehicle regardless of the make-up of the remainder of the restraint system. Limited passenger compartment intrusions of up to 150 mm (six inches) were found to be acceptable. It was shown that the vehicle could be designed to provide a reduction of repair costs for low speed impact damage. Improved driver visibility and vehicle conspicuity were also needed to increase safety. A review of braking capability indicated that an automatic anti-skid braking system could be justified.

To provide the additional occupant protection desired for the RSV, the structure and occupant compartment have to be improved to prevent excessive intrusion in an accident. In addition, the occupants themselves have to be restrained during such an event to insure that they remain within the safe confines of the compartment. Finally, protruding components must be eliminated. Development of the RSV restraints began with the utilization of the Calspan crash victim simulation computer program (CVS III) with input decelerations produced by complete car crush simulations.[29] It was clear that either a lap belt or a knee blocker would be necessary in conjunction with a torso belt or an air bag to provide the required restraint. Preliminary results of the computer investigations indicated that an advanced belt system[5] could provide a survivable impact speed about 5 mph greater than that for an air bag system. The results of the parametric study were subsequently confirmed by tests on the Calspan HYGE sled.

The Phase II RSV incorporated an inflatable belt to take advantage of the indicated greater impact speed potential. However, during Phase III, a driver air bag was developed for the RSV as an alternate automatic restraint system. In the final vehicles, a driver air bag and a passenger air belt are mounted for the front seat occupants. It must be emphasized, however, that the knee blocker formed at the bottom of the instrument panel, the special energy absorbing trim panels on the doors, the crushable foam padding on the

A, B and C pillars and roof rails, and the see-through headrests and modifications to the seats all form integral components of the total RSV restraint system.

The air bag system has advantages in that it is completely passive, unobtrusive and provides effective distribution of impact forces on the occupant. The improved air belt on the other hand is anchored further back in the vehicle structure and may not be as susceptible to degradation of performance should serious intrusions occur. Also, since it provides satisfactory restraint up to 30 mph operating as a conventional belt, air belt system inflation could be deferred to a higher impact speed than is commonly used with air bag systems. Repair cost savings could result since restoration of this system after crashes would be needed only in incidents of higher velocity change. In addition, the belt supplies lateral support in accidents other than frontal impacts. On the other hand, the automatic inflatable belt has two major shortcomings - it is nearly as expensive as the air bag and it is far more likely to result in objections by the user because of discomfort, inconvenience or appearance.

While a broad spectrum of data went into the design and development of the RSV, there obviously had to be program constraints. The most significant of these concerned scope and timing. Since actual production and sale of the automobiles had not been contemplated, the funding of the investigations was significantly less than would have been invested by an automobile company in the development of a new production vehicle. Development activities were directed primarily toward crash safety systems with less emphasis on refinement of basic automotive systems common to current cars. For instance, a major expense of developing an advanced emission system for 1985 was avoided by accepting a current system. As another example, after application of energy absorbing door panels to the interior of the doors, the remaining space across the rear seat was inadequate for three full-size occupants. However, the actual widening of the vehicle was not undertaken because it was not felt to be cost effective in the demonstration of the overall concepts. Indeed, the choice of developing the RSV from a current mass-produced vehicle, while providing a reliable basis for production aspects, imposed several design and performance limitations on the final vehicle design. Timely availability of results was also important. To be effective as an aid to defining 1985 safety requirements, the RSV program had to be completed sufficiently early to permit a reasonable lead time for production cars to include similar features. As a result, in many instances where an entirely new concept or direction was involved, developments could be carried only to a feasibility demonstration level. It must be borne in mind that, although the RSV documents practicable improvements, additional research, development and testing will be required before new standards based on its performance can be implemented in production vehicles.

2.0 STYLING

All styling activites for the RSV were carried out by Chrysler Design Office personnel. To satisfy budget constraints, the normal Chrysler corporate styling approval procedure was dramatically reduced and certain elements were not addressed at all, but strict engineering guidelines were employed in the mechanical designs of all parts and components (which were the responsibility of the RSV project staffs at Calspan and Chrysler). These designs are described in subsequent sections of this report.

A basic consideration in the styling effort was to retain as many of the original Simca 1308 body components as practicable, retain its attractive appearance, and yet have a distinctive look of its own.

2.1 Exterior Styling

The exterior styling of the RSV was accomplished in two stages. The initial activity involved converting the Simca 1308 (Figure 1) directly into the Phase II RSV.[24] Subsequent changes during Phase III culminated in the final design.[22] In Phase II the front end sheet metal and the car's wheelbase were increased by adding 80 mm (3.15 inches) between the dash and the engine to provide additional crush space.[3] Restyling of the front end was performed to incorporate a new soft bumper system for pedestrian and property protection with the added length. Aerodynamic considerations influenced the Phase II design, but since no actual aerodynamic testing was undertaken, it was necessary to rely on the judgment of the aerodynamicists. The rear end was modified during Phase II to relocate the gasoline filler tube farther forward, out of the high speed rear impact zone, and to integrate a soft rear bumper having the same general construction as the front bumper. Larger, 14 inch wheels were also included at that time to accommodate larger brakes for the increased weight.[24]

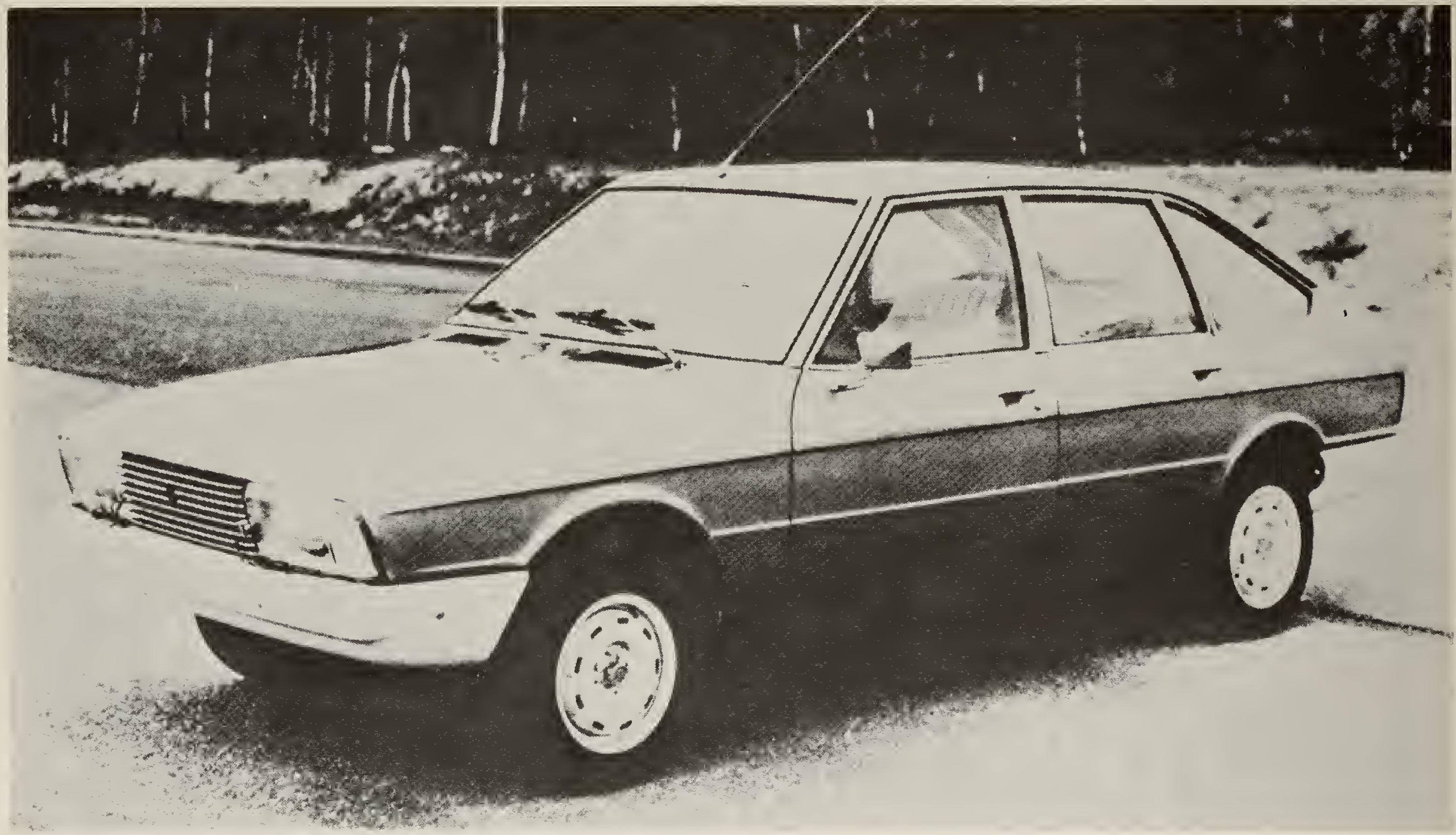


Figure 1 BASE VEHICLE – SIMCA 1308

Restyling of the RSV front end was undertaken in Phase III to accomplish three goals. First, the wheel openings were to be reduced to return to the Simca 13 inch wheels from the 14 inch size that had been specified in Phase II. Second, a larger engine envelope had to be accommodated to permit use of the Omni/Horizon 1716 cc engine and factory air conditioning in place of the Simca 1442 cc powerplant. This engine change was made so that actual emissions equipment and fuel economy evaluations could be performed rather than estimated as had been considered acceptable early in Phase II. Third, the rear end was modified to provide improved rear body, low-speed impact protection. Structural design of the body components is addressed in Section 3.

While new styling was undertaken during Phase III, the Phase II appearance was retained as much as possible. Four factors affecting RSV front end styling were carried over from Phase II - added crush space aft of the front wheels, reduction of damage in low-speed impacts, cleaner aerodynamics, and pedestrian injury reduction. In Phase III, full scale aerodynamic testing was performed in an attempt to reach the 30 mpg fuel economy goal added for Phase III (see Section 4.10). Visible effects of this test program on styling include the size of the engine cooling slots, front corner plan-view radii, a large, lower air dam, front wheel opening fairings, transparent headlamp covers, flush wheel covers, aerodynamic outside rear-view mirrors, elimination of rear roof pillar drip molding, and addition of the rear deck spoiler (see Figure 2).[21,23]

For the final RSV, the rear of the car was modified during Phase III to integrate the aerodynamic spoiler and to change to production 1978 Dodge Aspen taillamps for reduced RSV build program costs. High-level rear lamps in the roof pillars, the soft bumper system, and the relocated fuel filler were retained from the earlier Phase II vehicle. As with the front end, the goal was to maintain a "family" car appearance shown in Figure 3.

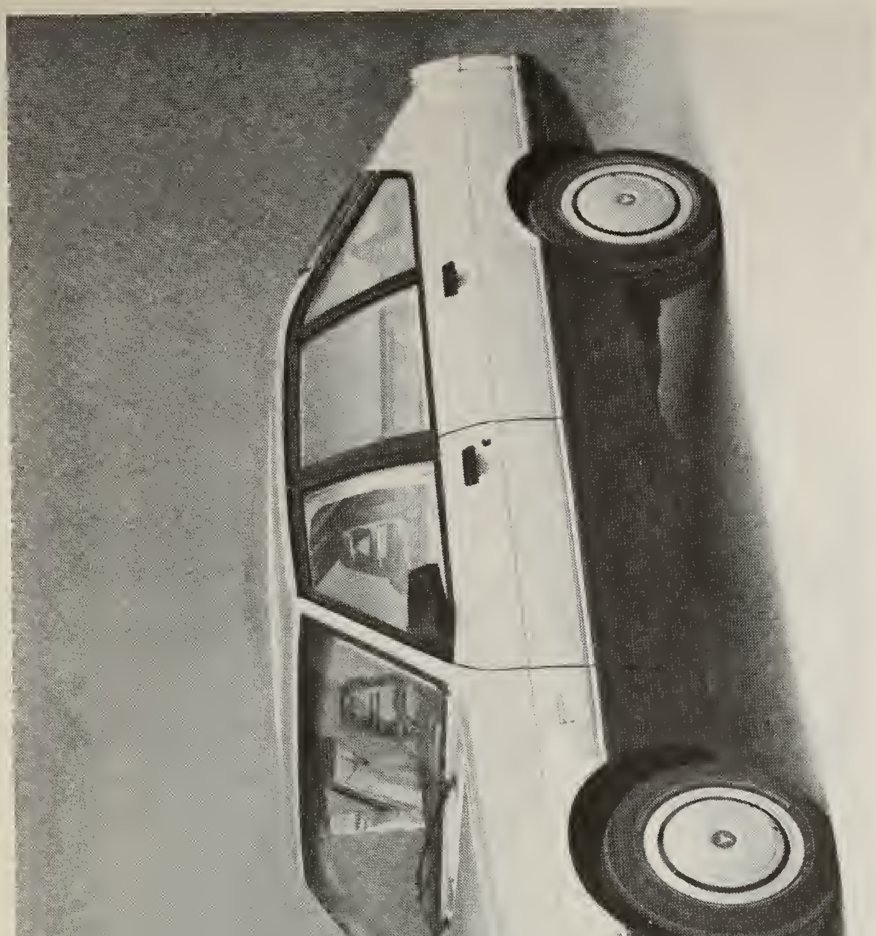


Figure 2 FRONT QUARTER VIEW OF RSV

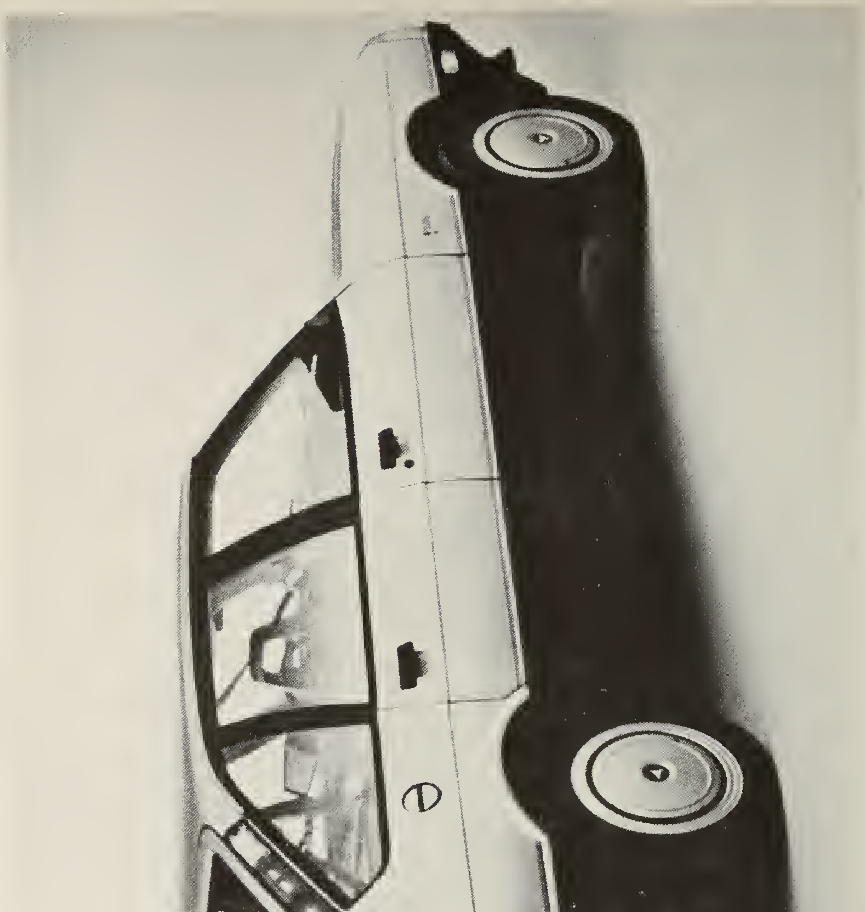


Figure 3 REAR QUARTER VIEW OF RSV

Additional exterior styling effort was directed toward the side rub strip/reflectorized band, color selection, emblems, striping, and tire sidewall and wheel cover design. Although the appearances of the front fenders, hood, cowl top, and front and rear bumpers have been changed from the Simca 1308, the overall effect incorporates all of the desired functional characteristics into a vehicle which should have a very high degree of consumer acceptance as a family sedan.[22]

2.2 Interior Styling

The primary areas of interior styling addressed during Phase II were new door trim panels and pillar covers to provide space for energy absorbing materials for occupant protection in side impacts, a new lower instrument panel pad for knee support and energy absorption in frontal impacts, a new "see-through" headrest for rear impact protection with minimum reduction of visibility and an automatic inflatable belt system. These components are discussed in Sections 3.7 and 3.8.

Redefinition of occupant energy absorption requirements in side impacts, new instrument panel knee blocker shape requirements, new light controls, and changes in the belt restraint configuration were the reasons for additional restyling of the interior in Phase III.[22,24]

As with the exterior, Simca 1308 characteristics and components were retained insofar as possible. The new door trim uses Simca door and window operating hardware mounted in the original locations as shown in Figure 4, and identified later in Sections 3.5 and 3.7 as well as in the appendices. This results in their being recessed, which should provide added safety as well as minimizing build costs. Padding 32 mm (1.25 inches) thick has been added around all door openings. Seats and seating attitude are unchanged except for removal of the Simca front seat-back recliners and application of new upholstery materials. The original Phase II "see-through" head restraint has been replaced by a production Volvo unit. The basic Simca

Figure 4 DOOR TRIM

headliner was modified in shape to provide for clearance to the roof roll bar and new construction and materials were specified. Basic instrument cluster components were retained from the Simca with some minor changes. When the new knee blocker and lower instrument panel were designed in Phase III, the upper instrument panel surface and the windshield and passenger air outlets were left unchanged. The panel shape is shown in Figure 5 and Drawing 95410 of Appendix A.

The steering column is an all new design based on the Simca but using new or modified elements mounted at a slightly shallower angle. The Simca column lock was repositioned; a modified Omni/Horizon combined wiper/washer/dimmer switch was added; G.M. air bag slip rings were added plus a new shaft to accept a modified Volvo steering wheel and a new column cover were required. The center cover of the Volvo GT steering wheel was redesigned by Calspan to enclose the driver air bag and provide the "tear open" capability needed. The Simca rear seat heat ducts were modified to pass over the passenger belt inflator unit mounted between the front seats and to serve as a decorative cover for the inflator.

The remainder of the interior styling effort was applied to color and materials selections which would complement the exterior and retain the overall conservative appearance. As with the exterior, it is felt that the interior styling should be readily accepted by consumers.

2.3 Paint and Trim

Exterior paint was chosen to be the type currently used on Chrysler production vehicles. The light grey on the upper body is color coded RA2 and the lower black is color coded DX9. All exterior bright trim is carryover Simca painted with black DX9 to simulate a black-out treatment. Name plates were designed by Chrysler's Design Office and made by Marui Industrial Co. Ltd. of Japan. These name plates (Figure 6) are made of soft plastic with some bright detail and red accents. The headlamp trim bezel is bright vacuum-metallized on the soft plastic surface.

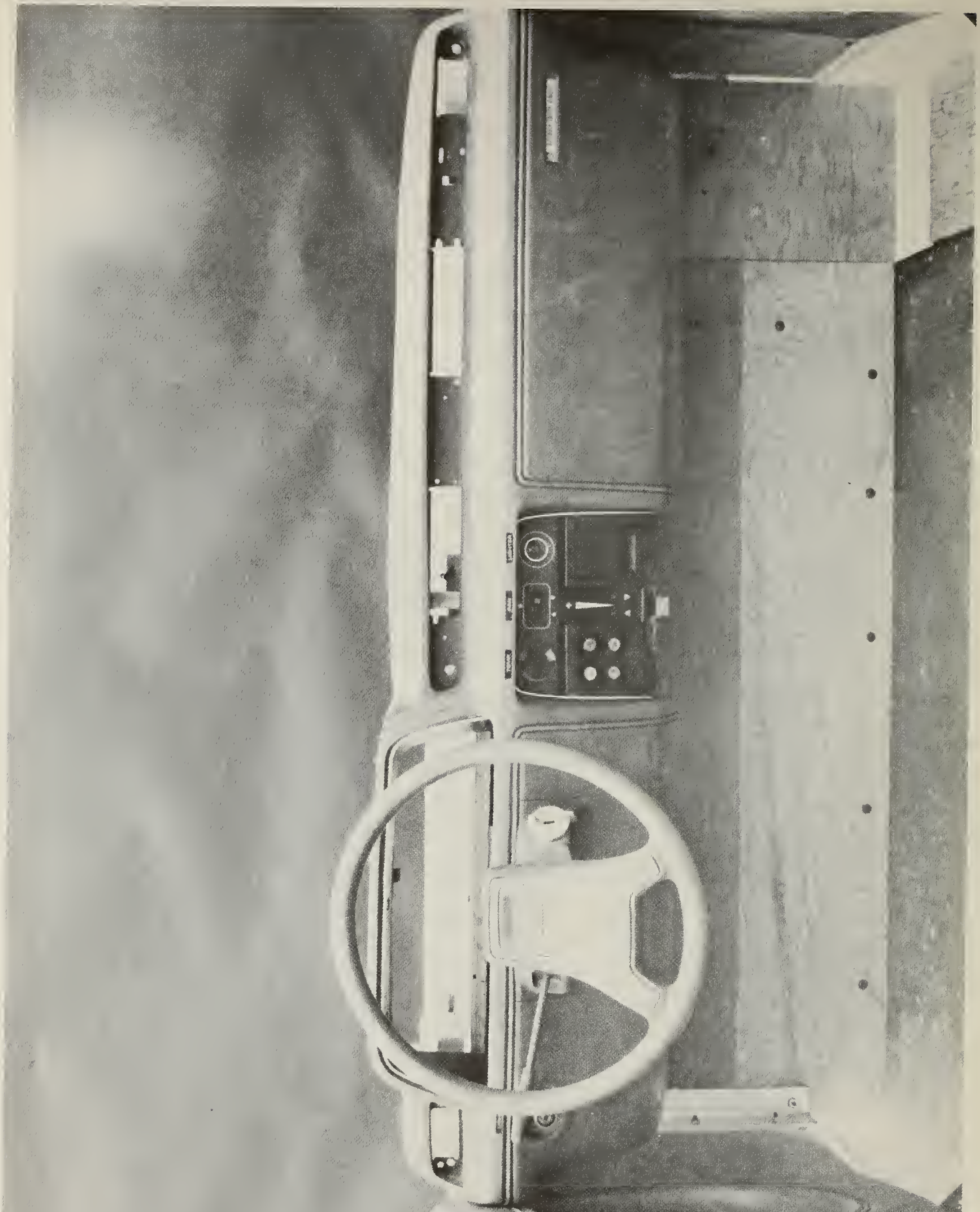


Figure 5 INSTRUMENT PANEL

Figure 6 RSV INSIGNIA

3.0 BODY

The body of the RSV has evolved directly from the Simca 1308 with a minimum of changes to the structure and components. Phase III and IV RSVs were assembled from parts obtained from CKD (Completely Knocked Down) 1978 Simca 1308 cars.[22,23] Other production car parts and a limited number of entirely new components have been added or used to replace Simca parts where required to achieve a special purpose unique to the RSV. Appendix A, Volume II, illustrates the parts involved; the Bill of Materials from which the RSV was fabricated comprises Appendix G.

Major design goals for Phase III were to resurface the outer front end panels and structure for the increased length required by the new engine, incorporate aerodynamic aids, improve front seat head room, reduce vehicle pitch and steering column intrusion during frontal impacts, reduce the weight and strength of the side structure allowing added intrusion in car-to-car side impacts and improve manufacturing feasibility and reduce production costs.

While redesign of many areas would be ultimately desirable for a truly production-engineered car, this was not always practicable. In some areas where new parts were developed the design was not completely oriented toward mass production so that program costs could be minimized by keeping tooling and fabrication costs consistent with the small number of RSVs to be built. In other instances although all-new production design might have been preferable, Simca pieces or production parts from other current cars were utilized in order to avoid the engineering, development and tooling costs.

3.1 Body Structure

The evolution of the RSV from the Simca is immediately apparent from inspection of RSV body-in-white structure (Figure 7). Yet, it is in this very area the RSV differs most from the Simca. There are, in fact, only a handful of major body structural components which are identical to those of the Simca (shown as unshaded parts in Figure 8). As indicated, new materials

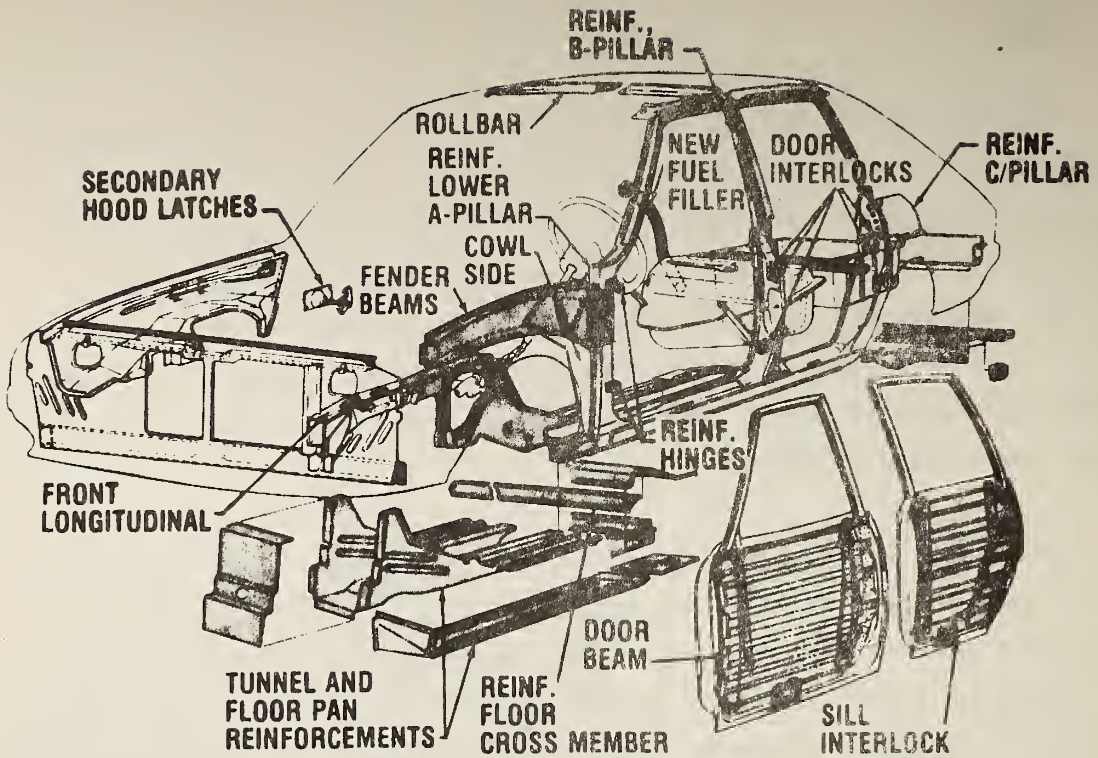


Figure 7 PHASE III STRUCTURE

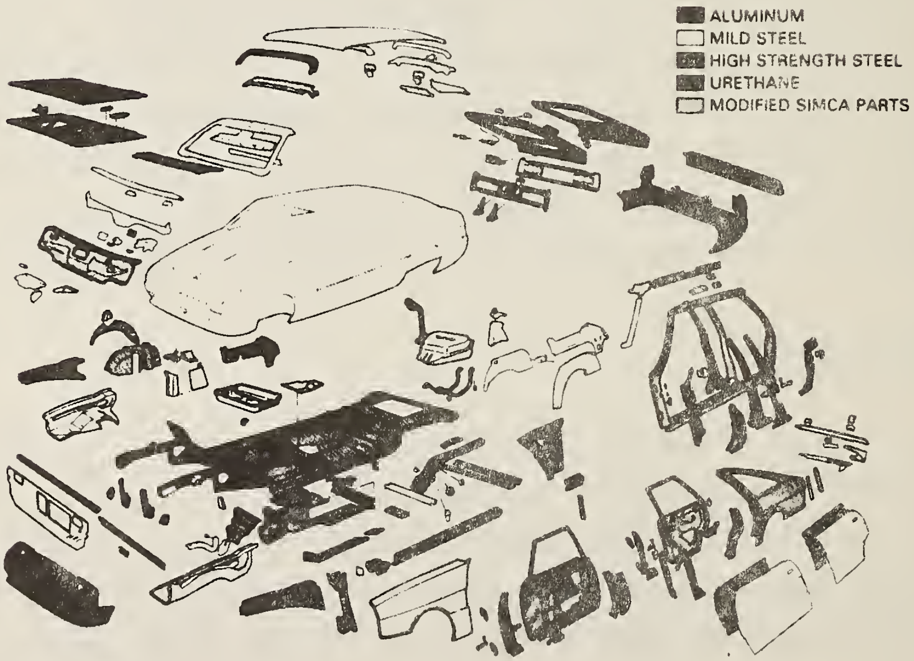


Figure 8 RSV MATERIALS UTILIZATION

or small changes of some sort were required on nearly every Simca part. However, the Simca design did permit a very satisfactory base from which the Calspan/Chrysler RSV has been derived.[20]

The new parts were to embody the manufacturing trends of the near future.[24,25] Extensive use was made of high strength/low alloy steels (HSLA). Forming and welding technology for these materials is just now evolving and their use is not yet commonplace in the quantities used in the RSV. Aluminum usage was limited to hood and hatch inner and outer panels in deference to recycling and raw materials energy considerations.[4] One- and two-side galvanized materials were not used on the RSV because of supply difficulties although they would be applied in many areas for corrosion protection on car designs currently being generated.

3.1.1 Front End Structure

Impact performance testing during Phase II showed an acceptable but not ideal response. A need for reduced vehicle pitch and occupant compartment intrusion to provide improved restraint performance[5,9] in frontal barrier impacts was identified. Reduction of steering column intrusion was considered desirable to reduce driver head and chest contacts. Dash intrusion reduction was also required to permit use of knee blocker restraints replacing the Phase II "semi-passive" lap belt, as well as to accommodate the use of air bags, should they be installed.[6,7] These changes resulted in a reduction of crush distance and were accompanied by significant increase in peak accelerations in high speed frontal impacts.[22] Accelerations about 50% greater than the 40 to 45 g at 72 kph (45 mph) to 80 kph (50 mph) goal set for body accelerations were found following dynamic barrier impact testing in Phase III.[15] Such levels had not been fully considered in earlier work since the computer simulations used were based on static crush tests which produced failure modes unlike those experienced in the final crash tests.[26] This was compounded by the fact that several small but significant changes were made between the early static testing and the final front structure evaluation crash tests. Subsequent computer analysis has identified the specific component force-deflection properties causing the high level accelerations. They indicate that little relief is possible without increasing either the desirable limited aggressivity or the passenger compartment intrusion; redesigning for more crush space and greater overall car length was another, but at that point impracticable, solution. Additionally, simulations of the structural response at lower barrier impact speeds have shown no significant reduction in accelerations - except below 48 kph (30 mph) speeds. This is not unreasonable in light of the nearly constanct force, constant mass nature of the RSV design. On the other hand, impact speeds greater than 72 kph (45 mph) are likely to be survivable with a restraint system which does not rely on the cowl/dash area for support. In general, however, the objective was that the basic impact performance levels for frontal barriers, offset car-to-car, limited aggressivity, low speed damagability and pedestrian impacts were to be retained.

At the start of Phase III, changes had been effected to provide the added length needed for the new 1716 cc engine. Many other modifications discussed below were incorporated to improve the front end structure of the RSV; in effect, it is entirely new forward of the dash. Drawings 95020, 95030 and 95040 in Appendix A, Volume II, show these parts.

3.1.1.1 Yoke Panel

The one piece yoke panel was changed in Phase III to accommodate an Omni/Horizon condenser and ESA module, RSV headlamp assemblies, and the new front end shape. Vertical reinforcements were changed from hat sections to z sections (see Figure 9) of equivalent strength to increase packaging space for front end components. They serve to frame the yoke panel opening, tie the upper and lower crossmembers together, and provide inboard mounting brackets for the front rails. Outboard gussets tie the outer rail surfaces to the lower crossmember.

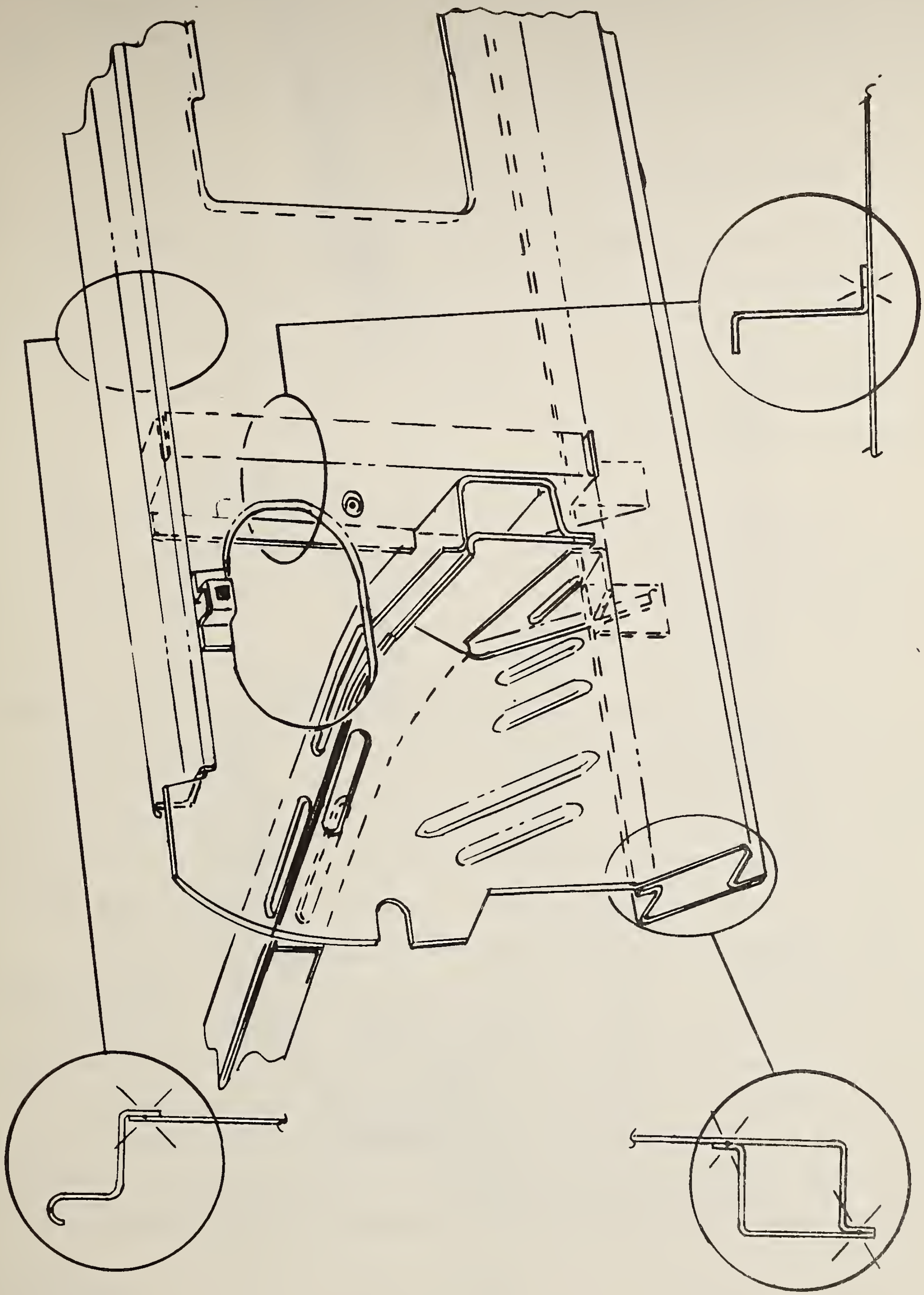


Figure 9 YOKE STRUCTURE – PHASE III

Upper and lower crossmembers were revised to provide sections equivalent to the Phase II design, but have a slightly different shape due to the front end restyling and spot welded construction used throughout. Drawing 95010, Appendix A, Volume II, shows the parts. The yoke panel and gussets are made of mild steel with HSLA used for the remainder.

3.1.1.2 Front Longitudinals

With the change made in Phase III from the 1442 cc engine and drive train, packaging requirements necessitated lengthening the longitudinals 83.8 mm (3.3 inches) and splaying them outboard 31.8 mm (1.25 inches). The length change was accomplished by adding 64.5 mm (2.54 inches) forward of the front suspension and 19.3 mm (0.76 inches) aft of it. The front rail or longitudinal is shown in Figure 10.

The original longitudinal was assembled from five basic parts - front outer, middle outer, rear outer, inner, and a rear extension. All parts are HSLA steel except the front outer panel which is mild steel to promote initial failure in impacts

Static crush testing and subsequent crash simulations showed that a problem existed in RSV vs. RSV front-to-side and front-to-rear impacts because the front longitudinals were too aggressive to the struck vehicle. Hence, the middle outer panel is notably thinner than the other parts to limit resistance and hence ensure compatibility in small car/large car and front-to-side impacts. Two slots were originally located in the upper surface of the inner panel adjacent to the thin middle outer panel to further assure limited aggressivity. The rear portion of the longitudinal assembly tended to be overly rigid in the area of the large clearance hole for the steering mechanism. Notches were, therefore, cut into both the rear outer and inner panels at the bottom of the flange surrounding this clearance hole to initiate a failure in this region during high speed frontal impacts. Design of this notch is critical since this part of the longitudinal must sustain rather high cyclic loading from the front suspension lower control arm. Final

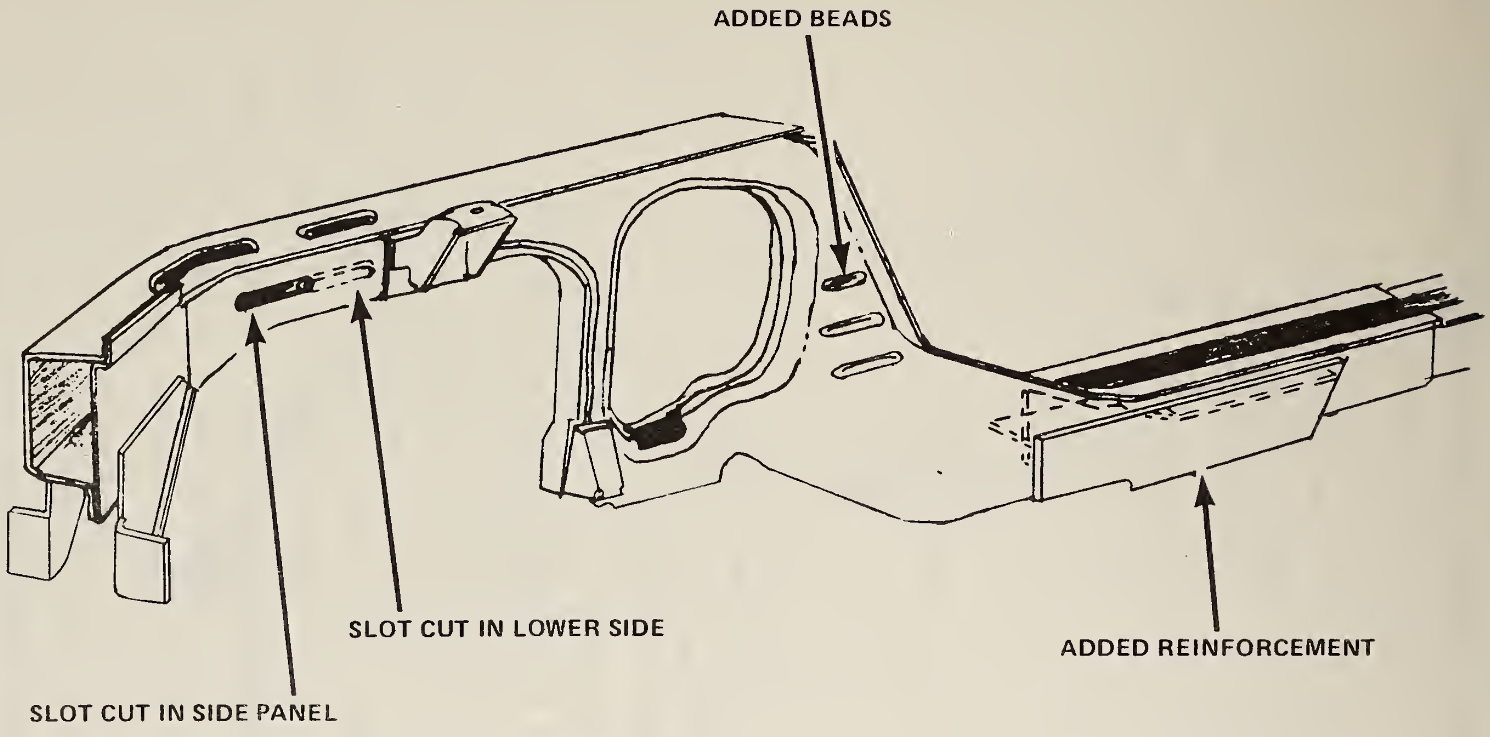


Figure 10 FRONT RAIL MODIFICATIONS

evaluation of the full success of the design cannot be accomplished until durability testing has been completed. Some compromise between crush.load and suspension load carrying could prove necessary.

The length of the inner and rear outer panels of the longitudinal was extended to provide greater overlap with the rear section and reduce the tendency of the longitudinal to bend rearward in the area of the toe pan/floor pan juncture. Because of the significant section reduction required in the longitudinal to allow it to pass under the floor just aft of the relatively stiff area around the steering clearance hole, the front rail of the Simca tended to bend up and aft, resulting in excessive intrusion in the floor pan area during high speed impacts. Increasing the overlap will reduce this tendency. Increased gage and a change to HSLA were the only changes made to the rear extension from the original Simca design.

Crash Test No. 3 (high speed frontal barrier impact at 74 kph (46 mph)) also indicated that several additional modifications were required to improve frontal barrier impact performance (see Figures 11 and 12). The primary modification was a reinforcement located just aft of crush zone III beneath the forward end of the front floor pan. This reinforcement reduces the rearward bending deformation of the longitudinal observed in Test No. 3 and in Phase II frontal impacts. That bending deformation and the resulting upper dash penetration, due to engine contact, had been considered acceptable during Phase II primarily because the Phase II restraint system utilized a semi-passive lap belt to restraint lower body motion rather than the knee bolster utilized in Phase III. Test No. 3 indicated that the upper dash penetration "bottomed out" the knee bolster, resulting in high dummy occupant femur loads and low upper torso loads, in turn, preventing the torso belt from stroking at the required load level. As noted, the pitch of the vehicle which led to the penetration was high in Test No. 3. The consequence of limiting upper dash penetration is a reduction in total available crush distance with attendant higher passenger compartment accelerations. It is essential, however, to limit dash penetration in cars with restraint systems that require the use of a knee bolster.

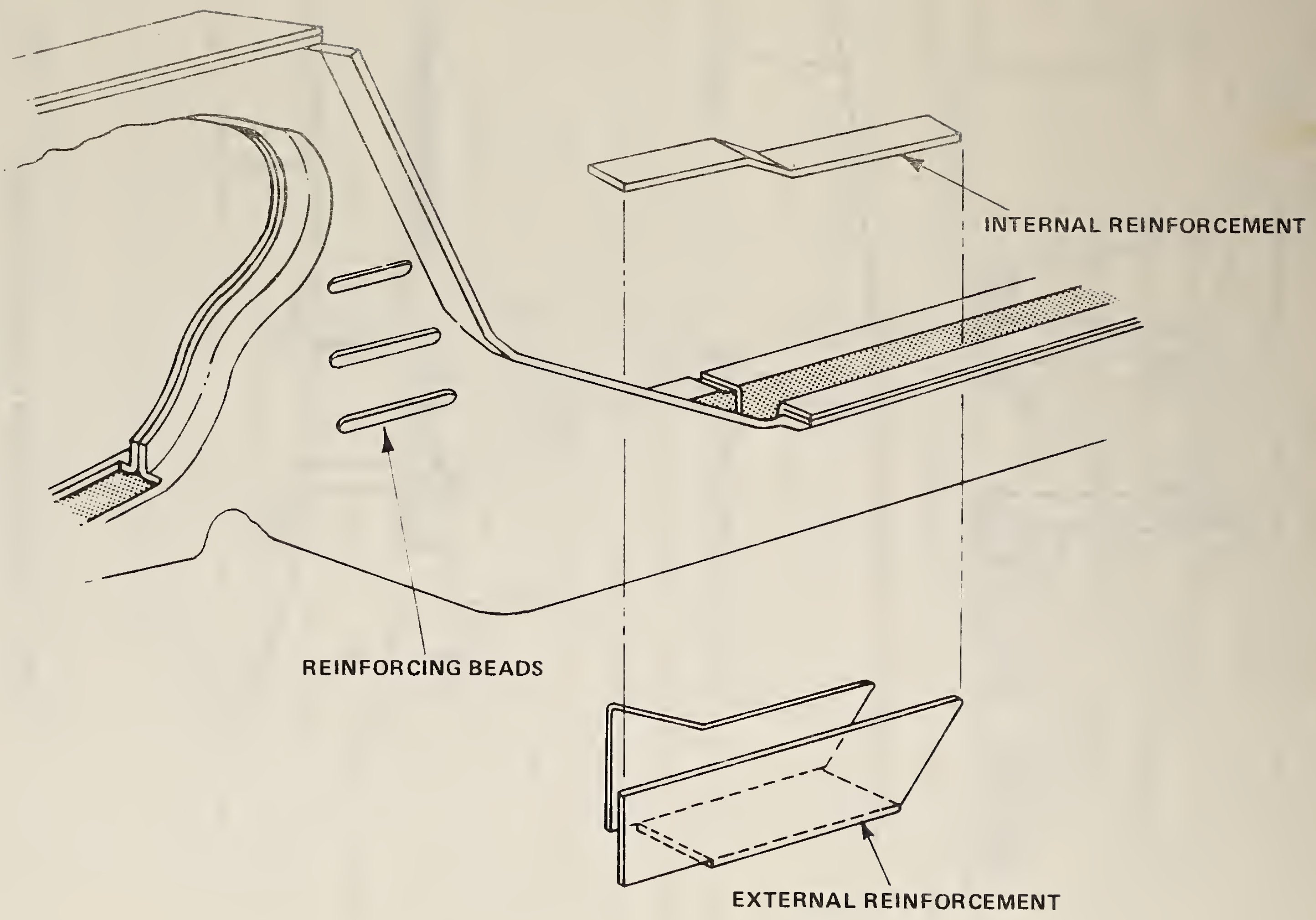


Figure 11 ADDED REINFORCEMENT (EXPLODED VIEW)

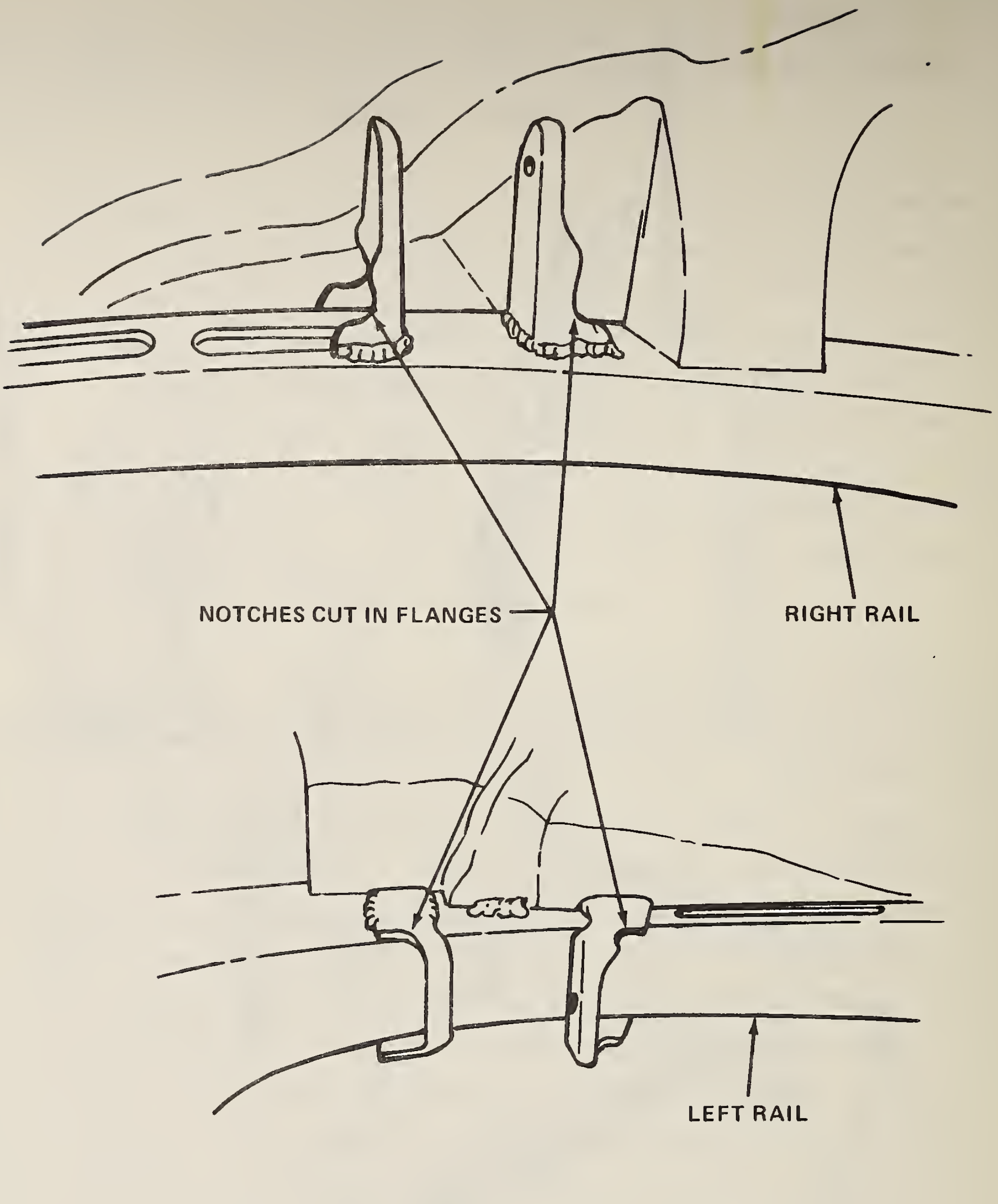


Figure 12 ENGINE MOUNT MODIFICATIONS

It is believed that the weight, gage, and cost of this front longitudinal reinforcement could be significantly reduced by design optimization based on more recent test results and further impact simulation. The floor pan patch over the reinforcement was specified primarily to allow access to the inside of the longitudinal for test vehicle modifications; it would be part of the floor pan on a production design. Further, for high production a separate reinforcement would undoubtedly be eliminated.

A high strength low alloy steel reinforcement (shown in Figure 13) was also designed to simulate a lap joint between the dash panel and the front floor pan. This was installed to ensure structural integrity at a location which showed joint separation in Test No. 3. Modification of both panels to form an actual lap joint was impracticable.

The front rail modifications, combined with the new upper load beam configuration described in the following paragraph, effectively eliminated vehicle pitch and dash penetration. This was demonstrated in high speed frontal barrier impact Test Nos. 9[13] and 10[14] in which both vehicles exhibited a high degree of structural integrity. The intent of the front structural design was to carefully balance the force levels developed in the front longitudinals with the forces in the upper load path beam and the total force required to absorb the energy levels expected in impact zone No. 2 (car-to-car compatibility) and zone No. 3 (high speed impact). This balance between upper and lower load paths relative to the RSV center of gravity would, therefore, restrict total car pitching during frontal impacts. There was no need to reinforce the longitudinals for low speed damagability as the forces desired for limited aggressivity were found to be consistent with the loads induced by the soft pedestrian protecting bumpers.[20]

3.1.1.3 Upper Load Path Beam

The upper load path beam was redesigned on the basis of Phase II impact test results to provide improved manufacturability and a better balance of upper to lower load path forces.

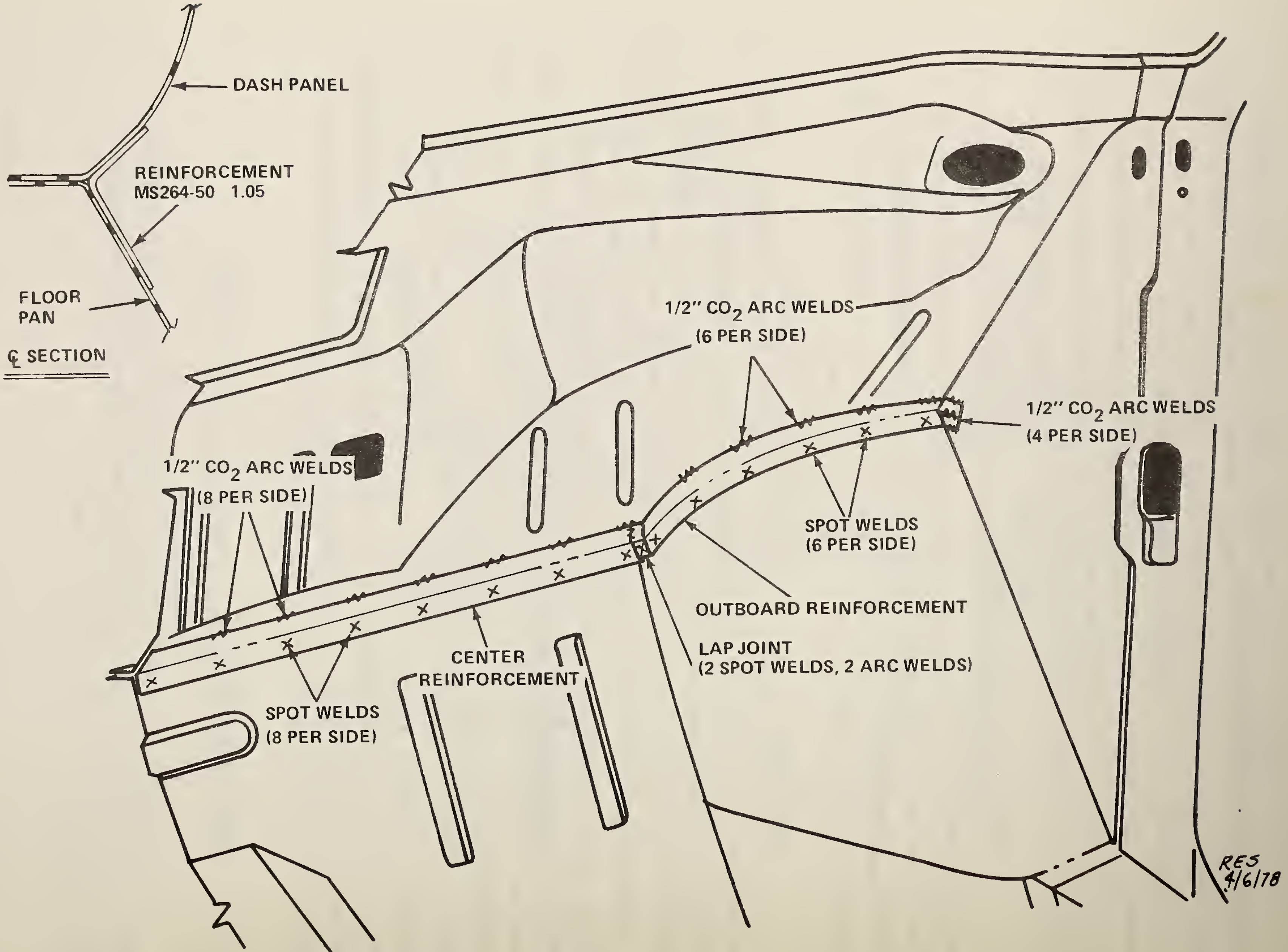


Figure 13 DASH TO FLOOR PAN JOINT

The Phase II load beam was of two piece construction and separated from the side shield. This design did not lend itself to high-speed assembly techniques.

The Phase III load beam outer (see Figure 14 and Drawing 95030, Appendix A, Volume II) is of one piece HSLA construction; the load beam outer is spot welded to the fender side shield which acts as a closure panel. Also incorporated is a better attachment to the cowl side and A pillar reinforcement. A weight reduction of 6.3 kg (14 lbs.) is also achieved.

As with the front longitudinals, the upper load path had to be balanced with respect to the vehicle center of gravity if pitch were to be minimized. For this reason, the upper load path beam does not extend all the way to the radiator yoke assembly. The initial crush force developed by the fender side shield, hood assembly, and fender balance the longitudinal satisfactorily. Extension of the beam would result in greater forces than desired. Since most low speed damagability contact forces are likely to be at the level of the front longitudinals rather than the upper beam, cutting them back is consistent.

3.1.1.4 Fender

The front fender is all new and resurfaced to accommodate the increase in length of front end sheet metal and relocated wheel opening. Its shape conforms to the new Phase III aerodynamic front end and still matches the original Simca door contours (see Drawing 95030, Appendix A, Volume II).

3.1.1.5 Fender Side Shield

The all new, mild steel, fender side shield reflects the increased length and engine accessory packaging necessary with the 1716 cc engine.

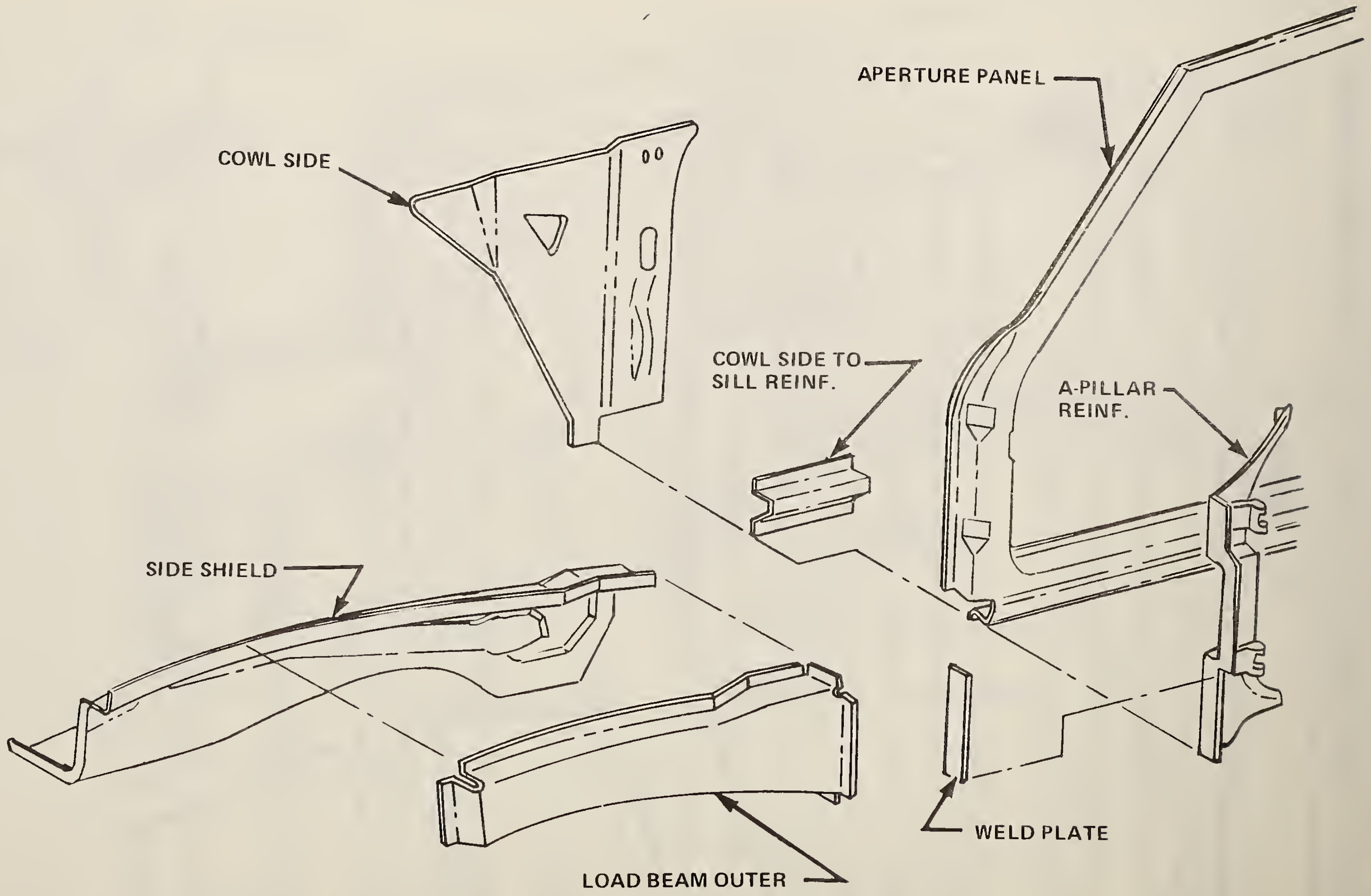


Figure 14 UPPER LOAD BEAM CONSTRUCTION – PHASE III

It also acts as the inner load beam closure for the full length of the load beam as well as supporting the yoke at its forward end (see Drawing 95030, Appendix A, Volume II).

3.1.1.6 Hood Assembly

The hood has been lengthened and resurfaced to match the rest of the new front end sheet metal. It has downstanding spot-welded flanges at the periphery with structural adhesive bonding inner and outer panels together. Aluminum was used for both the inner and outer panels for several reasons. Initially, weight savings was the primary factor. In addition, the softer material is less injurious to pedestrians. As determined in Phase II, use of aluminum had to be restricted to removable elements of the car if uncontaminated steel scrap was to be obtained from recycling centers. An all purpose type of aluminum is required which can provide the high surface finish needed on the outer and be drawn well enough to form the inner panel without causing cracks.

A major effect of the aluminum hood is the reduction of pedestrian head/torso contact forces during impacts. This may be as important as front bumper stiffness and shape in injury reduction. Finally, the lighter aluminum hood can be more easily lifted without a counter balance system. This results in further weight savings. Although the steel Simca hood did not use a counter balance, one would have to be considered on a medium size family car in the U.S. with a hood as heavy as the Simca.

A note of caution should be added here. In the interest of low weight, the RSV design does not employ any additional slam reinforcements in the area of the hood primary latch. Such reinforcement may prove necessary after results from the Phase III RSVs are available. Without it, considerable local denting could occur during closing.

The hood, shown in Drawing 95510, Appendix A, Volume II, is bolted to standard Simca hood hinges. An Omni/Horizon four-door hood prop is used, a new primary hood latch striker is located at the front, and new secondary strikers are located at each side mid-way along its length.

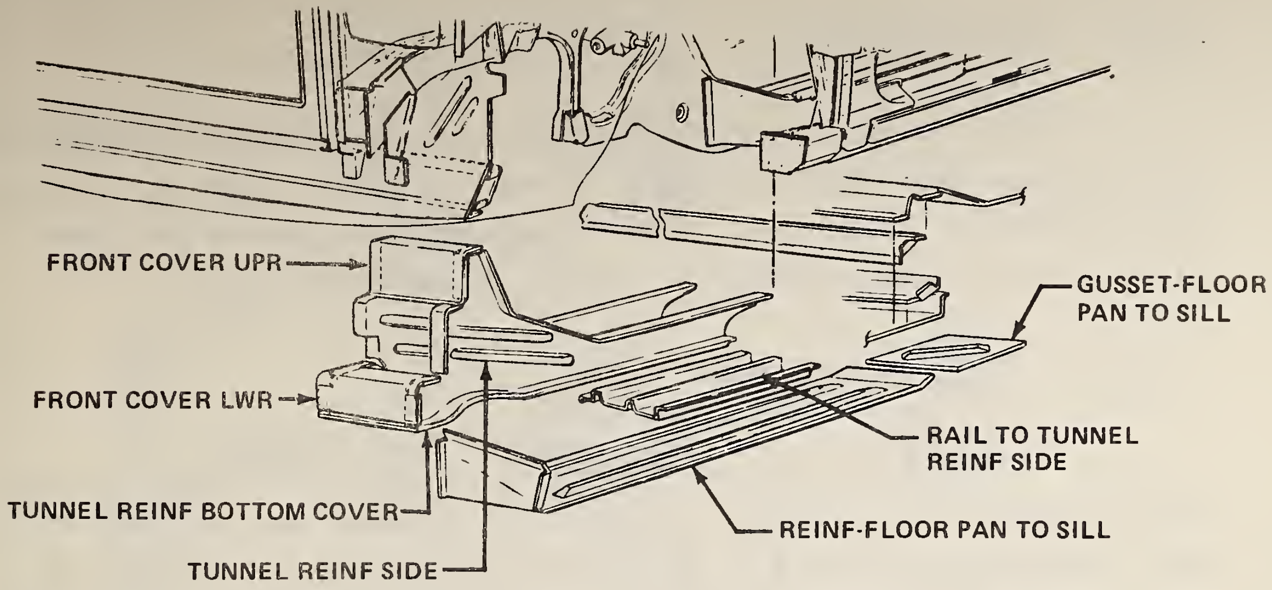
3.1.1.7 Cowl Top

The cowl top panel used in Phase III, as shown in Drawing 95040, Appendix A, Volume II, is a rework of the Simca panel. The panels were reworked to match the new hood surface which contains two predominant character lines near the outboard edges of the hood. The new cowl top surface was employed to blend these hood character lines into the body at the base of the windshield. A modification to the two cowl top inlet grilles is also required to reflect the same surface revision.

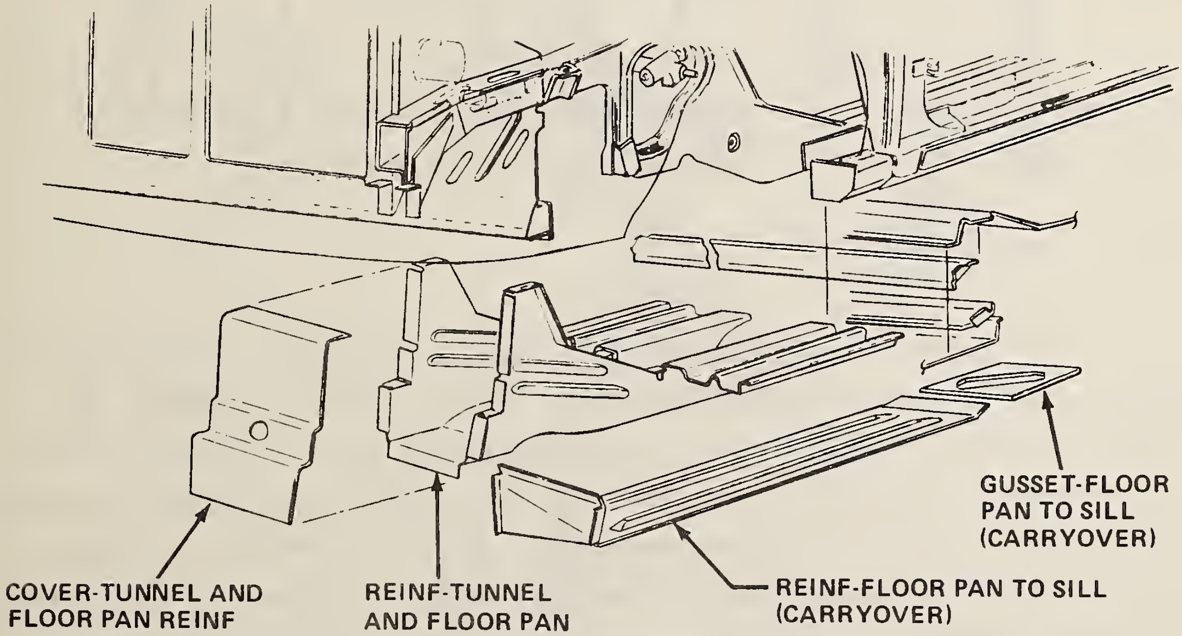
3.1.1.8 Tunnel and Floor Pan Reinforcements

The floor pan and tunnel reinforcement in Phase II was a multi-piece assembly which served to hold-off the lower suspension crossmember and steering rack at the floor pan when driven rearward by the engine during high speed frontal impacts. In addition, a reinforcement between the front rail and the sill below the floor pan was added to prevent the floor pan from shearing from the sill.

In Phase III, the tunnel reinforcement was redesigned to reduce piece count from seven to two (see Figure 15 and Drawings 95210 and 95220, Appendix A, Volume II) for a reduction of manufacturing, welding and handling cost, and to improve the overall producibility. The floor pan-to-sill reinforcement and gusset are from Phase II. Construction of all of these parts is of HSLA steel.



PHASE II



PHASE III

Figure 15 TUNNEL AND FLOOR REINFORCEMENTS

3.1.1.9 Cowl Side Panel

The cowl side panel (see Figures 7, 14 and Drawings 95120 and 95030) is a new panel made of HSLA, designed to act as a closure panel for the upper load path beam at its aft end. It also helps provide a better load beam/A pillar joint or load path than the Phase II configuration.

3.1.1.10 A Pillar Reinforcement

The A pillar reinforcement (Figure 14) is an external reinforcement for the lower A pillar, acting as a hinge reinforcement and load beam attachment. Depressions for welding of the door hinge body halves are provided, as well as spot welding flanges for attachment of the load beam. A local weld plate acts as a vertical stiffener.

3.1.1.11 Roof

The roof, shown in Drawing 95310, Appendix A, Volume II, is a carry-over Simca roof panel. This choice avoids tooling costs which would be encountered if a completely new roof panel were specified.

3.1.2 Side Structure

Performance specifications for the side structure, established in Phases I and II, limited exterior crush to between 200 mm (8 inches) and 300 mm (12 inches) for car-to-car impacts in the 65 kph (40 mph) to 80 kph (50 mph) range. A review of accident statistics indicating marked incidence of fatalities above that level of intrusion led to this decision. Dynamic testing in Phase II resulted in 206 mm (8.1 inches) of crush in a 63.5 kph (39.43 mph) RSV-to-RSV perpendicular side test. In view of the higher allowable limit of 300 mm (12 inches), the structural strength was reduced during Phase III. The RSV side structure is shown in Figure 16 and Drawing 95120, Appendix A, Volume II. Verification of the integrity of the revised

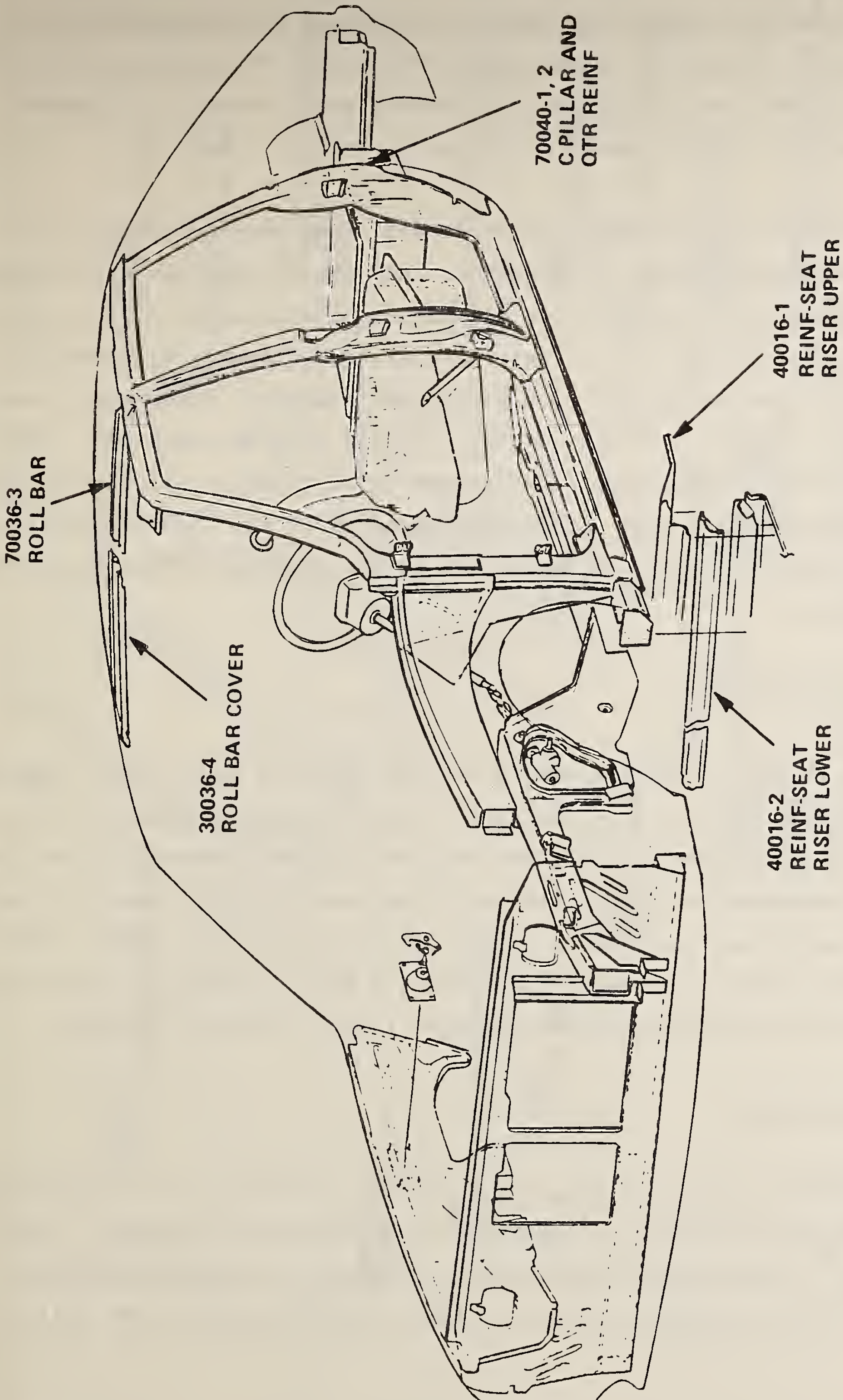


Figure 16 SIDE STRUCTURE

design was determined by both static crush testing and by dynamic crash tests. Excellent high speed side impact performance was demonstrated with crush limited to 185 mm (7.3 inches) in an RSV-to-RSV 90 degree side test[10] at 63 kph (39.1 mph) and to 234 mm (9.2 inches) when struck at 60 degrees from the front by a 1975 Plymouth Fury[12] at 51 kph (31.7 mph).

In view of these modest crush levels, some further reduction of side structure strength might be feasible. Any changes of this nature should be accompanied by close attention to the RSV front structural forces in the compatability zone No. 2. A very delicate balance of forces is needed to provide satisfactory RSV-to-RSV side impact performance. Other test formats which were not covered in Phases II or III should also be analyzed. Pole or similar concentrated load impacts and impacts with rigid or deformable moving barriers would be of concern. Since many elements of the side structure support loads from frontal, rear and rollover accidents as well, this is of particular concern.

3.1.2.1 Side Aperture

The Phase II aperture was .8 mm high strength steel (HSS) compared to .8 mm mild steel in the baseline car. Phase III cars returned to the mild steel aperture (see Figure 17) for the reduced allowable strength, cost, and formability advantages of mild steel for large panels. (Considerable forming difficulties were found in Phase II when forming this part of HSS.) Reinforcements were added in critical areas of A, B and C pillars to carry impact loads and assure satisfactory performance in terms of overall strength.

3.1.2.2 Sill Inner

The mild steel sill inner of 1.0 mm in the base car was increased to 1.4 mm HSS during Phase II to increase side structure integrity. Static crush testing[4] of each type of part early in Phase III indicated that the improved sill inner provided better B pillar weld retention at the bottom edge.

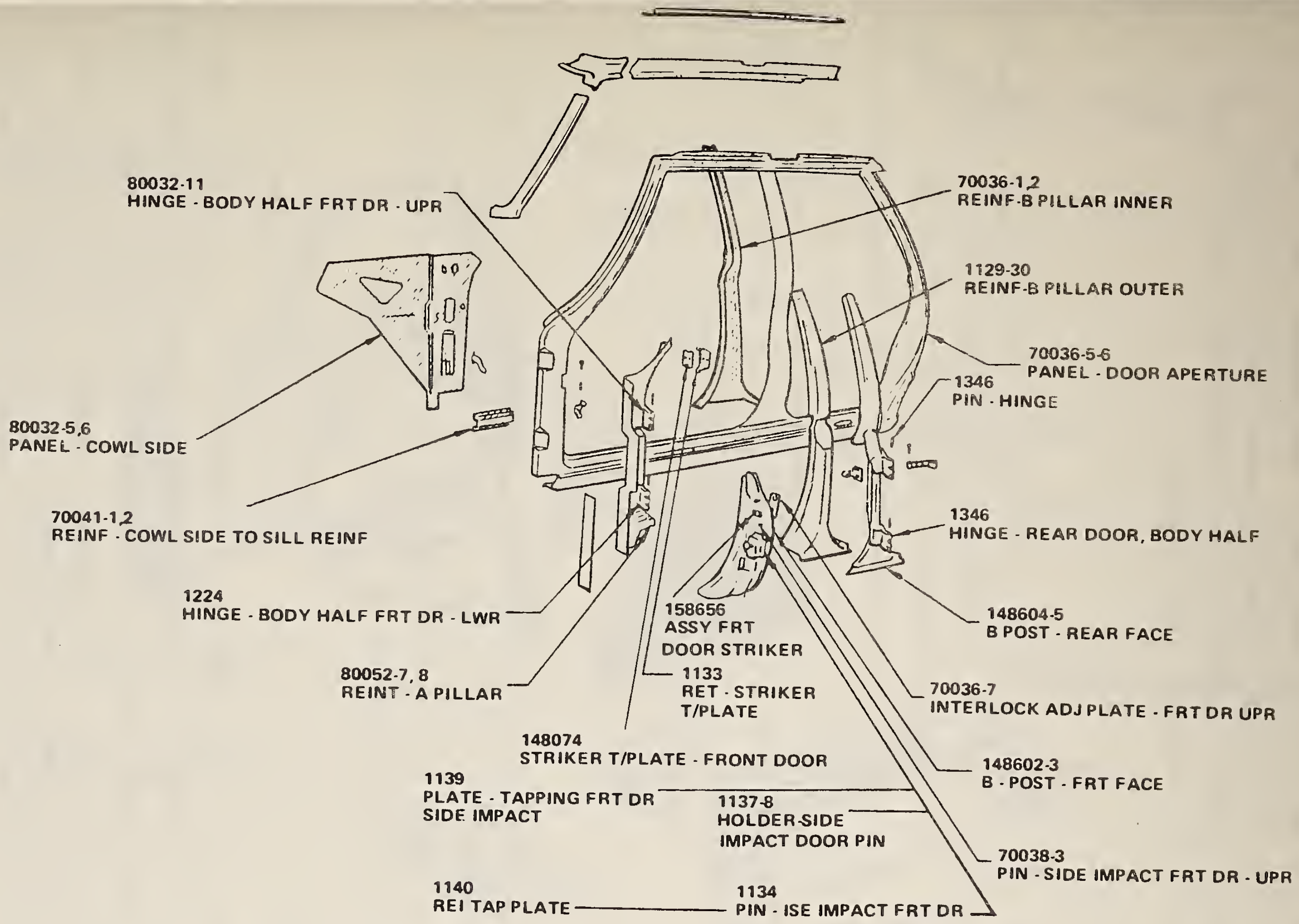


Figure 17 RSV APERTURE SYSTEM

Phase III test vehicles were built using both the base (1.0 mm mild steel) and improved (1.8 mm HSS) sill inner parts. Satisfactory results were obtained with both sill inners during side impact testing. Therefore, the Phase III specification was changed to the original Simca part for manufacturing simplicity, cost and weight reduction.

3.1.2.3 B Pillar

The baseline Simca 1308 B pillar consists of a two-piece construction of 1.2 mm mild steel welded to the aperture. The Phase II and Phase III designs utilize a four-piece construction (see Figure 17). The major strength improvement in the Phase II RSV was accomplished by adding high strength steel inner and outer reinforcements 2.0 mm thick. The relatively low intrusion experienced during Phase II testing indicated retention of the original baseline Simca 1.2 mm mild steel B pillar components, along with the high strength steel reinforcements would be satisfactory; subsequent side impacts confirmed it.[10,12]

3.1.2.4 C Pillar

Improvements to the C pillar during Phase II consisted of adding a lower reinforcement of 2.0 mm HSS and a gusset to the wheelhouse of 1.7 mm HSS. These two pieces were combined in Phase III to improve producibility (see Figure 16). The new material is also HSS 1.8 mm gage.

3.1.2.5 Doors

The Phase II door improvements consisted of full height door beams (1.8 mm HSS) with extensive door beam end supports, hinge pillar reinforcements and latch surface reinforcements. The cross section of the door beams was optimized during Phase III to allow a gage reduction to 1.4 mm HSS with only a slight decrease in strength (see Figures 18 and 19, Drawings 95130 and 95140, Appendix A, Volume II). In order to improve door hinge retention of

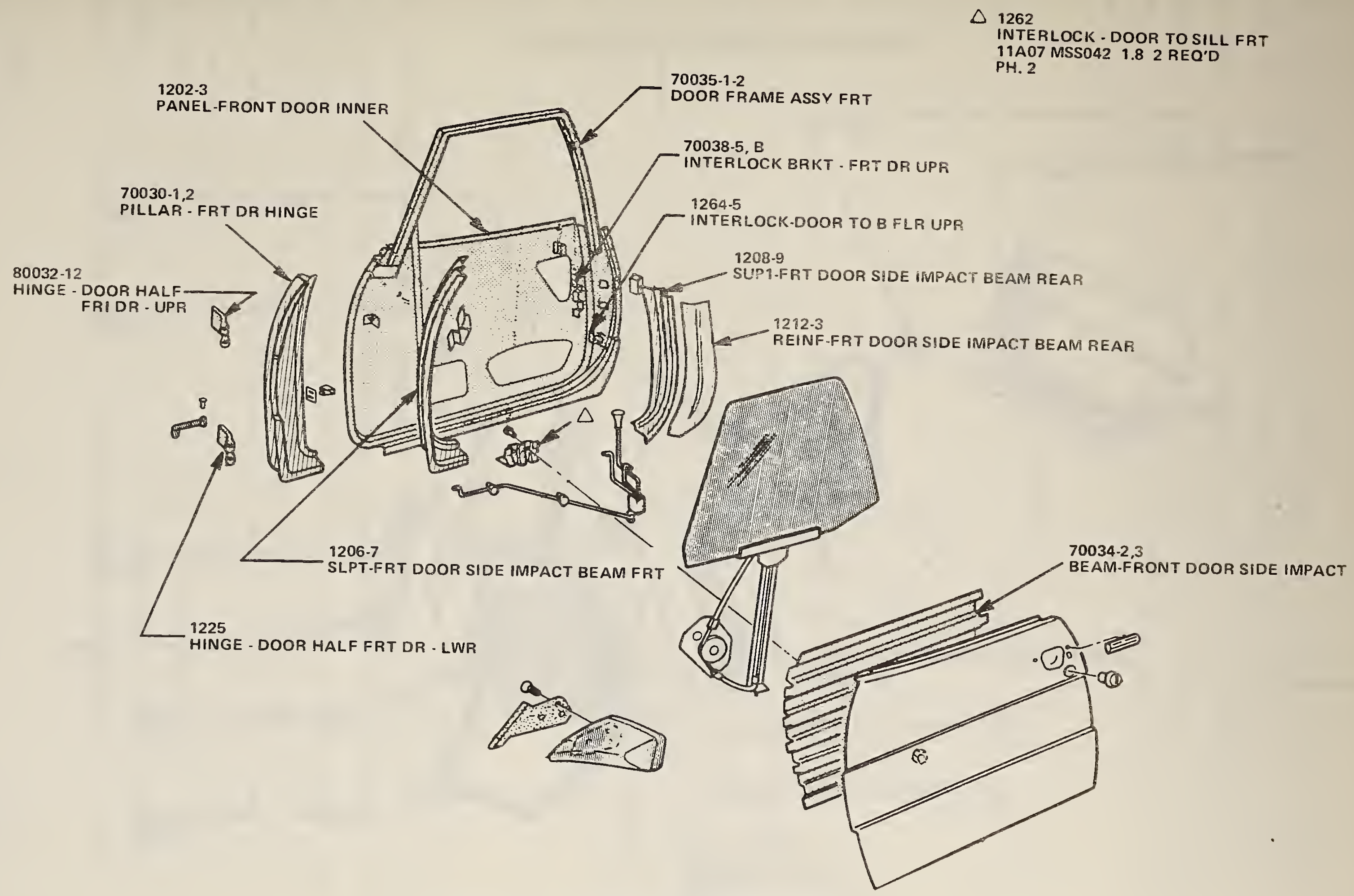


Figure 18 FRONT DOOR STRUCTURE

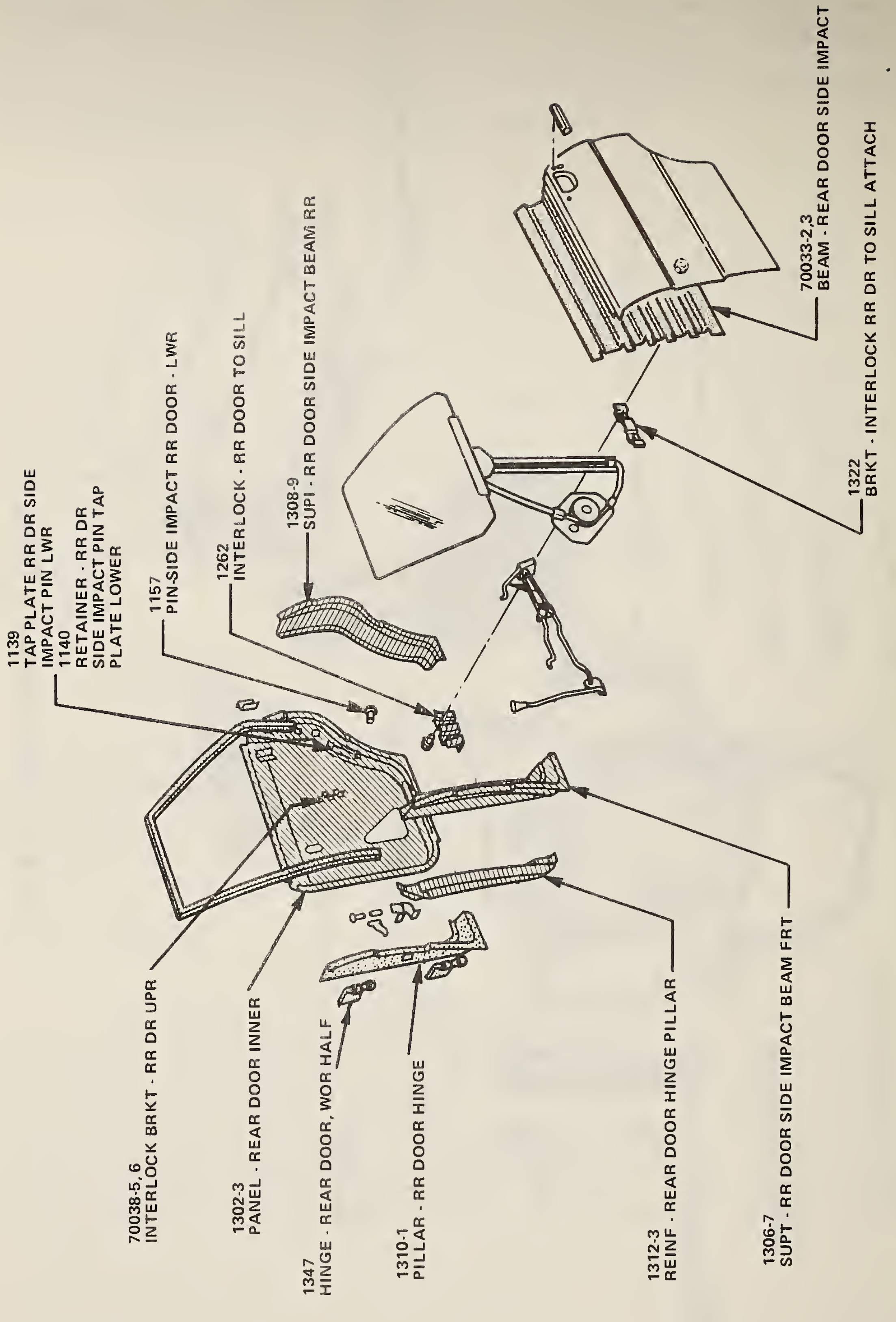


Figure 19 REAR DOOR STRUCTURE

the front door, the hinge pillar reinforcement (1.8 mm HSS) was eliminated while the strength characteristics were retained by increasing the gage of the hinge pillar from .7 mild steel to 1.8 mm HSS. This allowed improved welding of the door half of hinge to the hinge pillar outboard of the hinge center line (see Figure 24). A weight reduction of .5 kg (1 lb.) for front doors resulted.

While the doors of the RSV are one of the more complex components and result in the rather large increases to car weight and cost, they are designed to provide several structural functions. They serve as longitudinal columns in frontal and rear impacts and, because the effective length is nearly as great as the door opening, they contribute significantly to retaining the door during impacts. Because the total height is reinforced by the beam, the door functions well in side impacts regardless of the height of the striking object. The strong tie to the door hinges and locks is further enhanced by the use of substantial door hinge and lock pillar parts. The reinforcements allow the door interlocks at the rear and bottom of the doors to be securely attached to rather rigid members which, in turn, prevent "extruding" the door through the opening during severe impacts. The result is a well integrated design which maximizes results at minimum weight.[10,12]

3.1.2.6 Seat Riser Reinforcements

Test results from Phase II showed that the floor pan structure was not strong enough to transmit high side impact loads across the car in spite of the relatively large box beam element formed by the front and center floor pan joint area in the base Simca. This was due in part to the rather thin gage mild steel used and in part to its location somewhat forward of the B pillar area where it would be preferred but where it would interfere with rear seat occupant foot room. Two full width seat riser reinforcements of 2.8 mm HSS were added in Phase II (see Figure 7 and Drawing 95220, Appendix A, Volume II). In conjunction with the overall reduction of side structure in Phase III, both the upper and lower reinforcements were reduced in section size and a weight savings of .5 kg (1 lb.) was made. The upper reinforcement was reduced in gage to 1.9 mm HSS and shortened to bridge only the tunnel width. The lower reinforcement gage material remained 2.8 mm HSS.

The primary purpose of the seat riser reinforcements is to prevent the floor pan from buckling during high speed side impacts. These parts, combined with the added roof roll bar reinforcing, contribute significantly to the reduction of interior intrusion during side impacts.

3.1.2.7 Roll Bar

During Phase II a roll bar of 1.7 mm gage HSS replaced an existing Simca 1308 roof bow between the B pillars to prevent excessive roof crush in case of vehicle rollover and, more importantly, to provide an upper load path for side impact forces entering through the B pillars. To increase the head room for the front seat occupant in Phase III, the roll bar vertical height was reduced and it was moved rearward (see Figure 16 and Drawing 95310 in Appendix A, Volume II). Offsets were added at the outboard ends near the roof rail to retain the tie to the B pillar while placing the main center section farther aft than in Phase II. The gage was increased to 2.9 mm in HSS to retain the same strength as the straight Phase II design. The weight remained the same at 4.2 kg (9 lbs.).

3.1.3 Rear Structure

Rear structure changes for Phase III were made in three areas. Their efficacy was demonstrated in rear impact tests.[7,9,15] The first change, based on Phase II impact testing results, was to reinforce the rear side rail to provide additional strength and protection for both the occupant compartment and the fuel tank in high speed rear impacts. The Simca rail makes a transition in both plan and side views; the Phase II change was to straighten the rail by moving the rear portion inboard one inch to provide a better load path as well as an additional clearance for the fuel fill tube.

The second change was to improve the design of the fuel filler routing in the right hand quarter panel assembly. During Phase II it was relocated to a position forward of the crush zone above the rear wheel opening rather than behind it as in the Simca 1308. The number of parts in this region could be further reduced from the Phase III design in high volume production to provide lower cost, lower weight, and a more easily assembled configuration. Parts are shown in Drawings 95320 and 95220, Appendix A, Volume II.

The third change was made to accommodate and adequately support the rear bumper. The specific constraints are detailed in the rear bumper analysis section of this report. The complexity of the assembly for this design could be reduced by the restyling and redesign required for high volume production.

Three-piece construction was used in the Phase II luggage well design. The center piece, composed the lateral walls and floor, was corrugated to promote collapse during a rear impact. The design has been changed to avoid difficulty in stamping the corrugated part. The center panel will have a flat floor with a shallow X pattern depression for stiffening and two shallow dimples on each lateral wall to promote collapse during impact.

3.1.3.1 Liftgate

For both Phases II and III, the liftgate was stamped in aluminum from production tools designed for steel stampings by Chrysler/France specifically for the RSV. The only modifications made to these panels were the addition of patches welded to the rear of the original aluminum panels to accommodate the rear spoiler and a relocated latch and key cylinder. The liftgate was assembled using a structural adhesive in a manner simulating current production line techniques. The aluminum material selected required the same considerations for alloy compatibility between inner and outer panels to permit reclamation as described in Section 3.1.1.6 for the hood. The liftgate assembly can readily be removed, so it too was made of aluminum for the weight saving effect while still providing uncontaminated scrap from wrecks. The liftgate and associated parts are shown in Drawing 95320, Appendix A, Volume II.

3.2 Packaging

The packaging of the occupants is summarized in the table below. More specific dimensions are included in Section 5.2.

Roominess Index	mm	inches
Front Headroom	95.25	37.5
Rear Headroom	91.69	36.1
Front H-Point to Heel Pt. Vert.	21.34	8.4
Front Leg Room	103.76	40.85
Rear Leg Room	85.98	33.85
Front Shoulder Room	123.70	48.7
Rear Shoulder Room	129.03	50.8
TOTAL	650.75	256.20

Total Interior Volume - 2.69 m^3 (95.103 ft^3)

EPA Cargo Space - .538 m^3 (19 ft^3)

3.2.1 Engine Compartment

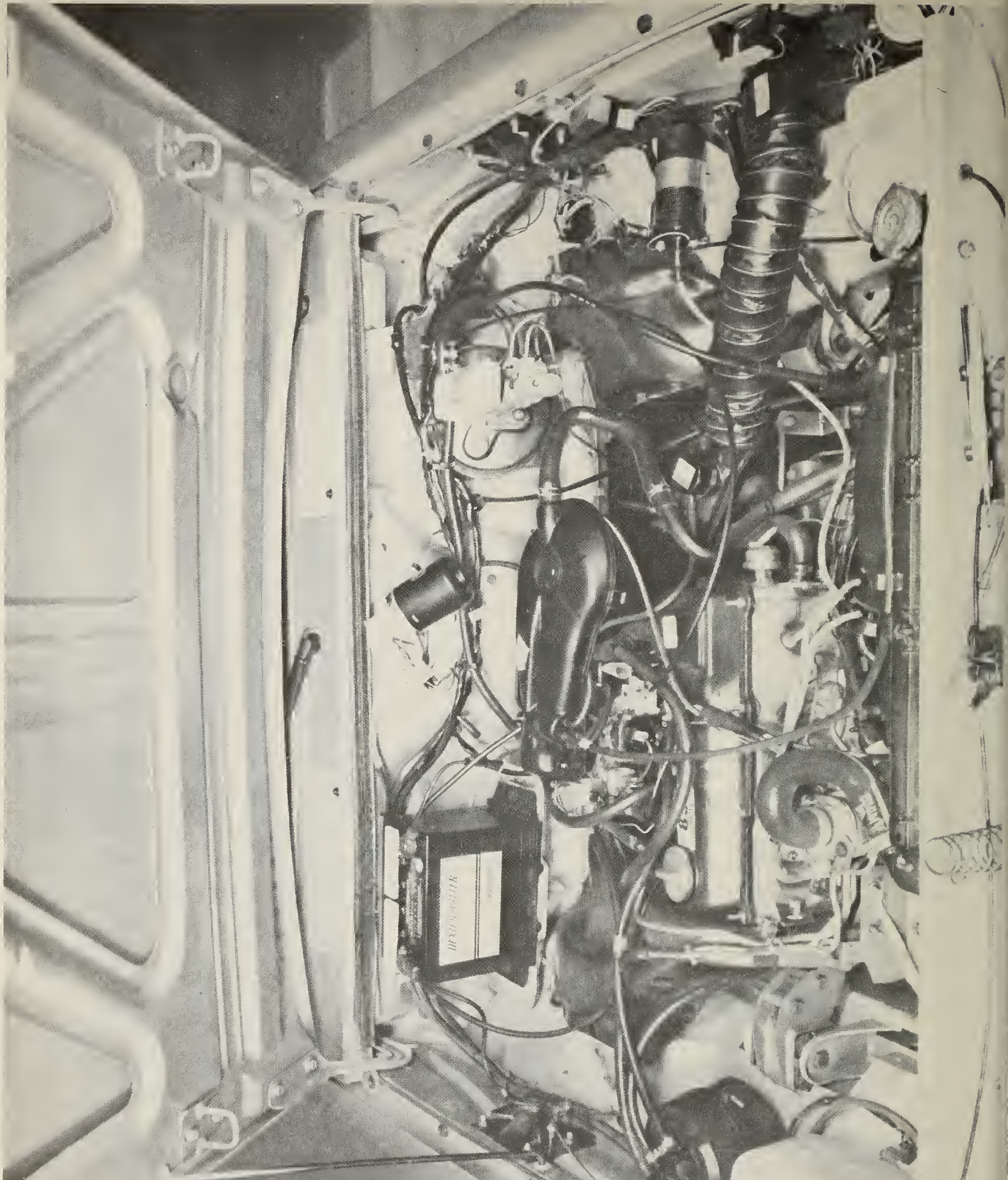
The decision to switch from the Simca 1442 cc powertrain to the 1716 cc powertrain of the Omni/Horizon in Phase III brought with it major revisions to the RSV engine compartment. In addition to the wheelbase increase, the front overhang from wheel centerline to yoke was increased 65 mm (2.56 inches), hood height at the yoke panel was increased 14 mm (0.55 inches), and the rails were splayed 32 mm (1.26 inches) outboard per side. These modifications were required to provide space for the new engine and cooling system and for options such as air conditioning, power steering, and anti-skid brakes. In addition, the following components were either added or relocated in the engine compartment as shown in Figure 109, page ii of Volume II:

- Omni/Horizon Windshield Washer Bottle and Pump
- Coolant Recovery Bottle
- ESA Module
- Evaporative Emissions Cannister
- Diagnostic Connector
- Ignition Coil
- Starter Relay
- Voltage Regulator
- Ballast Resistor
- New Domestic 45 amp-hour Battery
- Crash Sensors

Finally, the windshield wiper motor was rotated 120 degrees clockwise from the Simca 1308 position to avoid being hit by the carburetor in frontal collisions and violating the occupant compartment (cf Section 3.9.1.2). The final engine compartment configuration is shown in Figure 20. In addition, Drawings 90010 through 90120 in Appendix B, Volume II show the installation of the various ancillary equipment. While the relative location of none of the engine compartment components is changed, the engine location in the compartment is slightly altered when an automatic transaxle is specified. See Section 4.1 for details.

3.2.2 Seating Arrangement

Early in Phase III, the decision was made to retain the Simca 1308 body width and the consequent encroachment on occupant space by the trim panels rather than incurring costs associated with widening the car. For the majority of the population, the available space is acceptable. The front hip room has been decreased by 140 mm (5.51 inches) to 1249 mm (49.17 inches) from the base Simca's 1389 mm (54.69 inches) by the new door energy absorbing



trim panels. The effect of this change is minimal in the front seating positions because of the bucket seats. By eliminating the rear seat arm rests, the rear hip room has been increased by 70 mm (2.76 inches) to 1355 mm (53.35 inches) in comparison to 1285 mm (50.59 inches) for the 1308 base vehicle.

The front seat shoulder room in the RSV also has been reduced compared with that of the base car. The reduction of 112 mm (4.41 inches) to a total of 1268 mm (49.92 inches) is again due to addition of the energy absorbing trim panels. Because the arm rests are designed as pockets in the trim panels, this loss of shoulder room does not appear to be objectionable. The seats themselves are shown in Drawings 95450 and 95460 in Appendix A, Volume II.

The published capacity of present production cars is based on the number of seat belts provided in the car, rather than on vehicle width or available shoulder/hip room. Thus, if the RSV is equipped with three rear seat belts, its rated occupant capacity would be five. With a rear shoulder room dimension of 1352 mm (53.23 inches), the RSV falls between the Dodge Colt Sedan and the Plymouth Volare Sedan in roominess. [The Colt has a rear shoulder room of 1270 mm (50.0 inches) while the Volare is 1412 mm (55.6 inches).] The Colt is designed for two in the rear seat while the Volare's rear seat is designed for three passengers.

The width of the 50th percentile male shoulder is 455 mm (17.9 inches). If three were sitting abreast in the rear seat of a car, the minimum required dimension would be 1365 mm (53.7 inches), 13 mm or about 1/2 inch greater than available in the RSV. This might crowd the passengers, particularly if bulky clothing were worn. On the other hand, room is available in the rear seat of the RSV for the following combinations:*

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*These dimensions were established in accordance with USA Male and Female Physical Dimensions for Construction and Industrial Equipment Design, SAE J833a.

- Two 95th percentile adult males 986 mm (38.8 inches)

- Three 95th percentile thirteen year old males 1250 mm (49.2 inches)

- Two 95th percentile adult males and one 95th percentile seven year old male 1306 mm (51.4 inches)

- Two 50th percentile adult males and one 95th percentile twelve year old male 1295 mm (51.0 inches)

- Three 50th percentile adult females 1219 mm (48 inches)

3.2.3 Luggage Compartment

The luggage capacity of the base Simca 1308 is 0.361 m^3 (12.75 ft^3). However, the luggage capacity range specified for the RSV is 0.396 to 0.538 m^3 (14.0 to 19.0 ft^3). After eliminating the spare tire and reducing the size of the fuel tank to a capacity of 44.9 liters (11 gallons), a portion of the rear floor pan was replaced with a floorwell to provide the desired increase in luggage capacity. The floorwell (shown in Drawing 95220, Appendix A, Volume II) is a three-piece welded mild sheet steel construction consisting of two stamped end caps and a center band. The SAE J1100a capacity of the luggage compartment is now 0.422 m^3 (14.92 ft^3) which falls within the desired range. As noted previously, the EPA cargo space is 0.538 m^3 (19 ft^3). The use of flatproof tires on the RSV eliminates the need to provide a spare tire and jacking system. It is possible to stow a B78-13 space saving spare tire with inflator bottle and the base car single scissors jack within the floorwell, but the luggage capacity would revert to that of the Simca 1308 base vehicle.

3.3 Bumper System

The philosophy behind the RSV bumper system design was to achieve the improved pedestrian protection without increasing production or repair costs and to improve aerodynamics and appearance without conflicting with the basic goals of the Federal Motor Vehicles Safety Standards.[1] In fact, current regulations were not to be a constraint on any portion of the RSV design where new approaches might provide additional overall safety. FMVSS 215, for instance, does not presently consider pedestrian safety; the proposed RSV design, which does, is a major departure from current systems. One of the primary objectives of the RSV program was to develop a bumper system to provide improved levels of both pedestrian and exterior vehicle damage protection.[3] To that end, the bumper design effort was directed toward the development of a novel, full-face, soft front bumper system.[27] Since the RSV front bumper system requirements are much more stringent than those for the rear system, it was believed that if the front system development were satisfactory, then similar application of the concept to a somewhat simpler rear system later would be straightforward.

The front bumper design evolved from guidelines developed in the Phase I study. The design was based on extensive computer simulation of pedestrian impacts during the development stage and was tested under both flat barrier and body block impact conditions. The final system, discussed in the next section, was evaluated in a series of low speed barrier and car-to-car collisions.

While the primary reason for selecting a soft, recoverable bumper was to improve pedestrian protection, this approach is also consistent with improving low-speed damage protection. The specific performance criteria are delineated below.

Front System

- When impacted at 22 mph, the acceleration of a vertically oriented body block weighing 100 lbs. shall not exceed 60 g's for the time interval of more than 3 msec.

- Eliminate all non-functional surface protrusions and provide a smooth contour and breakaway properties for all functionally necessary components.

- Collapse along the face should occur at 20 psi and shall not increase significantly up to six inches of deformation to reduce contact forces on the pedestrian's torso and lower extremities.

- The profile shall effectively control the pedestrian's kinematics and match his post-impact forward velocity as closely as possible to that of the vehicle.

- For flat fixed barrier speed of at least 8 mph and for front-to-rear impact speed up to 12 mph, no damage shall occur on the vehicle structure. Damage is allowable on the bumper contact surface and energy absorbing mechanisms; however, the subsequent cost to repair this damage shall be less than the cost of providing a completely damage resistant system.

- Air flow through cooling slots shall be adequate for engine cooling.

- Reduction of aerodynamic drag shall be considered in selecting the bumper shape.

- The system shall allow for proper mounting of the headlamps.

- The material shall be compliant and retain its shape in the temperature range of -20°F to 120°F.

- The design shall be consistent with the general cost, weight, producibility, and material reclamation goals of the RSV program.

Rear System

- No upgrading over conventional rear system impact performance and design practice is required.

- Energy absorption for flat barrier impact should be provided for an impact speed range of 2.5 to 5 mph.

3.3.1 Front Bumper

The decision to utilize a soft type front bumper system was made during Phase I. Analysis of accident statistics indicated a large number of pedestrian fatalities - as many as 10,000 in 1973. Further study of these accidents showed about half of the fatalities to be caused primarily by vehicle contact and half by ground contact after impact. An even more detailed review revealed that over 90% of those receiving fatal impacts were struck by those parts of the car within about 250 mm (10 inches) of the front. The RSV design addresses this problem. Preliminary computations indicated that a bumper system having local deformation capabilities that would keep forces below the levels generally considered sufficient to fracture bones could, when struck by a full width vehicle such as another car or a barrier-type fixed object, provide sufficient energy absorption to permit damage-free collision protection at speeds of 8 to 16 kph (5 to 10 mph).

The Phase I study[1] included low speed damagability considerations of the bumper system. Insurance reports indicated that most low speed damage occurs to the front of cars. Also, most accidents involve the front of one car and the rear of another. Since energy absorption occurs at both ends of the car, the capabilities required of the rear bumper may be reduced if the front is increased. Further, the overall cost savings may be greater if the front has a higher low-speed impact capability since the front is more frequently involved than the rear. Therefore, specifications were established to include a force limited body block impact combined with a car-to-car and a barrier impact.

Early in Phase II, whole body effects of the bumper system began to be of concern. A limited investigation of the effects of front end shape and energy absorbing foam characteristics, utilizing the Calspan 3-D occupant crash victim simulation computer program was initiated at Chrysler. While limited in scope, the study did cover 50th and 95th percentile males and 22.7 kg (50 lbs.) children, braking and non-braking cars, and vehicle pitch attitudes - all with a variety of front end shapes and stiffness characteristics. The findings[27] indicated that a rounded shape with crush characteristics similar to those obtained in the RSV would provide optimum results in limiting head and torso forces and accelerations and in reducing the velocity of the pedestrian relative to the ground (thereby tending also to minimize ground impact forces). It was found that shapes and force-deflection properties significantly different from those used on the RSV resulted in higher forces and accelerations on the pedestrians regardless of whether the shapes had higher or lower initial contact points or had heavier or lighter forces. An additional finding was that the force-deflection properties of the hood could have a major effect on occupant impact forces. For this reason, as well as for the weight savings, the RSV hood is constructed of aluminum rather than steel. Urethane or other plastics were considered for the hood, but were discarded because the combined effects of the engine temperature and sun radiation loads could cause severe distortion of the hood panel.

The difference in pedestrian impacts occurring during daylight from those after dark was studied since the deformable bumper approach would necessitate keeping the front lighting components aft of the crushable area so they would not be broken. Aerodynamic considerations would tend to favor a lighting system giving minimal airflow disturbance. A concealed headlamp design appeared favorable since it would give better fuel economy than a recessed headlamp. The latter would have increased aerodynamic drag at all times and expose the pedestrian to a discontinuous front end shape. The study tended to be somewhat inconclusive since more pedestrians were involved in daytime impacts, but the severity of impacts after dark was greater. Based on the lower weight, complexity and cost, a fixed recessed headlamp was chosen.

The elimination of the front-mounted license plate is another feature of the RSV design. In spite of several state law requirements, limited space and pedestrian safety considerations resulted in a front end design without a license plate attaching area. As cars get small and engine temperatures increase with added emissions equipment, resulting in a requirement for added cooling air inlets, space to mount front license plates will become more difficult to obtain. The metal plates, however, certainly present some degree of pedestrian hazard. Limitation of aerodynamic design was still another reason for removal of the license plate.

The turn indicator/parking lamp location also received some attention. Placement above the primary impact band would make the lamp more visible but would cause either the headlamps or turn lamps to be rather close to the car centerline if placed side by side and make identification more difficult. If placed one above the other, they would increase front end height, causing additional aerodynamic drag and reduced pedestrian protection capability. For these reasons, the turn lamps were located below the primary bumper impact band.

Aerodynamic considerations influenced Phase II shape; the rather rounded upper profile suggested by the pedestrian impact simulations is fully consistent with aerodynamic requirements. In an attempt to maximize engine cooling with minimal intake opening size, a large lower air dam and intake area were designed into the bumper below and aft of the primary impact band so that pedestrian contact would not occur.

Testing during Phase II indicated that the RSV damagability goals for car-to-car and frontal barrier impacts could be met. Pendulum impacts were also conducted and, while the complete series required by FMVSS 215 was not undertaken, general compliance was shown to be realizable. In fact, with the RSV type of design (in which all areas forward of the radiator yoke are deformable), the requirement for a pendulum test appears superfluous. The primary purpose of this standard seems two-fold. Firstly, it limits vehicle damage in low speed impacts and secondly, it enforces commonality of bumper heights. A simple barrier test can be used to assure the first requirement. The need for a universal bumper height is nonexistent with the RSV front end design. In fact, the RSV achieves an even greater degree of compatability between cars than does the current FMVSS 215. The current standard does not affect differences which can occur due to vehicle loading and to dynamic suspension inputs such as bumps, braking or acceleration. Bumpers such as the RSV design on the other hand could accommodate all of these effects and still provide a degree of low speed impact damage reduction equivalent to that of FMVSS 215.

Pedestrian impact testing conducted by Batelle Memorial Institute[28] verified the improvements provided by the RSV bumper system. At impact speeds up to 40 kph (25 mph), pedestrian acceleration levels were reduced by as much as half relative to current production cars. Further testing is certainly required as well as the possibility of a low volume production tryout to determine if vehicles having this type of system fulfill the life and injury saving potential identified by the RSV.

These concepts from Phase I and II were carried over essentially unchanged into the final design. Aerodynamics received greater attention than in Phase II. Wind tunnel testing of a full scale RSV incorporating a variety of concepts was accomplished (see Section 4.10). Advantages were shown for a larger plan view radius on the front corners, revised cooling, a slightly reshaped lower air dam, better coverage of the front surface of the front tires, an additional front air dam below and behind the one in the Phase II design and fixed covers over the headlamps.

A secondary benefit of the soft bumper concept is that the full ducted inlet to the radiator improves cooling. This was demonstrated during cooling evaluations at the Chrysler Proving Ground and resulted in an air inlet area smaller than would have been specified for a conventional front end design. At high speeds, all incoming air is forced through the radiator without any escape to the sides or below. When stationary, heated air from the engine compartment cannot recirculate around the periphery of the radiator. The Phase III secondary air dam also contributes to this effect and, since it is made of the same flexible material as the fascia and integral with it, it should sustain impacts and scrapes from rocks, curbs, etc. satisfactorily in spite of its proximity to the ground.

Weight saving is yet another benefit of importance in this case since the bumper is forward of the front axle on a car already with a forward weight-bias due to the front wheel drive. With a total system weight of 77 kg (35 lbs.), the bumper is only about half the weight of a conventional front bumper, grill, lower valance, etc. (depending on the particular design chosen).

The front bumper is shown on the car in Figure 21 as well as in other pictures of the RSV and in Drawing 95010 in Appendix A, Volume II. The front of the RSV was completely resurfaced during Phase III to accommodate the change back to 13 inch wheels and installation of the 1716 cc engine. As noted, other changes in the front bumper were made to improve aerodynamics (see Section 4.10), increase cooling for the larger engine (Section 4.3), and accept a new size of headlamp (Section 3.9.2.1). Beacuase of results observed in tests during Phase II, a different energy absorbing foam was chosen in Phase III to provide improved tear strength and specific energy intermediate to the two foams investigated during Phase II. The dynamic force/deflection properties of the new material (Davidson Rubber MC-1071 rim foam No. 624-127) are similar to the harder foam from Phase II except that light dynamic loading produces more deflection (see Figure 22) so the bumper was expected to yield an improvement in pedestrian protection. Phase IV tests confirmed it.

Figure 21 FRONT BUMPER

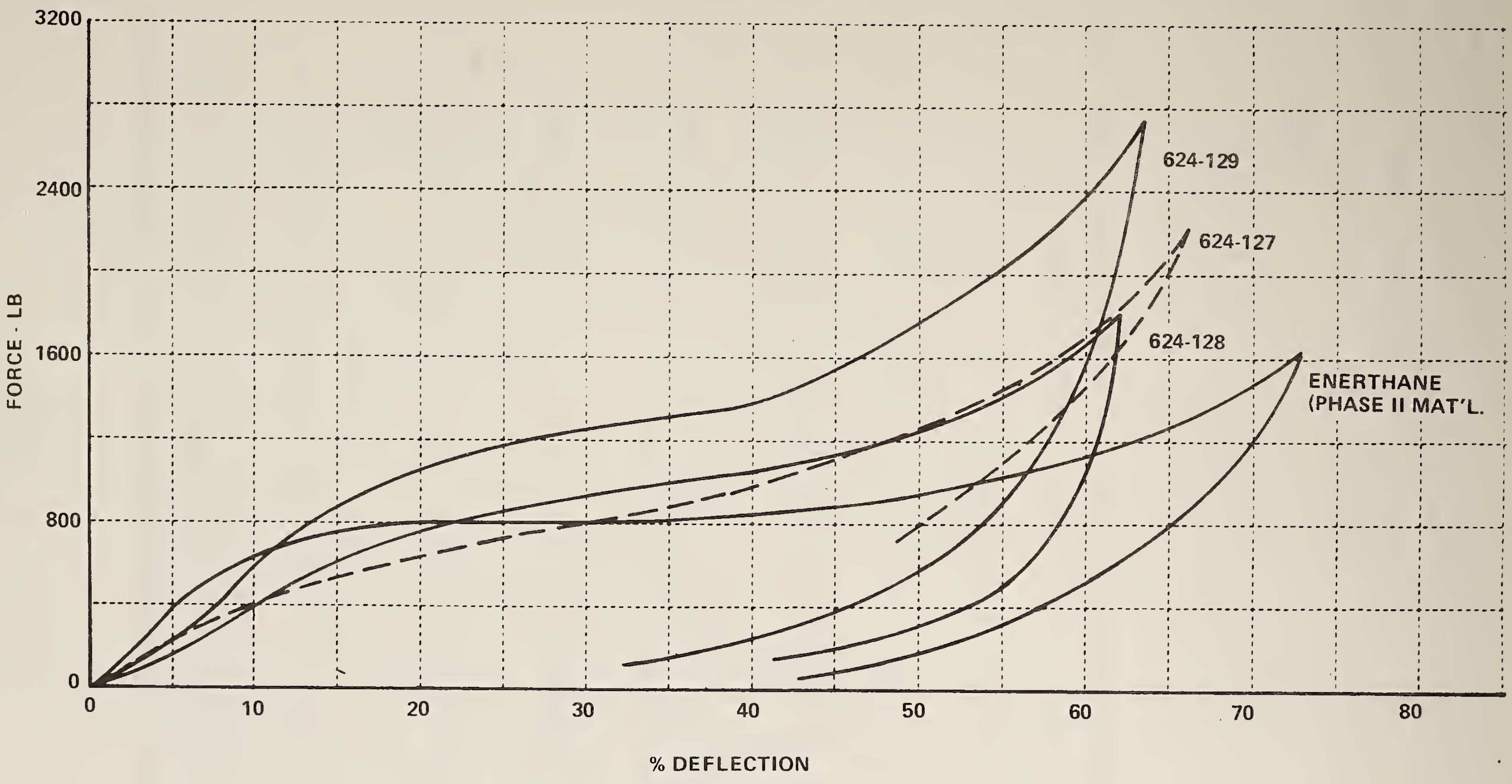

Figure 22 PERFORMANCE OF BUMPER ENERGY ABSORBING FOAM

Based on initial structural design parameters, design of front lighting and headlamp covers was accomplished in anticipation that no damage would occur to these items during low speed impacts. Other items which require evaluation before undertaking high volume production include:

(1) The number of low speed collisions and pedestrian impacts that can be performed before permanent damage occurs to the bumper under different temperature environments.

(2) The degree of production variation in material properties for high volume production of bumper materials.

(3) Effect of temperature on material properties.

(4) Effects of salt, oils, coolants, vibration, etc. on durability.

It should be noted that the bumper systems are not specifically designed to meet current FMVSS 215 test requirements. It appears, however, that at moderate temperature, compliance may be achieved. In addition, an RSV with air conditioning may require added structure to prevent functional damage to the condensor.

In general, the soft front bumper is believed to be less aggressive than a conventional car front when impacting the side of a present production vehicle below 30 mph. Tests conducted during Phase III between an RSV with a Phase II fascia configuration incorporating Phase III materials against the side of a 1975 Plymouth Fury[11] produced significantly lower levels of damage to the Fury than would have been expected had the striking car been a current model with a metal bumper on hydraulic energy absorbing mounts.

Styling of soft front ends will require an entirely new approach, especially for larger sized cars. Public acceptance of such designs already had been established for the "sporty" cars, many of which currently utilize a flexible fascia with various types of energy absorbing devices (these do not provide RSV type of pedestrian protection). It could prove rather difficult to transfer this acceptance to "family" cars.

3.3.2 Rear Bumper

The design of the rear bumper system was constrained by the following:

(1) Physical space requirements for the license plate and taillamps below the liftgate.

(2) Limitation on extending rear overhang to keep the size and weight of the vehicle to a minimum.

(3) Little or no change to the liftgate seal surface, seal mounting surface, liftgate, and quarter panel because of economic considerations.

(4) Minimum number of tools to be utilized for making the rear lower fascia from cost considerations. (In a production design, the quarter panel extensions would be designed as separate pieces, instead of integrated into the bumper, to control part fit at assembly.)

(5) Use of production taillamp assemblies to reduce program tooling costs.

Initially in Phase II, it was believed that the rear bumper of the base Simca 1308 could be retained without modification on the RSV and still be consistent with the bumper design philosophy of accepting reduced low speed rear impact capabilities because of increased front capabilities. Later in Phase II, it was determined that the visual effect of the standard Simca rear bumper was not esthetically pleasant when combined with the soft front bumper. Therefore, a soft rear bumper was added to the RSV. The result is considerably more attractive and does provide a freedom from small nicks and other minor surface blemishes which could result from minor impacts had the Simca bumper been retained. Also, since in Phase III a spoiler was added, use of the same deformable fascia material for the spoiler permitted a somewhat shorter overall length because the rear bumper would not have to extend far beyond the spoiler to provide protection for it. The rear bumper is shown on the photos of the RSV in Figures 2, 3 and subsequently in Figure 27; Drawing 95320 in Appendix A, Volume II also shows it in conjunction with adjacent body parts. The foam used is Davidson No. 646-23 which exhibits an energy absorption of 44.7 $lb.ft/in.^3$ at 70.1% deflection.

The size of the rear bumper energy absorbing system results in bumper mismatch with maximum loading of the struck car in RSV-to-RSV low speed collisions unless the struck car attitude is controlled, but this might be done with rear, automatically adjusted, air shocks or air springs.

The problems relative to mass production noted in the section of this report covering the front bumper are also relevant to the rear bumper.

The rear bumper system also is not specifically designed to meet current FMVSS 215 test requirements. It appears, however, that at moderate temperature comparable performance may be achieved except for corner pendulum impacts.

3.4 Glazing

While the need to change the glazing in the Simca was not particularly strong, it was felt that some improvements could be made. Various heat resistant glass materials were studied in an effort to reduce the need for air conditioning and thus lower the engine horsepower to drive the reduced capacity unit. Thinner glass and plastics were evaluated to effect a weight savings. High performance laminates were considered as possibilities to provide some improvement to occupant protection. Also, a change from a rubber retaining gasket (as used on the Simca) to bonding materials was felt to be most desirable for glass retention during impacts. Although the RSV related work accomplished in this area is by no means extensive, several intriguing concepts were found.

3.4.1 Windshield

The standard Simca windshield was used in Phase II. During Phase III the four layer Securiflex windshield, manufactured by Saint-Gobain Industries in France, was evaluated and selected for RSV use. The windshield is relatively conventional in concept, in some ways similar to today's three layer laminated windshields on U.S. cars. It is slightly thinner and has a proprietary additional 0.5 mm layer of plastic bonded to the inner surface. The purpose of this inner layer is to reduce occupant contact abrasions and lacerations during impacts severe enough to fracture the glass. That capability was borne out in independent Chrysler tests of the windshields on impact sled bucks with dummies having goat skin head coverings. These tests, at speeds of up to 72 kph (45 mph) showed dramatic reduction of dummy facial damage.

The Securiflex windshield was utilized on the Phase III crash test vehicles. In all cases, the windshield integrity was maintained. Glass slivers and sharp edges were not apparent on the inner surface after any of the crash tests.

While the review of accident statistics during Phase I confirmed the high level of involvement of the windshield as an injury producing element, this is not likely to be the case in the RSV. Utilization of passive restraints should nearly eliminate the windshield as an injury source. However, it is felt that use of the Securiflex windshield on the RSV will provide added protection where body extremities strike it.

Impact tests of standard Simca 1308's early in Phase II identified the need to alter the windshield retention technique. The rubber retaining gasket permitted the windshield to be pulled from the car by inertia forces acting on the glass during severe frontal impacts. Analysis of the body structure showed that the rabbet, or fence, into which the windshield was set, was slightly larger than the minimum size recommended by Chrysler design practice. Redesign was not practicable at that time. Phase II and early Phase III test cars used a butyl tape adhesive which also proved less than satisfactory for windshield retention in impacts. The bonding was then changed to a urethane material supplied by Essex Chemical Corporation. While not used currently in production by Chrysler, it is employed in many U.S. production cars. The production costs may be slightly greater than for the butyl tape used on earlier RSVs, but the windshields were retained. In bonding Securiflex windshields, it is necessary to remove the inner plastic layer from the glass in the bonding area, about 10-12 mm (0.5 inches) in width.

Since the rubber windshield gasket is used on the Simca also to retain the windshield reveal moldings, a new mounting method was required for the RSV. Double sided adhesive urethane foam tape from 3M Company is used for this purpose. No production application of this type is known, but it is used to attach moldings and nameplates on many current cars.

3.4.2 Front Door Glass

The baseline Simca one-piece front door glass has no separate vent wing. The addition of the front door hinge pillar reinforcement in Phase II eliminated the clearance to allow the full length Simca glass to be rolled down. The Phase II approach to this design problem was to divide the front door glass area into a fixed non-opening vent window at the front with a droppable shorter front door glass aft of the vent. This required a division strip/glass run channel between the two.

With the decision to incorporate fixed-housing aerodynamic side view mirrors in Phase III, it was apparent that the mirror housing would permanently occupy the lower front corner of the glass opening. This permitted the use of single piece front door glass reduced by the longitudinal length of the mirror attaching bracket. The shortening of the front door glass allowed the glass to clear the front door hinge pillar reinforcement. A new front glass run channel has been designed and Simca glass regulator hardware is utilized. During Phase II, various other means to provide added resistance to occupant ejection were investigated. These mechanisms were rejected, partly because of high production cost, but also because use of passive belt type restraints further limited the advantage of such a design. Simca front door lights were recut to fit the new opening.

3.4.3 Rear Door Glass

The Phase II rear door window was specified as a fixed non-opening pane because the space within the rear door was occupied by the door beam and energy absorbing material without any clearance for the glass and glass track mechanism. However, Phase II evaluations indicated a need for improved rear seat ventilation and a swing out, rear quarter window was proposed for this purpose.

A closer design study in Phase III indicated that by optimization of E.A. module thickness, sufficient clearance to roll the window part-way down (approximately 152 mm or 6 inches) could be achieved. This modification was, therefore, incorporated into the design instead of the swing-out quarter window. Program costs were reduced because the movable glass utilizes existing Simca 1308 window lift mechanism hardware while the swing-out quarter window proposal would have required a number of new mechanical components, glass frame components, and sealing modifications.

3.4.4 Rear Quarter Windows

As previously noted, the swing-out rear quarter window proposed in Phase II for improved rear seat ventilation was abandoned in favor of a roll-down rear door window. Therefore, the quarter window remains fixed in Phase III. During discussions on the clear plastic headlamp covers, with General Electric Plastics Division, other possible areas of plastic substitution for reduced weight were reviewed. The rear quarter window was chosen as an ideal application requiring very little tooling. The Simca glass parts were used as tooling models and the Phase IV vehicle has plastic rear quarter windows at a weight saving of 2.34 kg (5.16 lbs.).

3.4.5 Liftgate Glass

The RSV tempered liftgate glass is a direct carryover from the Simca 1308. Like the windshield, it is installed in the Simca with a rubber seal. Since there was some loss of strength because of the aluminum liftgage in the RSV, the adhesive was changed to the same polyurethane used on the windshield. Application of bonding here is marginal as the rabbets in the liftgate are exactly at the Chrysler recommended minimum size for bonding.

Alternate designs were investigated. A special Saint-Gobain liftgate glass was considered to provide some reduction of occupant ejection through the liftgate. A three or four layer backlight could provide some improvement, but costs would be considerably higher. This concept was, therefore, dropped. An even more intriguing concept would involve injection molding the entire liftgate and glass unit of the same Lexan polycarbonate plastic used for the rear quarter glass and headlamp covers. It could then be hard-coated and the periphery painted body color. Local steel reinforcements could be molded in place for hinge and lock retention. Weight savings would be high, greater protection from ejection would result, and manufacturing would be simplified. The compatibility of the plastic with heated backlight temperatures was found to be satisfactory. Due to funding limitations, this concept was pursued no further, even though a vacuum formed, hand made prototype seemed a possibility.

3.5 Hardware

A number of hardware components have been modified from the baseline Simca 1308 and Phase II configurations or substituted to provide increased safety, improved consumer acceptance, better producibility, coordinated appearance, and/or reduced vehicle weight.

3.5.1 Hood Latches

The Simca hood primary latch utilized in Phase II has been replaced by an Omni/Horizon-type hood latch for Phase III. The new latch (shown in Drawing 95510, Appendix A, Volume II) is much stronger and is actuated by a U.S.-type release mechanism from inside the passenger compartment. The new latch will minimize the possibility of inadvertent hood opening while the vehicle is in motion and will make theft of engine components more difficult.

Secondary hood latches, located at each side, about midway along the length of the hood, are the main means of reducing windshield intrusion by the hood in frontal impacts. They also act as a backup system for the primary latch should it fail on the road. Another purpose of the secondary latches is to alter the hood failure mode to force bending failure at several points between the latch and hinges during frontal impacts. In this way much of the energy absorption capability that otherwise would be lost due to the weaker aluminum hood construction of the RSV can be regained by increasing its efficiency. They also serve to provide a lateral tie between the fenders, thus preventing the fenders from buckling sideways and allowing a loss of energy absorbing capability, energy which should be especially effective in angled or offset frontal impacts.

The secondary latch system is comprised of a forged hook and mounting assembly located at each fender side shield (see Figure 23). These latches are always engaged when the hood is in the down position. Torsional springs keep the latches locked by engaging a bale on the hood inner panel.

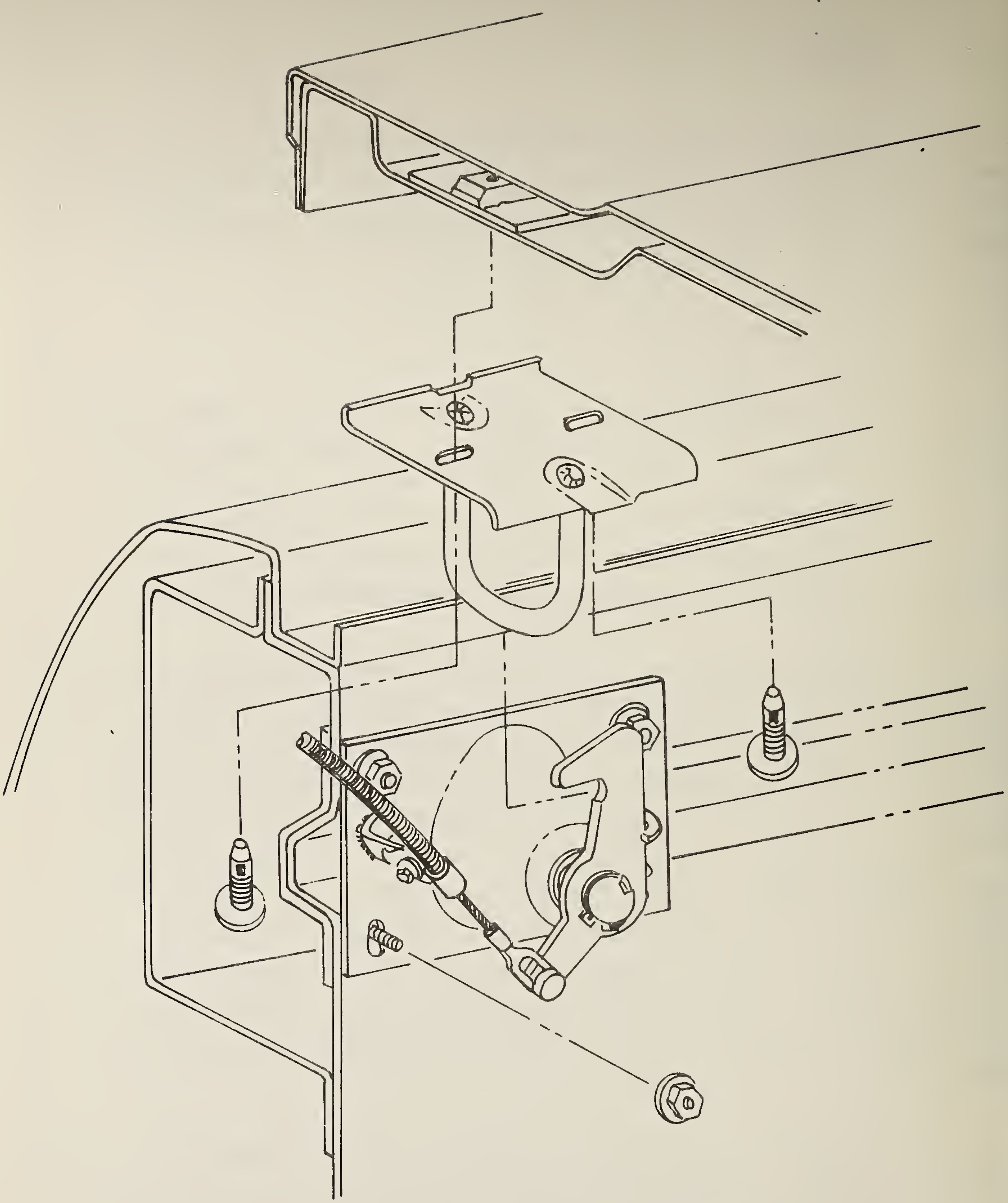

Figure 23 SECONDARY HOOD LATCH – PHASE III

Release of the hood is accomplished by releasing first the primary latch from inside the car. A pop-up spring lifts the hood 50.1 mm (2 inches). The secondaries are then released by pulling a lever mounted under the hood on the upper yoke crossmember and then lifting the hood. Some minor difficulties with this latch design have been experienced with the actual parts. The handle on the yoke mounted release is somewhat more flexible and prone to deformation than would be desired in a production design. Compounding this, the release force is rather high, in part, due to the high friction in the cables and the small turning blocks at the front release handle for the cables. Rotating bushings could ease this problem. The torsional latch springs, located on the latch hooks, seem to be stiffer than required to assure engagements; new springs could be redesigned to replace the production Chrysler seat back recliner spring used on the latch.

3.5.2 Window Lift Mechanisms

The front door window lift mechanism is primarily carryover Simca with one minor modification - the upper attaching bracket was modified to accommodate the relocated door inner panel. The rear door window lift mechanism is also a modified Simca part. Glass clearance is reduced in the interior of the door for the added reinforcements. As previously noted, the window drops only 150 mm to provide some rear seat ventilation. The lift mechanisms and other door hardware are shown in Drawings 95130 and 95140 in Appendix A, Volume II.

3.5.3 Door Locks

The outside door-lock cylinder (carryover Simca) requires a hole in the rear door beam support and door beam for installation and operation of the linkage. Other methods of installation of the lock cylinder could possibly reduce the size hole required, but it is anticipated that these holes have little or no detrimental effect on side impact performance.

3.5.4 Door Hinges

The basic Simca hinge, designed to be used for all four doors, is made of hot-rolled mild steel and employs a hollow hinge pin. The hinge assembly is welded to the body and to the door with door adjustment accomplished by bending the hinges. On the other hand, the RSV has three different hinges, each machined from high strength steel and using a solid high strength steel hinge pin. New hinges were designed for the upper and lower locations on the front door in order to optimize the upper load path loading into the door structure on front impact. The strength of all hinges was increased to improve side impact protection. The rear door hinges are the same for interchangeability advantages.

The type of hinge welding that is used (Figure 24) is not really production-feasible. The weld strengths at the door half of the hinge and outboard of the hinge centerline are critical for side impact safety. An alternate hinge design (Figure 24) would overcome the reliance on the above-noted welding, help to increase production feasibility, and improve the ease of production door adjustment by replacing the welding with a bolted attachment on the door half of the hinge. This approach would be recommended for a production design.

3.5.5 Door Interlocks

In order to prevent the doors from moving inward during side impact and to force the door beams into a tension mode, door interlocks were added during Phase II.[3] These consisted of a dovetail-shaped interlocking bracket at the latch, a pin which locked into a slotted bracket at the rear lower door corner, and an L-shaped bracket which locked into a sill slot (see Figures 7, 18 and 19). The Phase II designs were successful. In order to provide adjustment capability, however, the interlocks at the latch were replaced in Phase III by dual pin-type interlocks. The Phase III interlocks are shown in Drawing 95120, Appendix A, Volume II. These have been tested during Phase III and found to perform satisfactorily.[10,12]

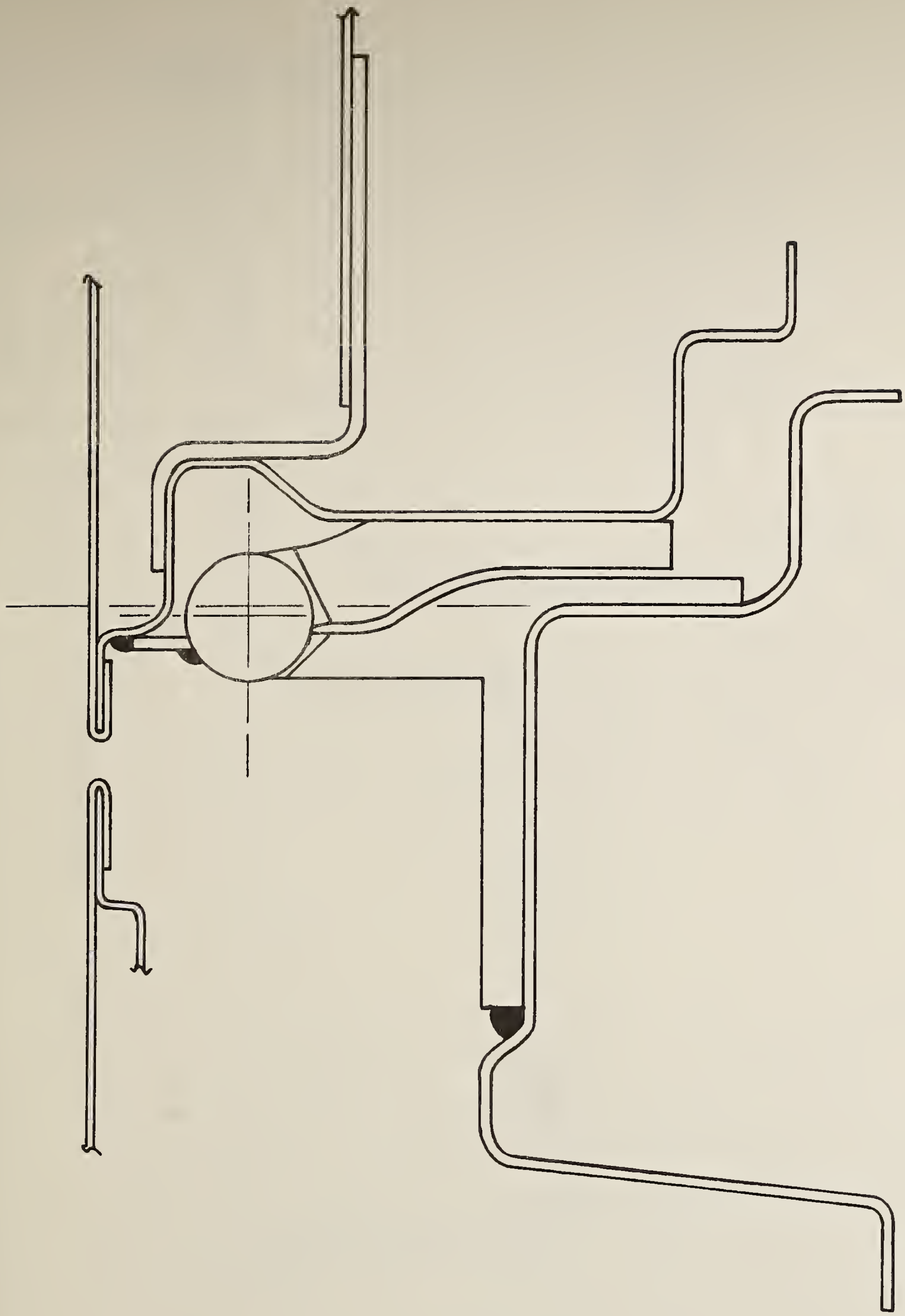

Figure 24 RSV DOOR HINGE DESIGN

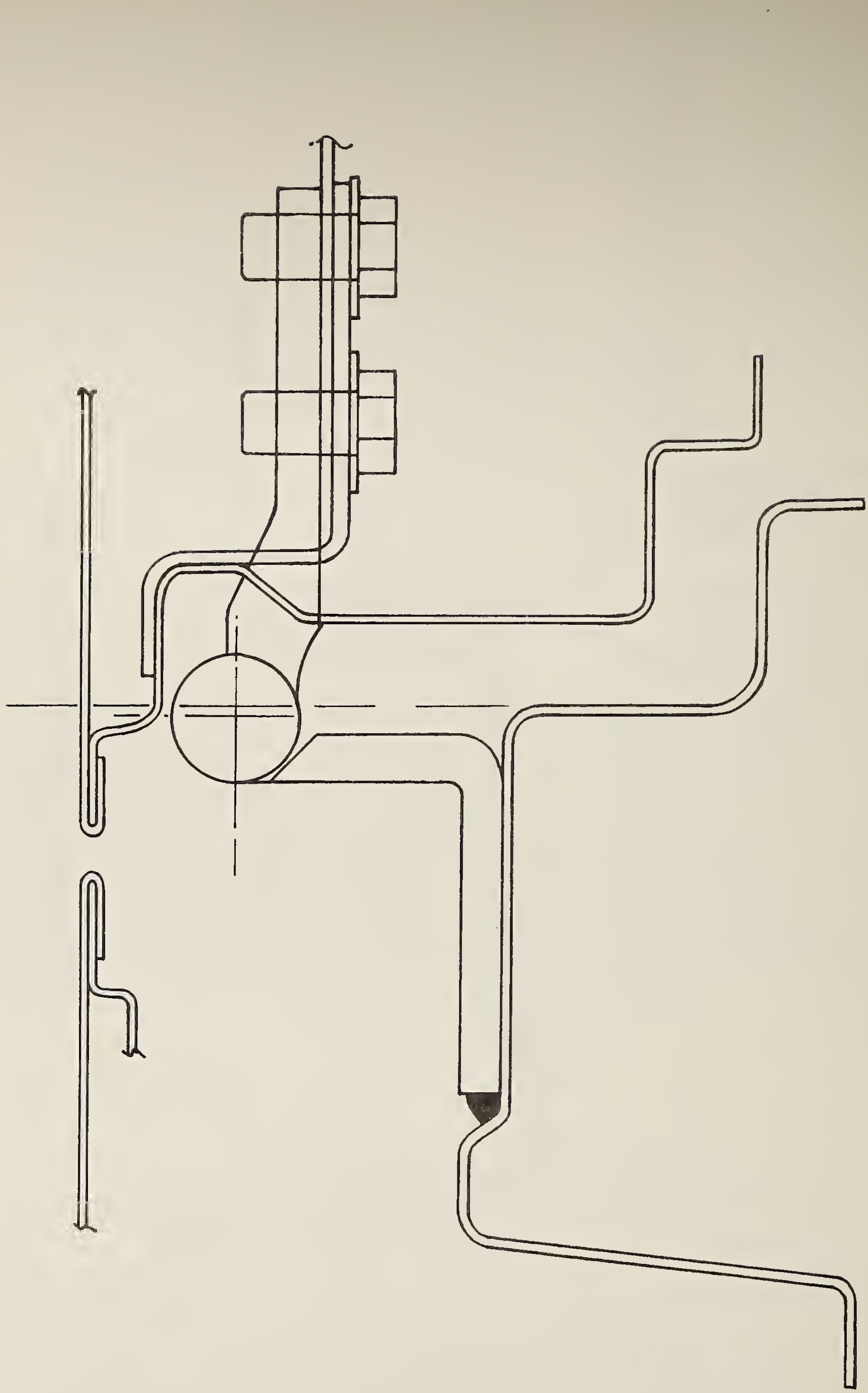

Figure 25   ALTERNATE DOOR HINGE DESIGN

3.5.6 Liftgate Latch

The Simca liftgate latch utilized in Phase II was replaced by a modified Omni/Horizon latch during Phase III. The reasons for this are two-fold: as with the hood primary latch, the Omni/Horizon unit is stronger than the Simca unit; additionally, the incorporation of the soft rear fascia required modifications to the Simca latch mounting provisions and latch actuation mechanisms (cf Drawing 95320, Appendix A, Volume II). The Omni/Horizon latch configuration was more readily adaptable to the remote actuation requirements encountered when the lock cylinder was relocated further forward on the liftgate due to the addition of the soft rear fascia. There was some concern over the mounting of the lock cylinder. Due to the rear spoiler applique, it was necessary to place the cylinder on a nearly horizontal surface in the liftgate. This could cause some difficulties with icing in winter weather. Due to the need to minimize RSV tooling costs, the Simca rear hatch sealing surfaces and much of the rear end structure were retained. If an all-new design were to be created, a new lock location and possibly a new latch mechanism would be developed. Use of the soft fascia in this case complicates the design.

3.6 Exterior Trim

The exterior trim of the RSV is quite simple. Chrome accents are limited to the head and taillamp bezels, the lock cylinder covers, and the small emblems mounted on the front bumper and fender. All other moldings or trim items are painted a low gloss black. These include the windshield wiper arms and blades, the windshield and backlight reveal moldings, the upper door window frames, the high level rear lamp bezel area, the door handles, wheel cover accents, side view mirrors, and the body side and bumper rub strips. While the extensive use of low gloss black may provide some reduction of glare from body components, its use was based primarily on appearance effects. Cowl top vent grilles, which are black on the Simca, were changed to body color on the RSV. This was done, in part, to cover the rework required to make them conform to the RSV hood contours and, in part, is due to the number of black accents already on the RSV. Narrow, dual-accent tape stripes on body front, sides, and rear spoiler, a tape RSV logo on the spoiler, and a Department of Transportation emblem on the wheelcover center are the only other exterior trim components.

3.6.1 Emblems

The configuration of exterior and interior decorative emblems for the Phase III RSV were designed by Chrysler's Design Office. These are shown in Figures 6 and 26. However, a significant departure from the conventional die cast emblems commonly used on U.S. vehicles has been used with the RSV. Marui Industrial Company Limited of Japan has manufactured RSV emblems in injection-molded plastic with decorative inserts that have the appearance of brightly chromed metal. The emblems are very light in weight, extremely flexible (for damage reduction and to permit tape application to curved surfaces), and are inexpensive to tool and produce in volume. Marui also produced the decorative, chrome-appearing, plastic surround bezels for the headlamps which exemplify the same weight, damageability, and cost advantages. While this type of emblem is not used for U.S. production by Chrysler, it has been used commercially by Mitsubishi, Chrysler's Japanese auto manufacturing affiliate, as well as other Japanese automobile companies.

3.6.2 Rub Strip

The Phase II RSV incorporated a flexible rub strib around the whole vehicle to avert minor "parking lot" type dents and scratches. The rub strip was approximately 25 mm (1 inch) thick. This presented a minor trim problem at the door opening cut lines. The thickness of the strip necessitated trimming the rubber at an angle in the plan view to allow the door to swing without interfering with the rub strip. These trim angles were considered somewhat detrimental to the appearance of the vehicle. The thickness of the strip was also deemed excessive, based on its ability to prevent damage and the cost involved.

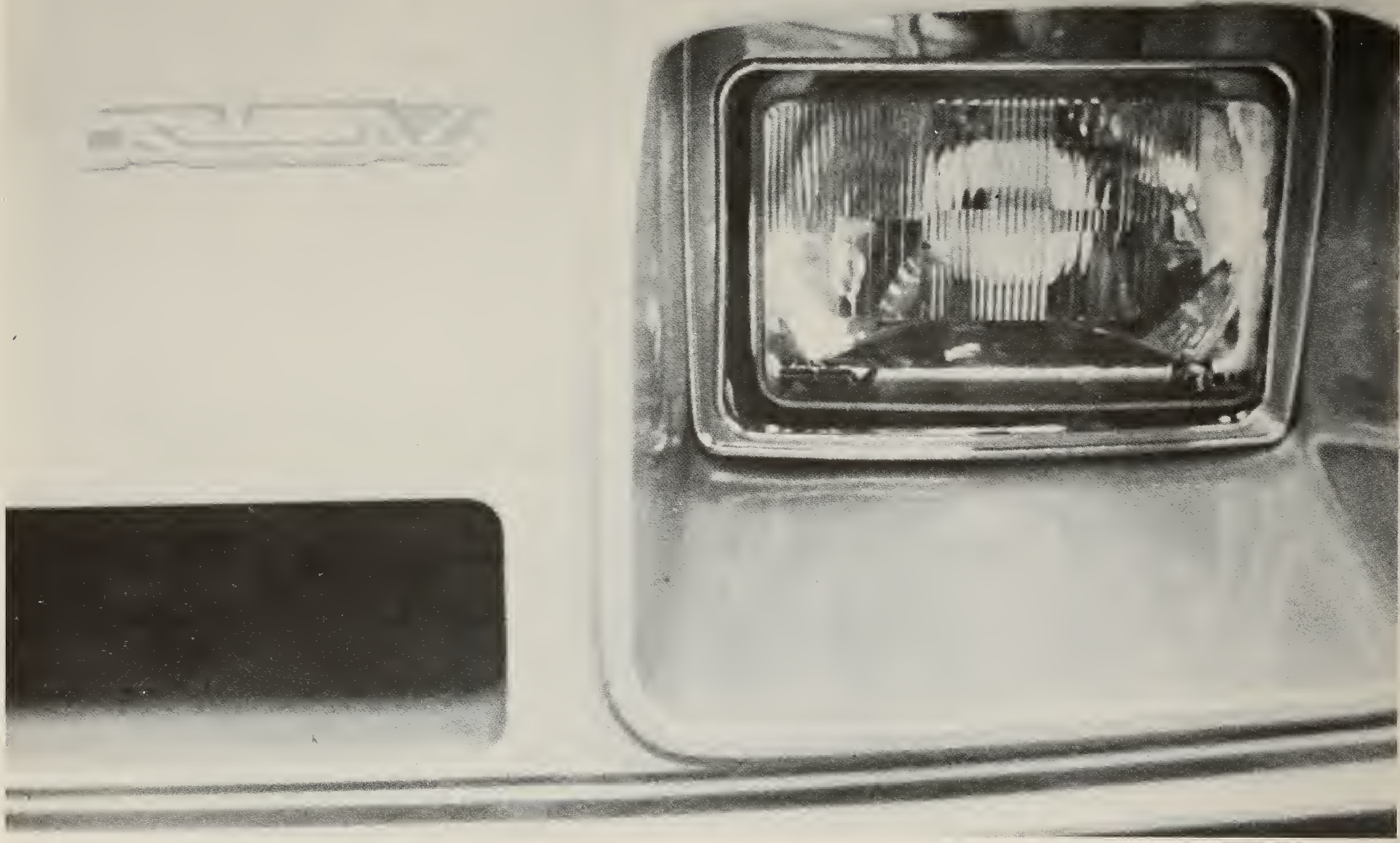

Figure 26 FRONT EMBLEM

The Phase III and final RSV rub strip still exists completely around the periphery of the vehicle, but is integral with the soft bumpers at front and rear. Its thickness has been reduced to 6 mm (.25 inches) nominal, which minimizes door swing and appearance difficulties. It also incorporates a recessed area to allow application of a black reflective-tape stripe. As in many production car applications, a foam tape with adhesive on both sides is used to attach the body side rub strips. Two strips of tape, one at the top and one at the lower edge, are used for all pieces except the very short piece between the rear door and the rear wheel opening which has three strips to meet Chrysler pull test requirements for such parts.

3.6.3 Tape Stripes

The standard RSV tape stripes include 3M black-on-white reflective tape integral with the rub strip, 3M red reflective pin stripes just above the rub strip, and a red reflective RSV logo and pin stripes on the rear spoiler (see Figures 26, 27, 3 and 4). The black-on-white tape stripe reflects white at night and is black under daylight conditions to blend with the rub strip for improved show room appearance. The red pin stripes, along with the black-on-white tape stripe, should be sufficient to define the vehicle at night. In addition, a reflective version of the Department of Transportation insignia is used in the center of each wheelcover.

A large red reflective tape stripe has been proposed by 3M for the vehicle instead of the small pin stripes (see Figure 28). This tape strip will be applied to one crash vehicle for evaluation. Personnel at 3M will evaluate the two reflective systems with photographic equipment during the build program. This wider tape stripe was not used on all cars as it was considered by the Chrysler design staff to be inconsistent with the RSV styling.

There was no specific accident study conducted during the RSV program to indicate a need for reflective material on the car. There undoubtedly are instances when reflective material would have prevented night time accidents with an unlighted car. Frequency of such cases was not identified so there can

Figure 27 REAR TAPE STRIPES

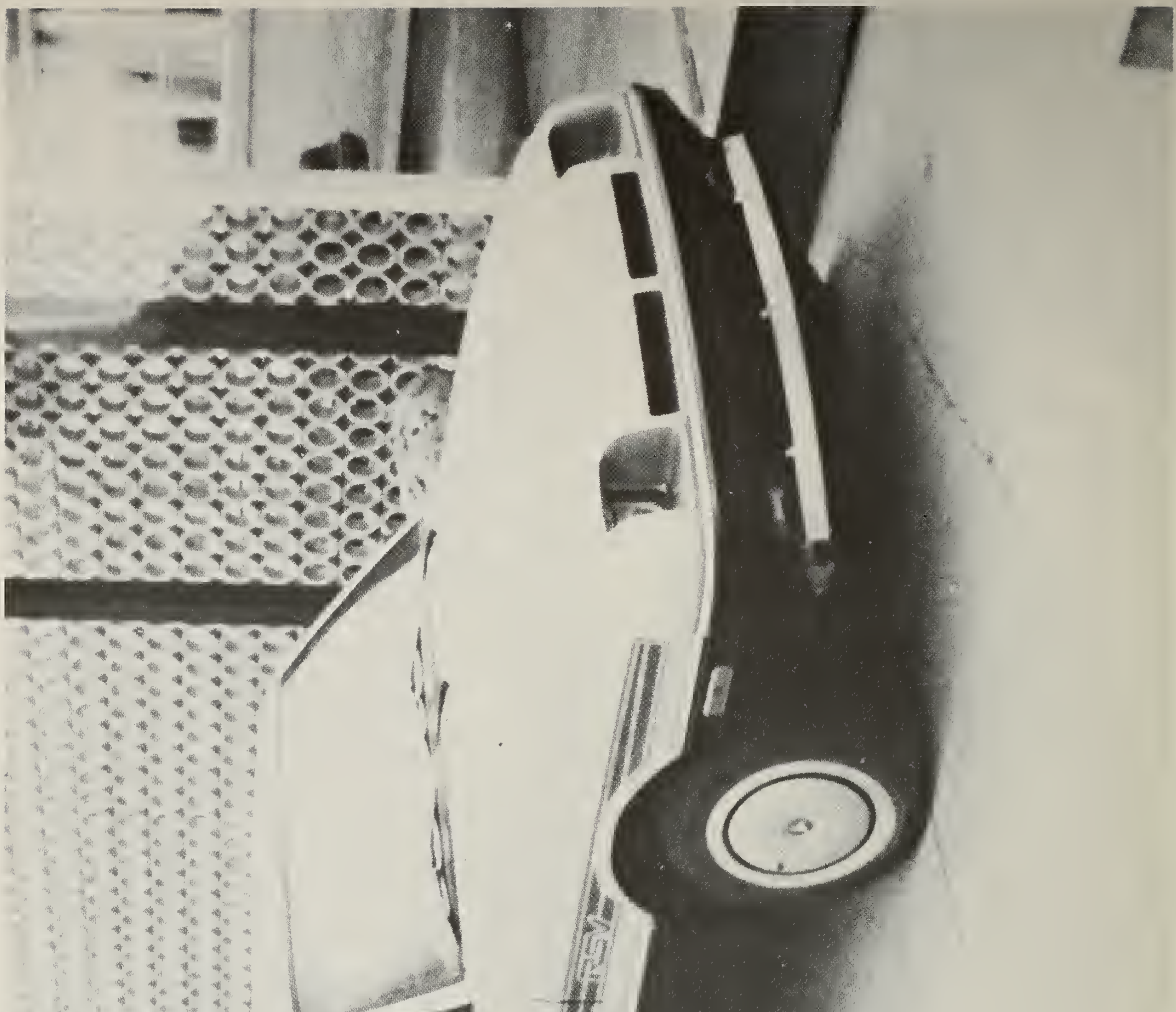

Figure 28 ALTERNATE STRIPES

be no evaluation of the potential cost effectiveness of the RSV installation. Any future mandated usage of large reflective areas should be considered only after an in-depth study. Current standards do mandate small reflective areas associated with rear and side marker lamps.

3.7 Interior Trim

Interior trim items were designed to retain as much of the original Simca appearance, design concepts and hardware as possible. As in the occupant restraint systems, discussed in Section 2.8, almost all changes during Phase III were associated with improved occupant protection. The areas which are readily visible are the door trim pads (Figure 4 and 34), the side roof and pillar padding (Figure 35), and the revised knee restraints (Figures 29 and 30). Also changed, but not immediately apparent, is the structure of both the front and rear seats. Trim materials were changed to provide an appearance compatible with the exterior paint.

3.7.1 Instrument Panel

A detailed instrument panel final design was not developed during Phase II. A basic concept for a knee blocker (lower panel) to investigate location, size, and installation was devised and impact tested both on the sled and on the dynamic crash cars. The panel shape was similar to that shown on the RSV Phase II mock-up car. Panel construction was of 1.19 mm (.047 inch) formed HSLA steel covered with a layer of Ensolite energy absorbing foam. Impact energy absorption was accomplished primarily by sheet metal deformation with the foam used to distribute impact forces on the occupant.

This basic concept was altered during Phase III for two primary reasons: the first was to limit design and development by retaining a maximum of Simca components; the second was to utilize the constant force capabilities of honeycomb materials for the primary energy absorber.

Figure 29 INSTRUMENT PANEL

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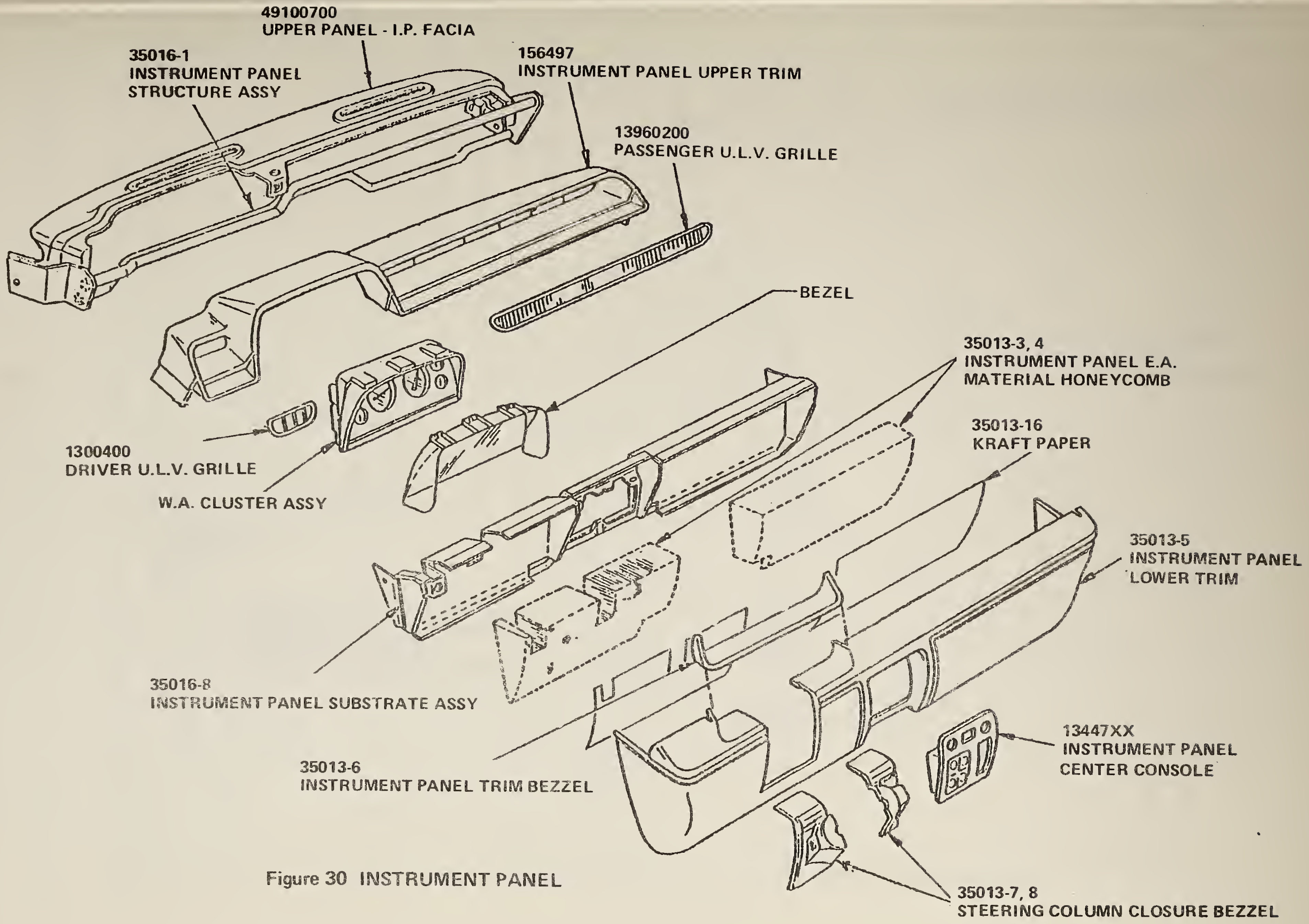


Figure 30 INSTRUMENT PANEL

Figures 29 and 30, as well as Drawing 95410 in Appendix A, Volume II, illustrate the RSV instrument panel and its construction. Many Simca instrument panel elements were retained - the upper panel, the top portion of the panel pad, the air distribution grilles, the instrument cluster and bezel, and the instrument panel center switch console. An all-new instrument panel knee blocker assembly and its tubular instrument support structure were designed. The former was composed of a stamped pan and tubular support to retain Hexcel aluminum honeycomb energy absorber blocks nominally 75 mm (3 inches) thick covered with Kraft paper and cemented to the stamped support pans. These components were then encapsulated into a complete assembly with a vacuum-formed PVC trim cover and held in place by injecting about 12 mm (0.5 inch) of urethane foam between the cover and the blocks. Other new parts were a lower cluster bezel to fill the space between the cluster and the new lower instrument panel assembly and a new steering column closure bezel to cover the upper steering column between the instrument panel and the steering wheel.

The instrument panel assembly functions to limit knee motion and, therefore, occupant lower torso excursion during frontal impacts. All of the tubular support elements are bolted to very rigid cowl side panels and act as tension members. However, since all of them include some offset, additional support is required. Phase III testing indicated a need to reinforce the lower instrument panel substrate tube behind the center switch console. Using static crush test results of femurs loading on the knee blocker, Calspan developed the support structure shown in Figure 31. The vertical tie rods are enclosed within the heater ducts that form the center console. This design results in instrument panel support which remains relatively stationary during impacts until all of the honeycomb energy-absorbing capacity is utilized before deforming.

The RSV instrument panel is not a production-feasible design for the U.S. The tubular construction, while following the general direction of the original Simca panel, is not applicable to the higher volumes required in the U.S. The panel could be redesigned as a stamping with a covering pad as simulated by the Phase II tests. Even better would be a padded, injection-molded substrate containing ribs and some supporting steel stampings which

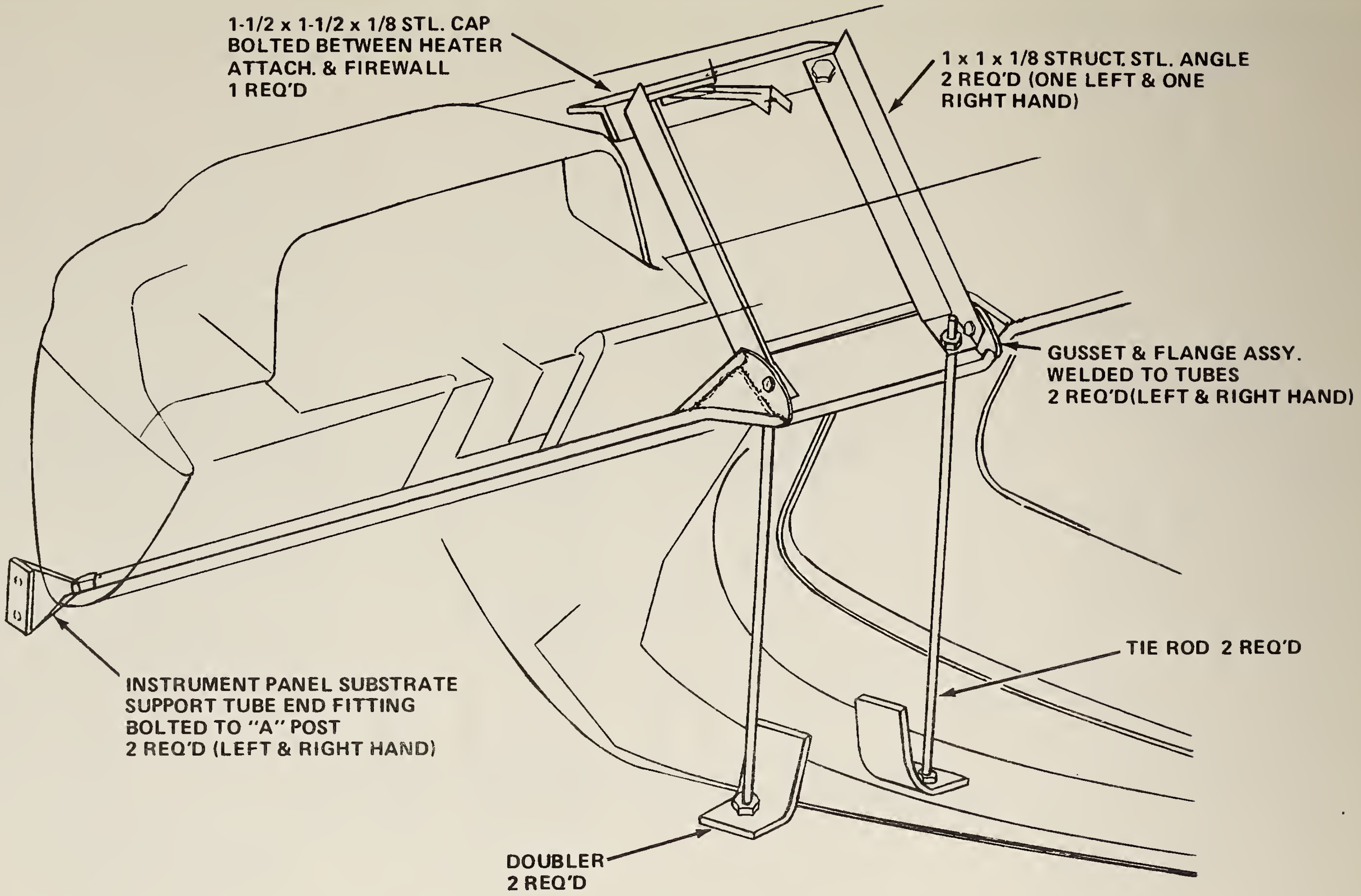


Figure 31 RSV KNEE BLOCKER SUPPORT STRUCTURE MODIFICATIONS

would provide the needed energy absorption by crushing the plastic and deforming the steel. Design of such a structure would have required not only a great deal of engineering analysis but very expensive tooling and considerable evaluation testing and tooling rework to satisfy the rather stringent force-deflection requirements. The RSV panel as designed simulates both the appearance and the impact performance of a production instrument panel design in a satisfactory manner.

3.7.2 Controls and Displays

The base Simca 1308 instrument cluster, reflecting typical European design, was used in Phase II. The standard Simca wiper/washer, light, turn signal, and horn controls were also used in Phase II. In Phase III, the warning lamps have been modified to reflect U.S.-type readouts (see Figure 32). These include left and right turn indicators, a low oil pressure warning, low tire pressure warning, a restraint system malfunction warning, a fasten belt indicator, and a warning to indicate the parking brake is applied.

The lighting control has been relocated on the instrument panel surface to the left of the wheel (see Figure 33). The controls for the turn signal, wiper/washer, and horn have been integrated into a single stalk on the left of the steering column by using a modified Omni/Horizon switch stalk.

3.7.3 Door Trim Panel

The Phase II door trim panel concept utilized an ABS plastic cover with integral arm rest, door pull, and window crank pocket. Aluminum honeycomb modules filled pockets at the belt line and lower door areas to absorb lateral forces in side impacts. For testing during Phase II, this construction was simulated by use of appropriately shaped honeycomb blocks covered with a layer of polyurethane foam. Results for occupant tolerances were very satisfactory.

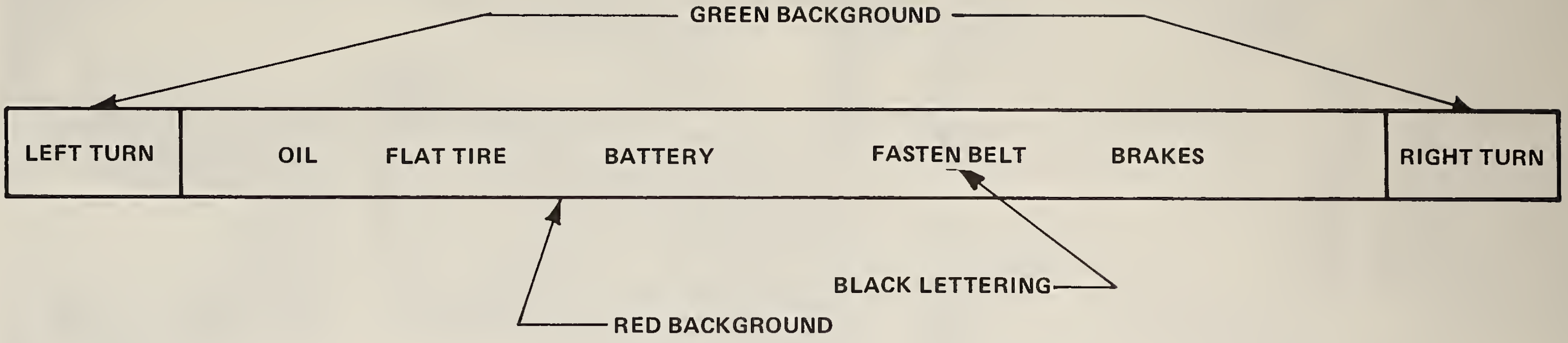
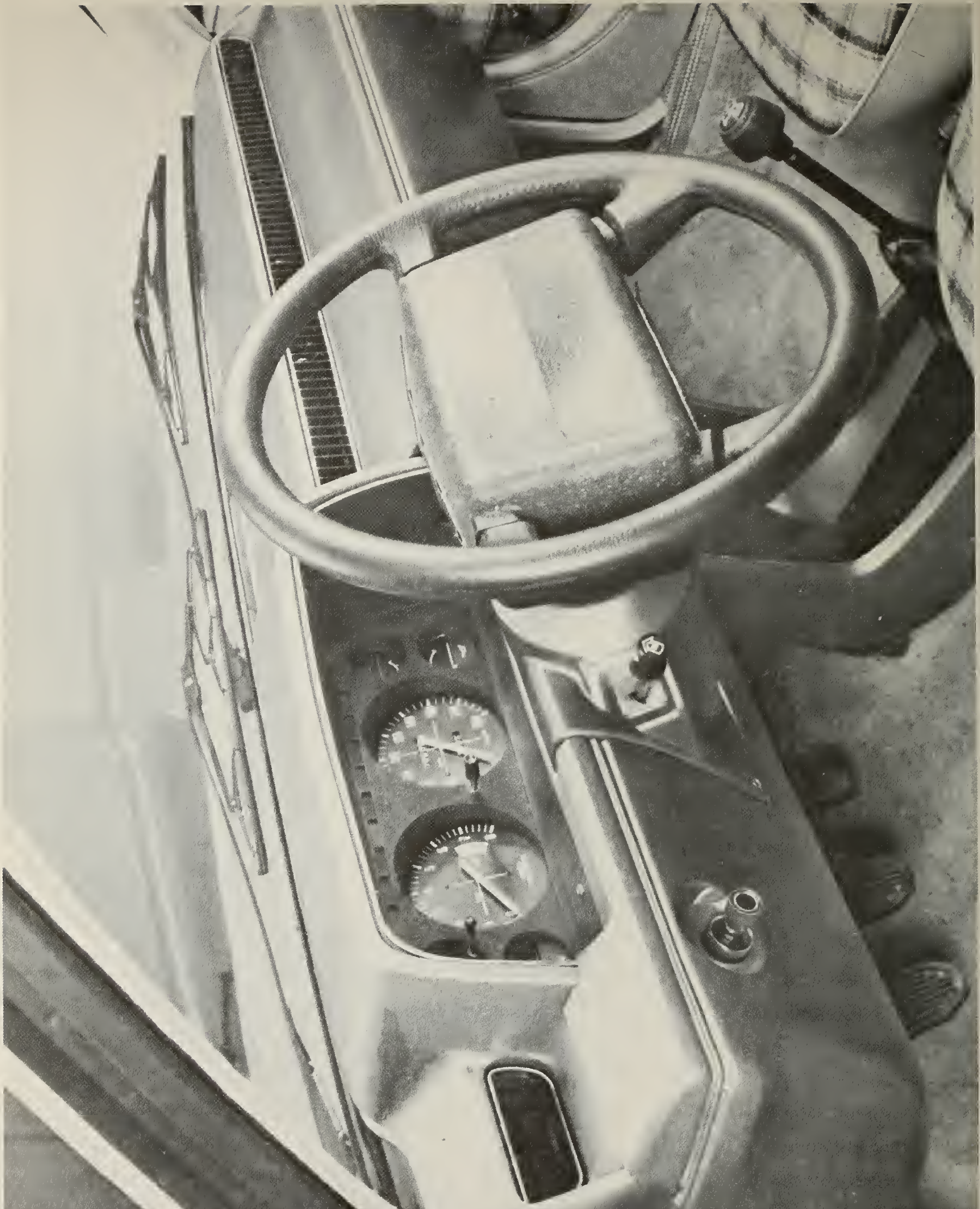


Figure 32 INSTRUMENT CLUSTER WARNING LAMPS



A newly-styled inner door surface (see Figure 34 and 4) was created in Phase III since the earlier concept had never been properly drawn up and the shape was only roughly defined. A new design incorporating the same features as in Phase II provided a pleasing appearance consistent with the performance requirements for the RSV.

On the front door panels, the forward upper portion has been reduced in section to provide greater clearance, and the door pull was changed to a horizontal handle in the armrest pad. Also, a cloth-covered insert was added to the area immediately above the armrest to provide an appearance consistent with the seat trim as well as to provide access for the trim pad attachment at the armrest/door pull location.

3.7.4 Radio Speaker Grilles

The base Simca radio speaker grilles are mounted near the lower front corners of the front door trim panels. Although the door trim panel configuration has been changed in the Phase III design, the same speaker location has been retained. Since this location is not the optimum for good sound distribution within the passenger compartment, an alternate, more ideal location which was evaluated during Phase III has the speakers in the rear shelf extension panels. This position, however, was not feasible because of interference with rear restraint system components.

3.7.5 Pillar Trim

In Phase III, it was deemed necessary that energy absorbing trim be applied to the A and B pillars and roof rails for improved occupant head protection in impacts. In Phase II, the standard Simca vinyl trim had been utilized with local additions of "enerthane" foam for side impacts. The Phase III trim (see Figure 35 and interior views in Figures 4, 29 and 33) consists of high density urethane foam that provides nominally 51 mm (2 inches) thick padding on the pillars and nominally 35.5 mm (1.4 inches) thick padding on the roof rails. The thickness was determined by head impingement tests.

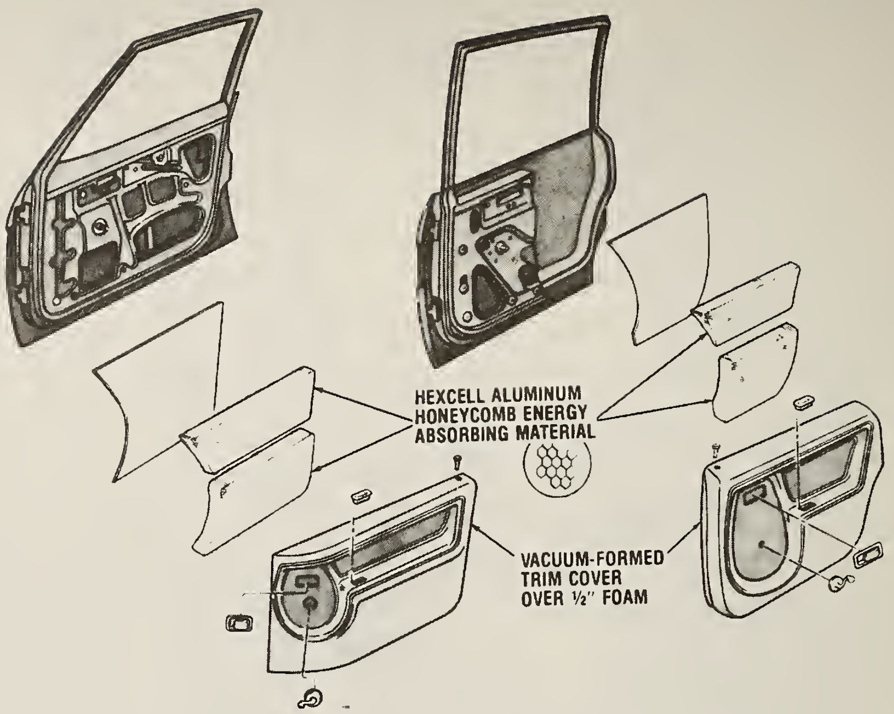


Figure 34 ENERGY ABSORBING DOOR TRIM

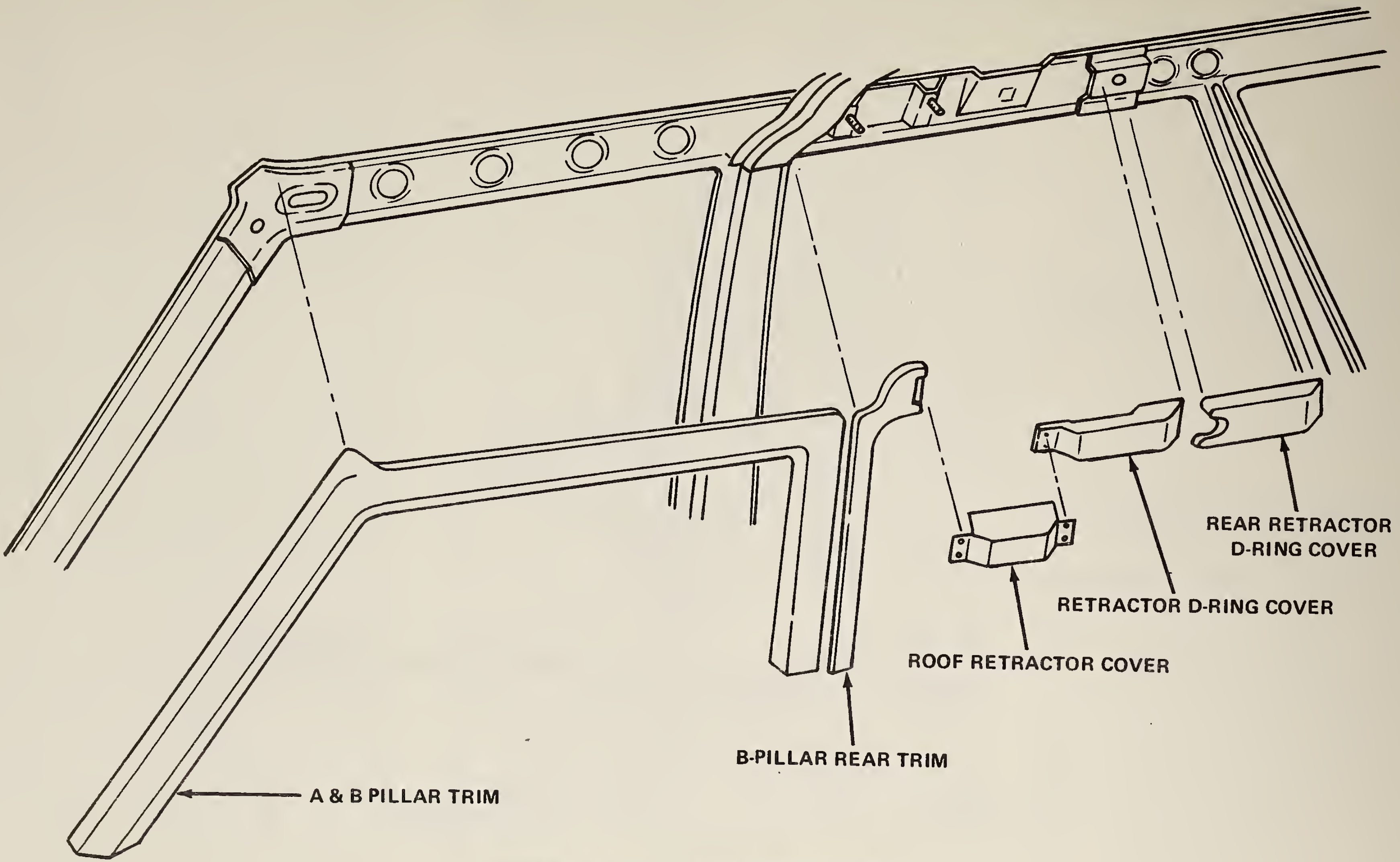


Figure 35 PILLAR TRIM APPLICATION

The A and B pillar trim also serves to conceal the automatic belt guide tube. The retractor D-ring cover and rear retractor D-ring cover pad the area fore and aft of the roof rail D-ring for rear seat occupant head protection. An ABS plastic cover trims the roof retractor.

The lower B pillar trim extends from above the belt line to the sill. The trim piece, made of vacuum-formed ABS plastic, covers the retractor for the optional lap belt and automatic belt D-ring stop.

3.7.6 Front Seat

The Phase II front seat reinforced structure was designed for loading by a 95th percentile occupant at a 24 g level in rear impacts. Reinforcements were added to the sides and back of the seat frame eliminating the Simca recliner mechanism. A seat frame anchor reinforcement was also added (see Figure 36) in Phase II plus a new headrest was designed to replace the Simca headrest for increased visibility, but the Simca tracks were retained.

In Phase III, the seat back frame side reinforcements were retained and inner and outer reinforcements were added to the seat frame to prevent failure at the anchorage points of the seat track. In addition, new seat tracks were designed to increase seat anchorage strength, improve head room, and allow the track to latch in the full rear position. A sheet metal knee blocker was installed on the rear of the front seat back frame to aid in controlling rear seat occupant kinematics.

Carryover Simca foam cushions are utilized, but special trim materials are used on the final Phase III RSVs as can be seen in the photographs of the RSV interior (e.g., Figures 29 and 38). Also, the specially designed "see-through" headrest used on the Phase II mock-up car has been replaced by a similar production Volvo headrest for simplicity and reduced program costs. Drawing 95450 in Appendix A, Volume II, shows the front seat; Drawing 95460 shows the rear.

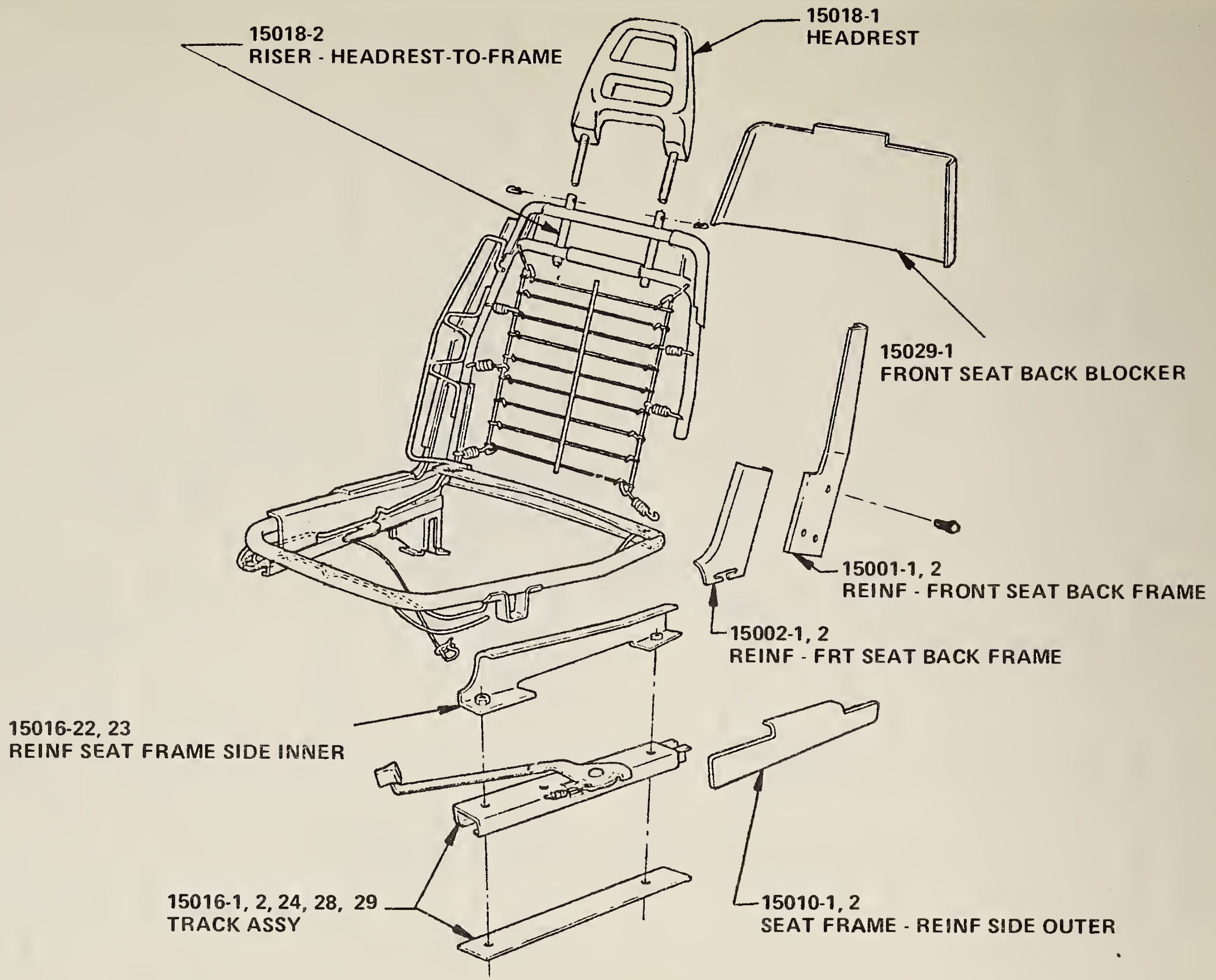


Figure 36 FRONT SEAT FRAME

3.7.7 Rear Seat

Limited Phase II rear seat sled tests demonstrated that the base Simca seat needed improvement because of frame failure in areas associated with a folding rear seat mechanism. In Phase III, the rear seat structure was reinforced near the seat cushion frame and pivot arms. Reinforcements also have been added to the seat pivot, pivot bracket, seat cushion frame and seat cushion rod (see Figure 37).

Additionally, the seat cushion pad over the floor pan tunnel has been modified, as well as the listing wires, to achieve a "softer" center seating position. This modification also provides clearance around the new inflator manifold and cover when the rear seat assembly is folded flat. As with the front seats, special trim materials are used.

3.8 Restraints

In the modern automobile the basic vehicle structure is designed to absorb the energy of a crash and resist intrusion of the occupant compartment. The restraint takes over within that compartment to save the occupants. The total restraint system is composed of the interior of the passenger compartment and the specific device designed to arrest the motion of the occupant. The interior of the passenger compartment must be designed to eliminate protrusions that might cause injury. In addition, for automatic or passive systems, a knee blocker for the front seat occupants is usually included in the design of the instrument panel. The rear of the front seat may be engineered to accept similar knee loads from the rear seat passengers as well as loads from the headrest for the front seat occupants in the rear-end collisions. In the RSV, the system includes the seats, headrests, seat tracks, the energy absorbing panels on the doors, the knee blocker and instrument panel and the padding of energy absorbing foam that covers the A, B and C pillars and the roof rail, as well as the restraining device itself that brings the body of the occupant to rest.

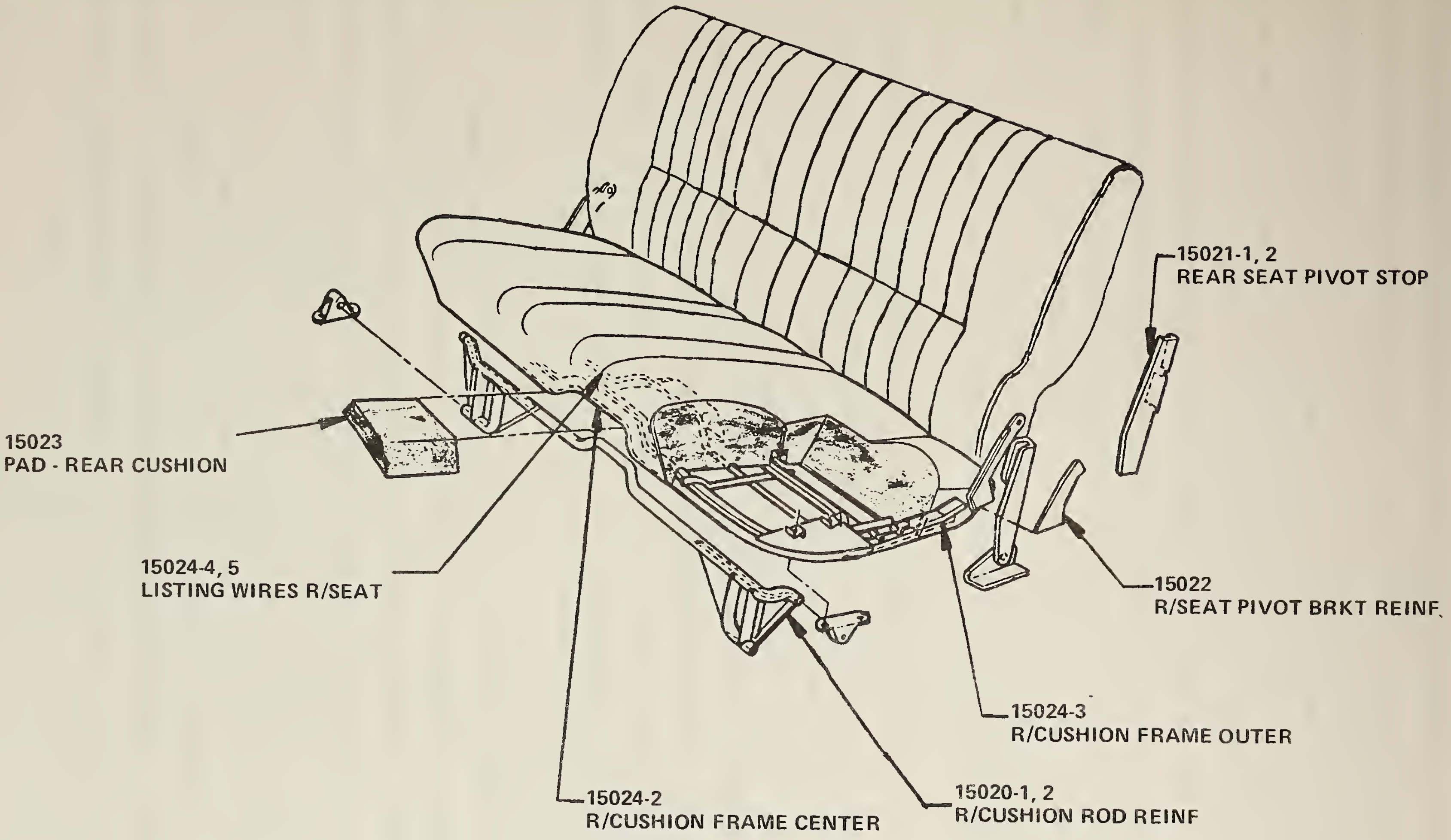


Figure 37 REAR SEAT

The interior components have been discussed in Section 3.7. They are designed to absorb energy in crushing with minimum decelerations when struck by a moving body. In cases where the primary restraint device is an air bag or an air belt, the system also includes such items as the sensors, the diagnostic and control box, the gas generators and manifolds, the slip rings and the interconnecting wiring that are required to deploy the devices and monitor the system readiness throughout the vehicle life to insure proper operation when required in an accident. The restraining device per se, on the other hand, controls the position and motion of the body during its deceleration in such a way as to minimize the likelihood of injury. These various components must work together in harmony to keep the occupant from vital injury during the abrupt change of vehicle motion that occurs in an accident. The restraint systems[5,6] are the subject of this section.

The automatic restraint systems that utilize a gas filled bag or belt tightening device require a signal to initiate action. That signal is provided by a sensor usually located near the front of the car. The sensor is designed to discriminate between a real accident and a sharp rap or hammer blow on the bumper. Change of velocity in the vehicle (the area under the acceleration-time curve) is the parameter normally used for this purpose; if the change of velocity is below the chosen threshold, a signal is not sent to the gas generators to produce gas. Since the success of a system depends upon its deployment at the time of an accident, it is important to be able to check that the complete system is in proper operating order. Hence, such systems also include a monitoring or diagnostic device that signals the driver in case of system malfunction. In addition, for air bag systems (since the driver air bag is usually mounted in the steering wheel), slip rings are required to transmit the crash sensor signal to the steering wheel-mounted gas generator. That is one of the critical electrical paths that the monitor system must check. For the Calspan/Chrysler RSV, the expense of developing a new deployment system was avoided. Our experience with a number of General Motors, air bag-equipped, automobiles indicated not only acceptable operation of the components and system as a whole but also good service life. Hence, the GM system was adopted. That decision also meant that available funding and effort could be expended on other more critical development.

Studies conducted during the Phase I of the RSV program indicated that some form of an air cushion or advanced belt would be required to provide the 40-50 mph level of protection specified in the RSV goals.[1] Additional characteristics that had to be taken into account included consumer acceptance (this, in turn, could be strongly influenced by whether it is an active or passive device), consumer utilization of the device (again, apt to be a reflection of consumer acceptance as well as legislated requirements), and of course, the ever-present cost considerations that bring with them questions of liability and the manufacturer's wish to market such products. Rough estimates[3] of performance capabilities based on previous experiences identified approximately the operating ranges of three possible systems as follows: force limited belts appear satisfactory up to about 40 mph; air bag-knee blocker systems, 40-45 mph; inflatable belts with force limiters, 45-50 mph. Other aspects which bear on the desirability of any specific system include: sensitivity to frontal angularity or offset, rollover protection, ejection reduction, side impact protection, and multiple impact protection. The responses afforded by each of these systems are different in each consideration. It is obvious that even if the same level of protection were attained, an active system utilized by only one-third of the driving population could not supply the same protection to the total motoring public that would be provided by a passive or automatic system that is effective for all motorists. On ther other hand, the additional costs of the automatic system to the driving public at large must be factored into the equation.

In view of the RSV objective to provide a safe, affordable vehicle for personal family use that will be an efficient element in the total transportation system, both driver air bag and air belt automatic restraint systems have been developed for the front seat occupants. They account for a large majority of the total accident exposure. Force limited active belts are provided for the rear seat. In addition, force-limited active lap belts are available for the front seat occupants should they want the additional protection so afforded against rollover, side impact, and ejection. Drawings 95430 and 95440, Appendix A, Volume II show the belt systems. The automatic restraint devices and their development are the subject of the following sections.[21,22,29]

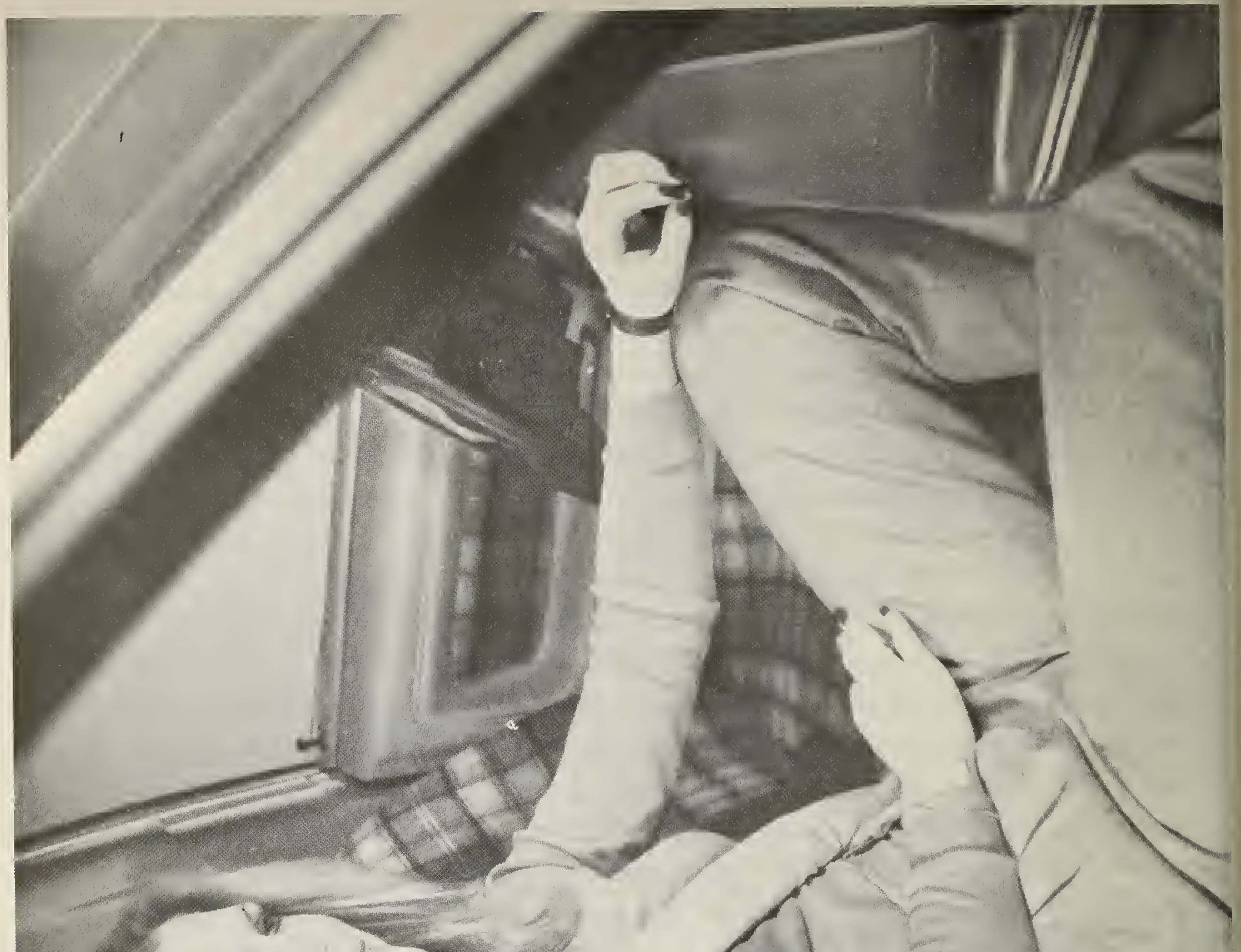
3.8.1 Automatic Air Belt Restraint System

The RSV air belt has a number of qualities that make it significantly better than conventional torso belts. The inflatable portion distributes torso loads over a greater area so that higher total loads may be imparted to the occupant's chest without causing internal injuries from local concentrations. It also provides an improved ridedown through removal of belt slack and constrains and cushions the forward motion of the occupant's head. It has the advantage of acting as a normal torso belt in any accident or condition where the inflatable portion of the device is not deployed. The program of development of the RSV automatic air belt restraint system is reported in detail in Reference 5.

During Phase II of the program the concept of the air belt was tested with idealized non-production components. The objective during the Phase III was to extend that development to a producible system without significantly compromising the performance level demonstrated in Phase II. Optimizing performance for the 50th percentile male was the primary goal for Phase III, just as it had been during Phase II. Demonstrations with other size dummies (notably the 5th percentile female and the 95th percentile male) were of secondary importance. Three general areas of investigation were undertaken in the development of the system. First, the preliminary design for Phase III was developed by substituting production type hardware and components for the idealized parts that made up the previous Phase II system. Then a series of development tests was undertaken to provide a matrix of data on parametric variations to enable selection of appropriate components for the final design. Finally, a series of validation sled tests identified the system performance.

Constraints on the air belt automatic restraint system design are numerous. In order to maintain the feasibility of using air belts for either the driver or the front seat passenger alone, or for both front seat occupants together, the inflator position was maintained at the rear of the seat track between the two front seats. From this position, it can provide the lower anchor point for either or both of the torso belts as well as supplying gas for the inflatable portion through a flexible tube aligned with the lower end of the belt. To maintain proper orientation of the lower part of the torso belt with seated occupants, D-rings were located on the lower inside corners of the front bucket seats. To control the line of action of its upper part, the upper end of the belt passes through a D-ring normally located on the B pillar. Figures 38 and 39 show the upper D-ring location on the B pillar. That D-ring moves to facilitate entry and egress. When the door next to the occupant is opened, the D-ring located on the B pillar progresses upward and forward along the roof rail over the top of the door to move the belt out of the way of the occupant as indicated in Figure 40. When the door closes on the seated occupant, the D-ring moves aft to the B pillar position wrapping the belt around the occupant and thus acts as an automatic system (cf, Drawing 95430, Appendix A, Volume II). Another D-ring is located further aft on the roof rail. The load limiting portion of the belt passes through this on its way to the retractor that is located just aft of the front seat occupant's head. The retractor is so located that it is out of the way of either front or rear seat occupant, but still in a position to minimize the amount of webbing wound on its reel to provide the necessary spool-off during automatic operation of the belt. The webbing connecting the upper end of the inflatable portion of the belt to the retractor is a special, energy absorbing, extensible material that limits the load and, therefore, the g forces applied to the occupant body by the inflated section of the belt. The crash sensors that call for deployment of the air belt when the velocity change reaches 11 mph are located on the left and right hand side of the radiator yoke, splayed outward about 15 degrees so as to respond to slightly off axis impacts.

At the beginning of Phase III, static and dynamic tests were conducted with alternate, consumer-acceptable production components that could be used to replace the idealized Phase II hardware. On the basis of the results from these tests, the production components were integrated into a preliminary design of the Phase III air belt system. Development sled testing was initiated using a 35 g deceleration pulse which was derived from results



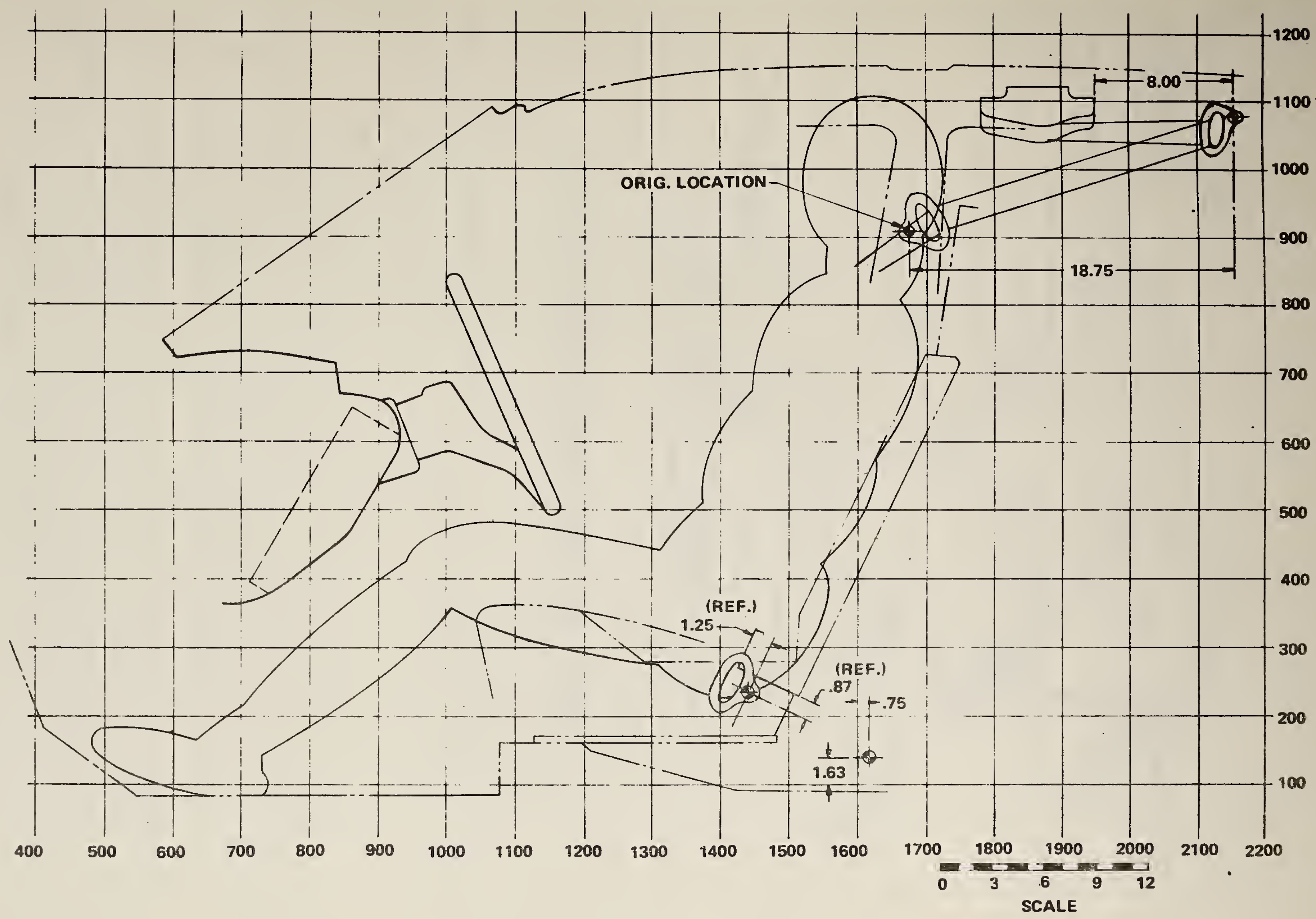


Figure 39 RSV AIR BELT ANCHOR POINT GEOMETRY

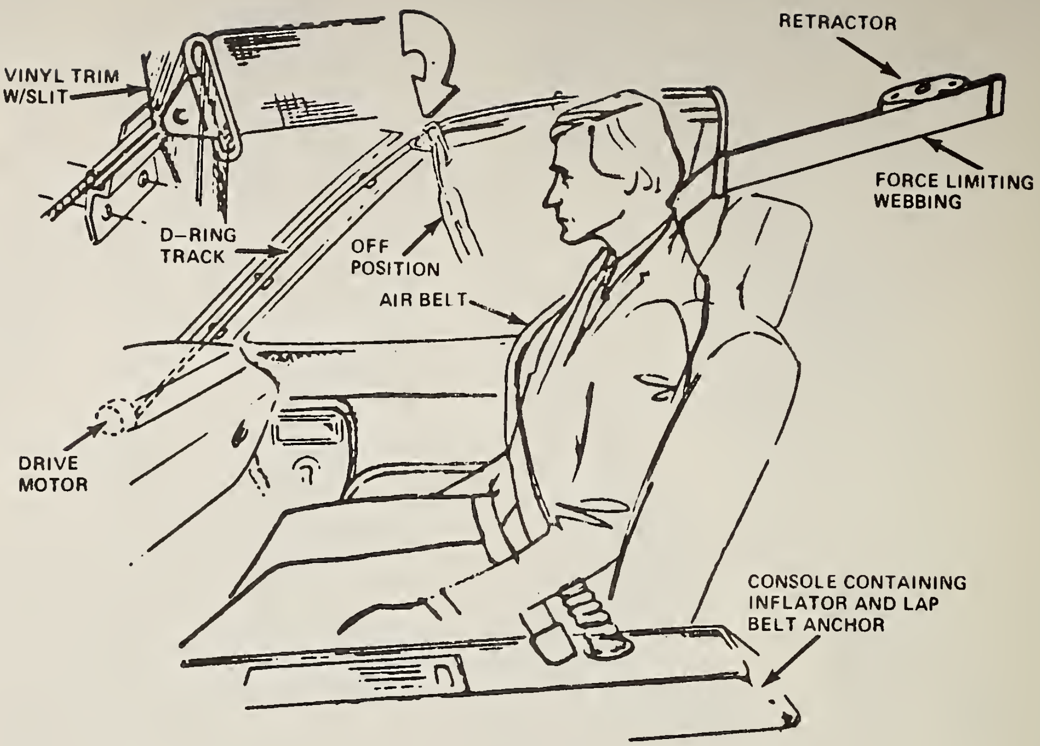


Figure 40 INFLATABLE SHOULDER BELT – PHASE III

of Phase II vehicle tests. Twenty-seven sled tests were conducted in the development effort. Twenty-four of these runs had two dummy occupants in either a driver passenger or passenger/passenger configuration; hence, data were generated for a total of 51 simulated occupant impact exposures. In order to obtain satisfactory system operation, it was necessary to make significant changes between the primary and final systems tested during Phase III, but on completion of this test work, final air belt restraint system hardware and geometry were defined.

The developmental tests indicated that use of an 860 kg (1900 lbs.) load limit webbing would require only about a 100 mm (4 inches) stroke, a distance that is available in the RSV passenger compartment. Further testing, however, showed that the D-ring above the rear door had to be moved 150 mm (6 inches) aft of the retractor to assure adequate working length of the extensible load-limiting webbing. The results of tests with porous and non-porous bag materials led to the decision to use a non-porous material with a vent-hole specifically sized to provide the desired collapse characteristics in order to obtain satisfactory repeatability. In addition, special sewing techniques were required to provide seams of adequate compliance to maintain their integrity during the extension of the force-limiting webbing. Finally, tests of belt force as a function of inflation pressure indicated little or no change above one to two psi. Typically, the unvented air belts inflated in about 25 ms to a pressure of 7-8 psi.

Twenty-five validation sled tests were conducted to indicate final system performance. A total of thirty-nine occupant exposures was obtained - eleven with one occupant, the other fourteen with two. Thus, the operation of the dual belt system was also validated for use with one belt. An inflator containing 65 grams of propellant was shown to be satisfactory for one belt; 110 gram units are required for two. Variables examined during the validation tests included occupant size, sled speed, seat positioning, lap belt use, and sled angle. As before, emphasis was placed upon the 50th percentile male dummy performance, but limited testing was conducted with 5th percentile female and 95th percentile male dummies. Again, the sled pulse was that previously used in the developmental tests, but the squib fire time was reduced from the 13 ms value used earlier to 8 ms in order to simulate better the effect of the initial soft front bumper portion of the RSV deceleration pulse in the sled pulse. For these validation tests final design components were used exclusively, i.e., the air belt system, retractors, Takata lap belt and webbing, Phase IV seats, Phase IV instrument panels, and knee blockers. In addition, the appropriate energy absorbing pillar padding was installed along the A pillar, B pillar and roof rail of the sled buck to provide a realistic environment.

An integrated producible restraint system resulted from these investigations. This system is shown schematically in Figure 40. Satisfactory performance up to the 72 kph (45 mph) speed regime for the 35 g sled pulse tailored to the Phase II vehicle performance objective was demonstrated. Acceptable kinematics and occupant injury criteria were obtained for both driver and passenger 50th percentile size dummies. Satisfactory performance was also demonstrated for the aligned (zero degrees) orientation as well as plus or minus 20 degree sled angle. Although acceptable performance was not indicated for the 5th percentile female at 56 kph (35 mph) or for the 50th percentile male in full forward or rear seat positions at 72.5 kph (45 mph) the 95th percentile male showed satisfactory performance through the 72.5 kph (45 mph)speed in both driver and passenger seated positions.

Subsequent comparisons of Phase III vehicle crash data[8,13,14] with the sled buck deceleration utilized in the development and validation sled tests,[5] have indicated that the sled environment was much milder than that experienced in the actual Phase III RSV vehicle crashes. As a result, the occupant performance measures obtained in the sled program appeared to be optimistic. The crash test results indicated a need to deploy the air belt more rapidly and in a slightly higher position in order to provide more head support and achieve the desired kinematics and results. Consequently, the following changes were accomplished:

(1) The internal diameter of the port leading from the manifold to the air bag was increased to 22.2 mm (7/8 inch), which provides a flow area of approximately 3.87 cm^2 (.6 sq. in.).

(2) The air bag on the belt was fabricated from two layers of neoprene coated material in order that it withstand the higher pressures and perhaps more rapid loading achieved by the increase in manifold port area.

(3) The D ring over the occupant's shoulder was repositioned upward on the B pillar. The mounting bolt is now .883 m (34-3/4 inches) above the top of the sill in order to raise the level of the top of the bag on the air belt nearer that of the clavicle and hence provide more support for the occupant's head. In addition, the gas generator flange was bonded to the manifold to eliminate the potential for gas loss by leakage.

Sled tests at Calspan and crash tests in Japan demonstrated the success of the three changes by compliance with FMVSS 208 requirements at the higher speeds representative of the lower values of RSV goals.

3.8.2 Automatic Belt Control

The automatic belt control module was redesigned in Phase III to improve operation of the drive motor and reduce the size of the control module. The module is approximately one third the size of the Phase II control relay box. The size could be further reduced to a single electronic "chip" if a final production design were to be developed.

The Phase III control is solid state, utilizing a current sensing circuit to determine whether the moving D ring has reached the end-of-travel mechanical stop on the drive cable. At the stop, the current rise through the stalled drive motor is detected and shuts off power to the system.

The system is controlled by one or a combination of the following switches:

Driver

- door switch
- ignition switch
- seat switch

Passenger

- door switch
- ignition switch
- driver's seat switch
- driver's door switch

Modes of operation:

- driver's door closed
- driver's seat occupied
- ignition switch in run position

The passenger's system may be retracted by:

- opening the passenger side door
- turning the ignition switch off
- pressing the emergency retract switch (see below)

It should be noted that turning the ignition off causes the system to retract the belts; in this way, delays for exit and entry of the occupants in the car are minimized.

An emergency retract switch is mounted on the center console of the instrument panel. It allows over-riding the normal control switches. To redeploy the belts, the engine must be turned off and restarted.

The circuit diagrams are shown in Figures 41 and 42. The passive belt control board is shown in Figure 43.

The Phase II drive motor is more powerful than that used previously. This DC driver motor and gear box assembly (see Figure 44) drives a spiral wound cable, moving in a split guide tube that carries the passive belt movable D ring. It functions like a flexible rack driven by the motor pinion gear.

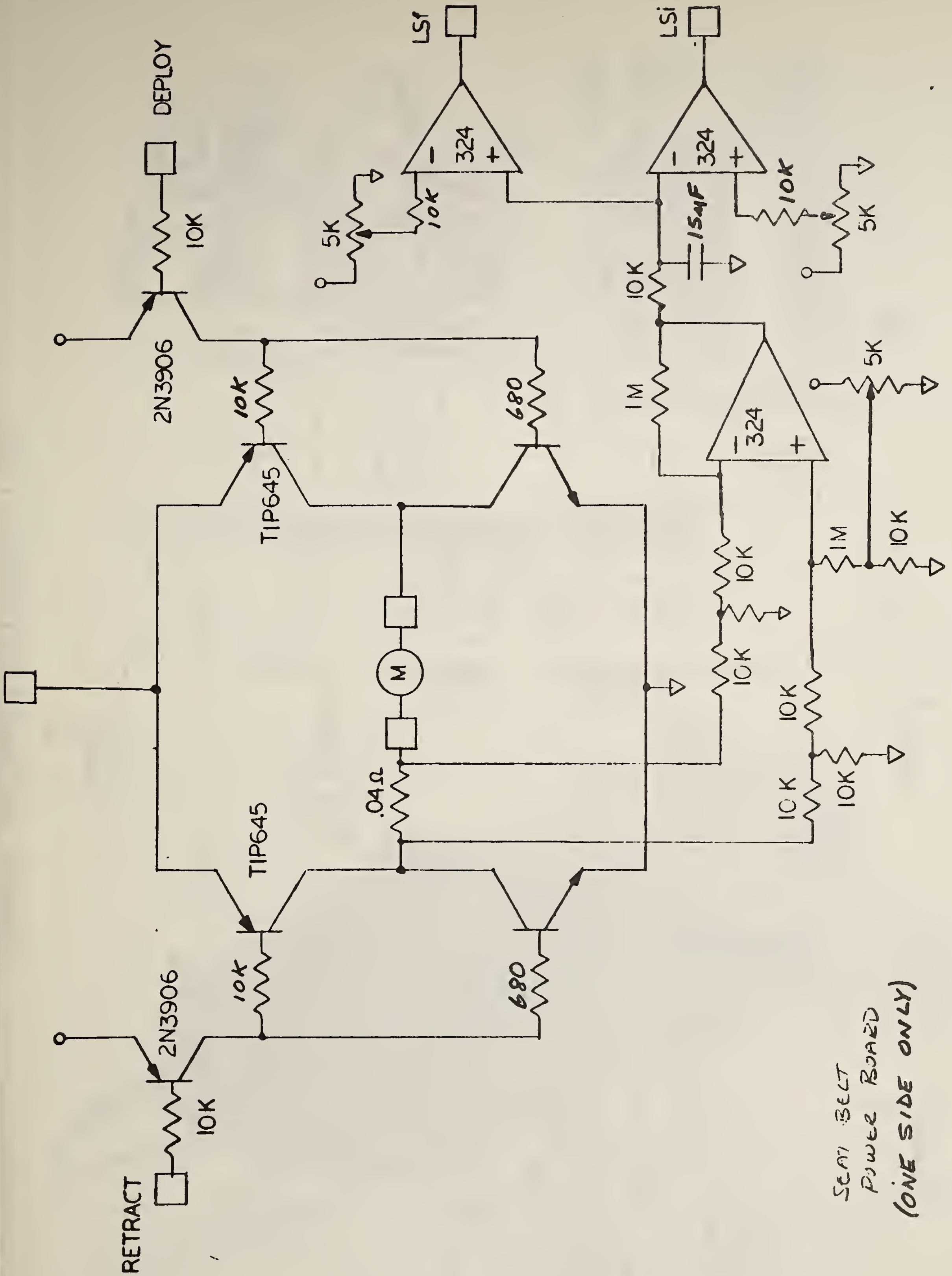


Figure 41 CIRCUIT DIAGRAM

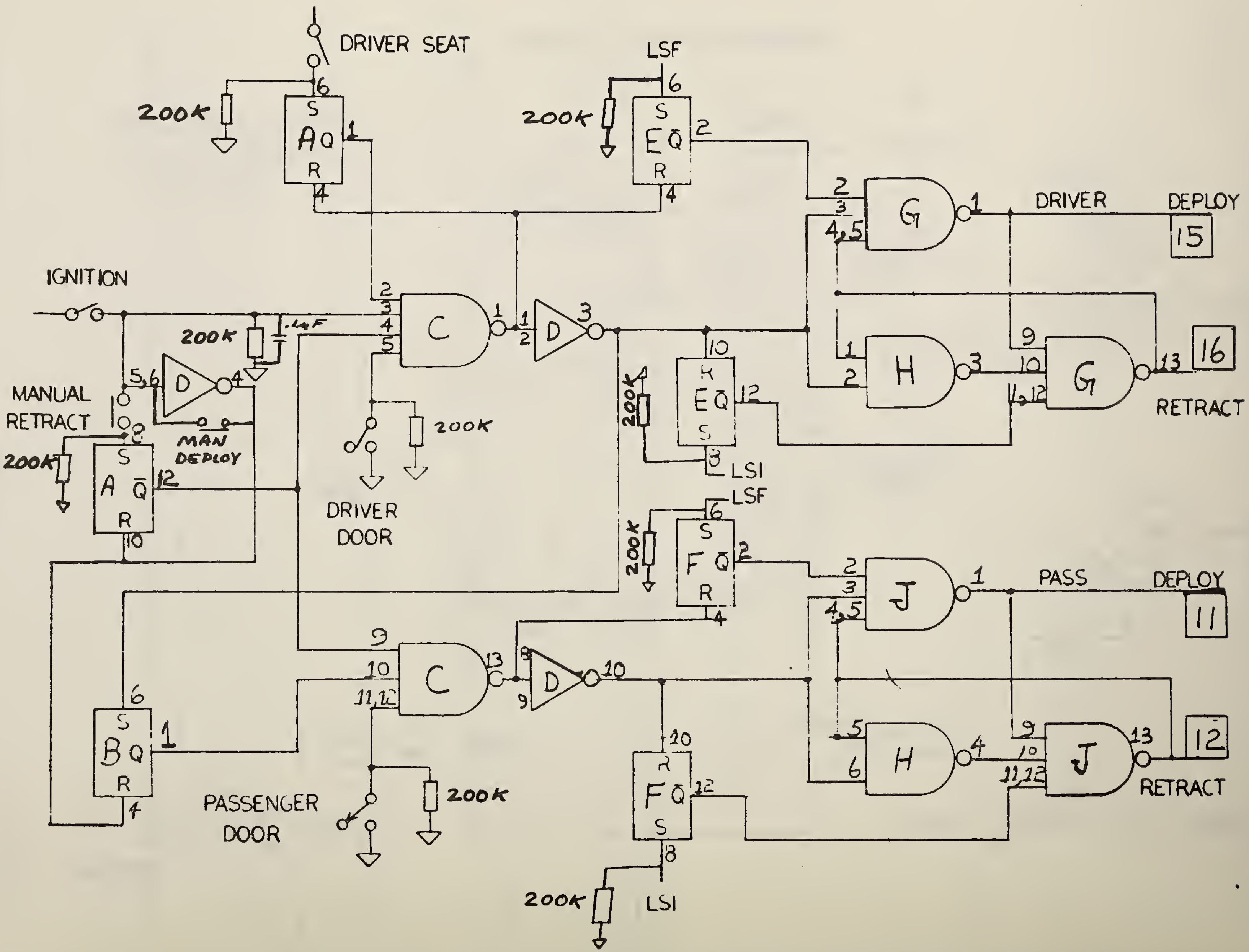


Figure 42 AUTOMATIC BELT CONTROL LOGIC

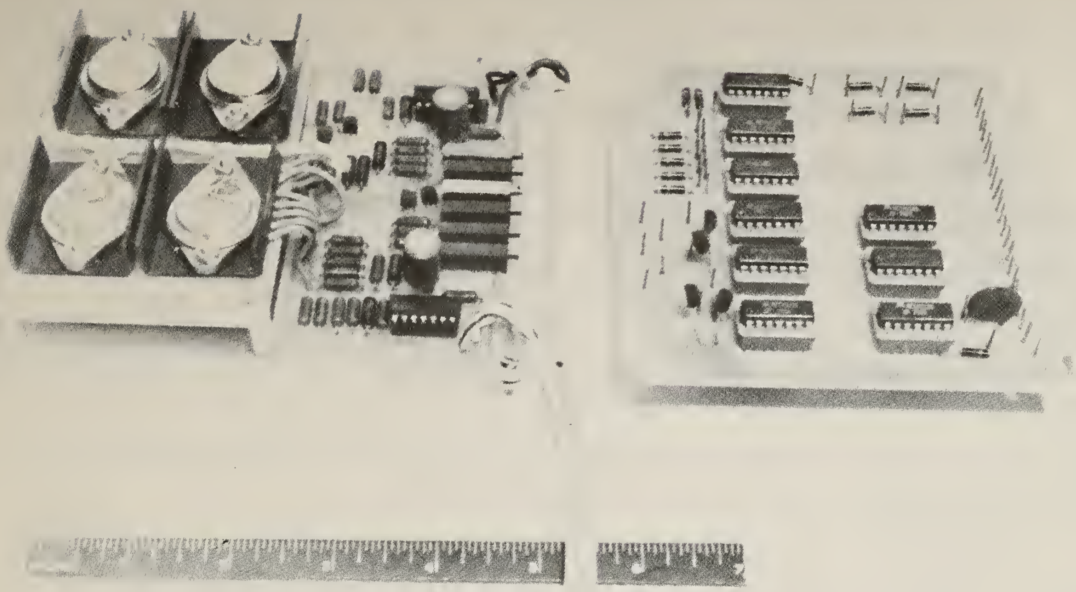


Figure 43 PROTOTYPE CONTROL LOGIC BOARD

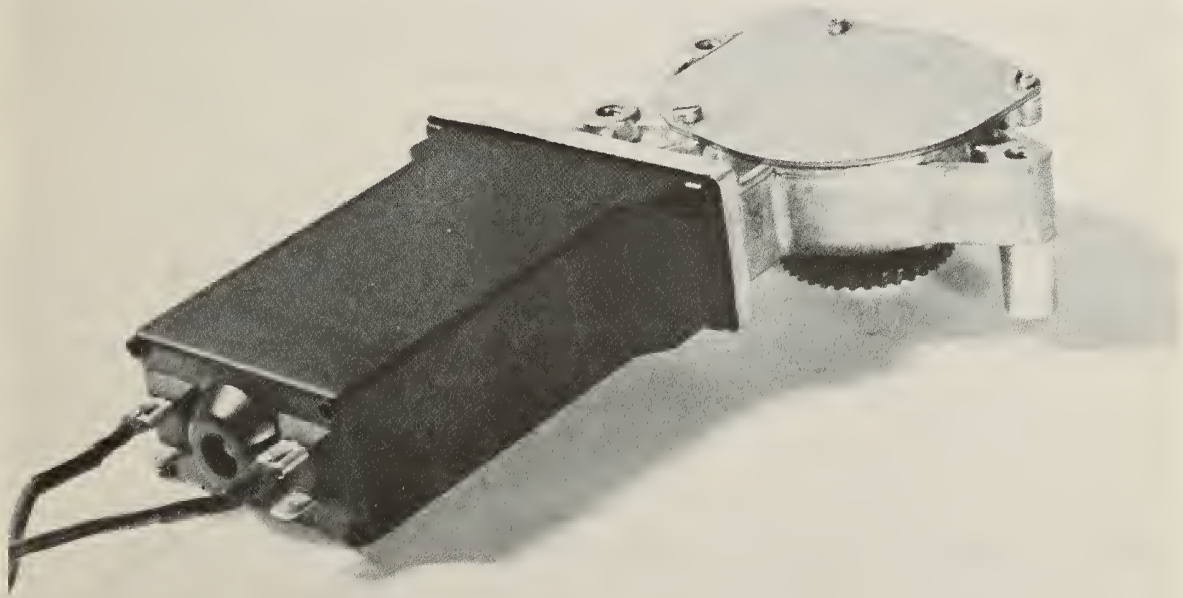


Figure 44 AUTOMATIC BELT DEPLOYMENT MOTOR

The drive motor is supported by a metal bracket bolted to the cowl side inner surface. Carryover Simca cowl kick trim was modified to conceal the drive mechanism.

The movable D ring is attached to the drive cable by a small tab soldered to the cable end. To prevent scuffing of the pillar trim, two small pieces of Delrin are riveted to the tab. A tapped steel block is welded to the tab, to which is bolted the D ring. A plastic cover trims the exposed bolt head and D ring. Both the cable guide tube and the D ring attachments to the cable are designed so that they will deform so that almost all of the upper torso belt loads are carried by the rearmost fixed D ring rather than the movable one.

3.8.3 Driver Air Bag Restraint System

The driver air bag restraint system for the RSV, as reported in Reference 6 in detail, was developed by the complementary use of computer simulations[3,29] and evaluation sled tests utilizing the anticipated vehicle deceleration pulse developed from the Phase II crash tests.[24] Prior to the performance of the developmental sled tests, simulations were run with the ABAG19 computer model* to indicate performance bounds for different driver air bag restraint system components. Design parameters evaluated include: bag size, gross bag shape, pressure inflow time history, venting, steering-column force/deflection properties, and vehicle deceleration pulse. A large portion of the modeling focused upon the steering column stroke for different driver air bag system and occupant conditions. The ABAG19 result indicated that a stiff .35 kg/cm^2 (5 psi) bag mounted on 1800 kg (4000 lbs.) collapse-load steering column could provide 64.4 kph (40 mph) protection for the 50th percentile male, the 95th percentile male and the 5th percentile female; in addition, acceptable results could be obtained for the 50th percentile male at 72.4 kph (45 mph). Early experiments provided very good correlations for

*The ABAG19 model is a one-dimension computer program that predicts the deceleration response of a body impacting a cylindrical air bag mounted on a collapsible, colinear steering column.

both chest acceleration and pressure time histories using the 35 maximum g deceleration pulse developed in Phase II. In fact, both the time of initiation of occupant deceleration and the initial gas flow were predicted well by the simulation. However, it is important to note that the ABAG19 occupant, bag and column are all colinear so that bag loads are always reacted in the optimum manner. Further, critical parameters such as knee bar position and compliance are not accounted for in the computer program. The early work indicated peak torso deceleration to be linearly proportional to the steering column collapse force and inversely proportional to the effective torso mass, while the column stroke length is inversely proportional to the column collapse force. For the same column stroke, increasing bag pressure from .21 to .35 kg/cm^2 (3 to 5 psi) reduced the peak torso deceleration by 5 to 10 g's. Reducing the torso bag deployment point distance by 10 cm (4 inches) reduced peak torso decelerations by another 10 to 15 g's. For the same collapse load, increasing the bag pressures reduced the required column stroke and decreasing the torso deployment point distance reduced the required stroke. These results indicated that the major function of the air bag is to improve ride-down rather than to dissipate energy. Equivalent improvement in ridedown may be achieved by increase in bag diameter for constant pressure or by increase in bag pressure.

Two series of sled tests were employed in the development of the driver air bag. Initially, a development series that provided a matrix of information on parametric variations to support selection of specific hardware was run. After the size and characteristics had been so determined, an evaluation series in which occupant size and positions were examined at different speeds was undertaken.

Prior to developmental sled testing, static bag firings were performed to compare unvented pressure/time histories and fill characteristics for three alternate air bag designs as well as to assess the potential contact area provided. Once the simulation and component tests were completed, the developmental sled tests were initiated. Parameters such as bag size and venting were adjusted for optimum 50th percentile male performance. In addition, the system effectiveness for the 5th percentile female and 95th percentile male occupants was also examined.

In order to simplify developmental sled testing, idealized knee restraints which consisted of aluminum honeycomb blocks supported in a rigid framework were utilized. Phase III instrument panels which incorporated aluminum honeycomb knee restraint inserts were used in the subsequent series of evaluation sled tests.

The final evaluation tests were conducted using the previously identified RSV 35 g Phase II anticipated sled pulse and the final system designed components (bag, column, instrument panels, seats, etc.). Variables examined included dummy size, seat position, impact speed, impact angle and lap belt use. As indicated by the results shown in Reference 6, acceptable performance was demonstrated for the 50th percentile male dummy at speeds in excess of 72.4 kph (45 mph) in the full forward, normal, and full rear seating positions, both with and without a lap belt in straightahead impacts. In addition, angular exposures at ± 20 degrees also produced satisfactory results. The maximum chest resultant acceleration recorded for the 50th percentile male dummy at 72.4 kph (45 mph) in those evaluation tests was 53 g's (18 g's greater than the indicated maximum sled acceleration) and the corresponding maximum HIC number was 703. The system is depicted in Figure 45.

One of the basic constraints in the design of the RSV driver air bag was the achievement of a satisfactory restraint system without a significant modification to the basic RSV steering column and knee blocker configuration. The base vehicle does not have a collapsible column; furthermore, the steering column angle is not shallow enough to promote axial loading. Consequently, the RSV driver air bag utilizes upper column bending as an energy dissipating mechanism. Test results, as shown in Figure 46, indicate that this approach is very repeatable and that the steering column shaft bend angle is proportional to impact velocity and inversely proportional to occupant size.

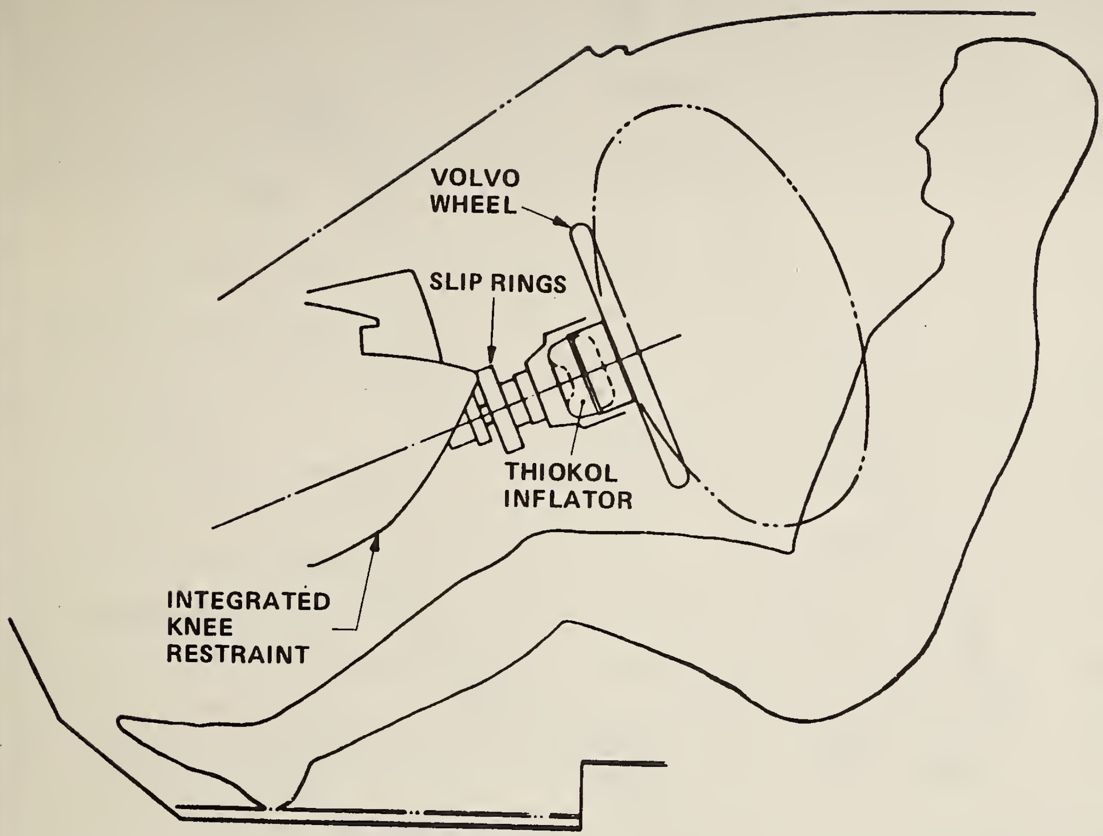


Figure 45 DRIVER AIR BAG SYSTEM

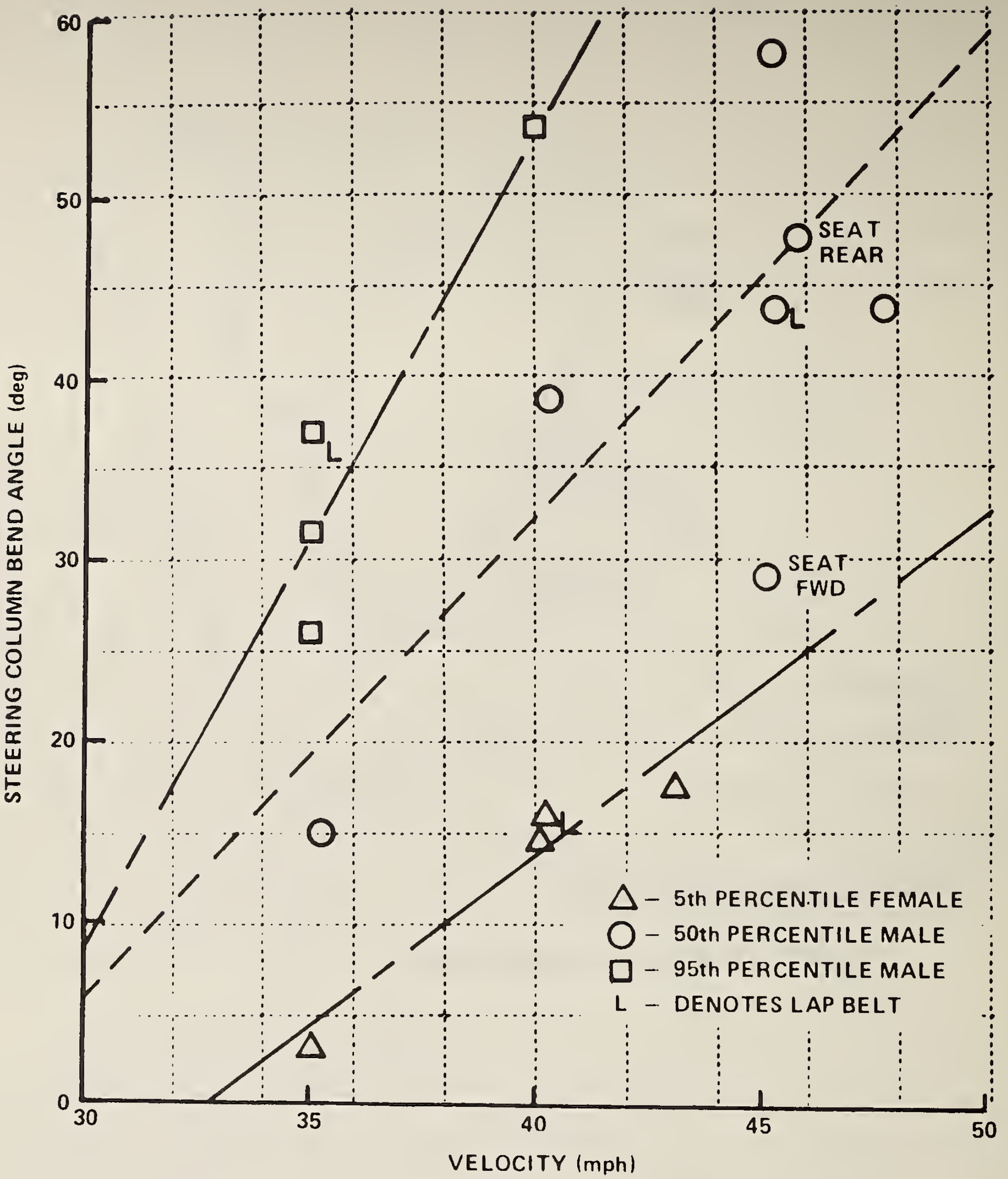


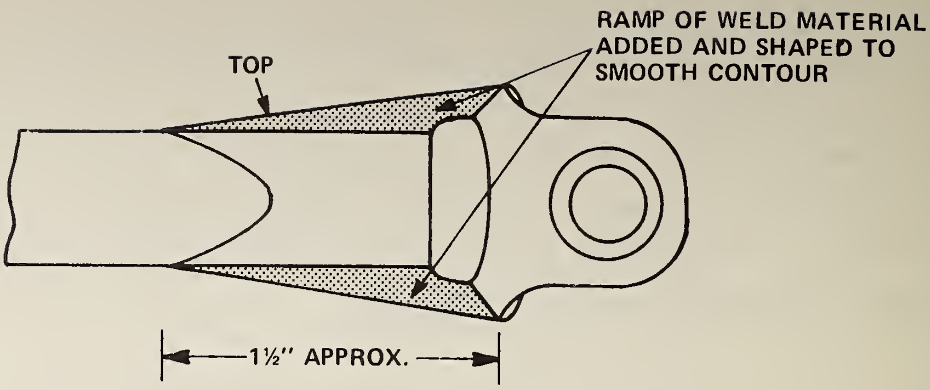
Figure 46 COLUMN BEND DEPENDENCE ON SPEED OF SLED IMPACT

Use of the process of column bending for driver energy management may result in contact of the driver's thorax with the steering wheel lower rim. To assess the magnitude of this potential problem, bench tests were performed in which steering wheels were loaded by a dummy torso. Those tests indicated that although the contact pressures are high (in the neighborhood of 7 kg/cm^2 - 100 psi), the associated chest deflections are within acceptable levels (less than 6 cm - 1-1/2 inches).

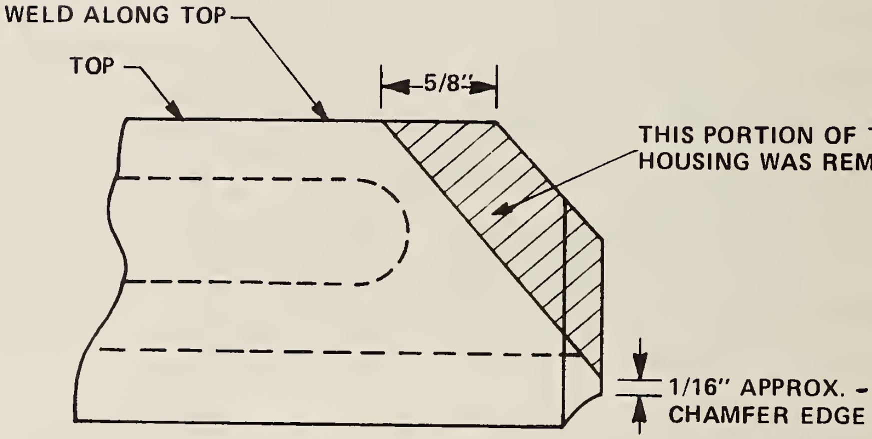
As in the case of the air belt restraint system, the more rigorous accelerations experienced in the actual RSV Phase III car crashes required revisions to the air bag restraint system. The changes included modifications to the steering column, its support brackets, the breakaway linkage, the wheel size and reinforcement of the spokes and their attachment to the wheel hub to withstand the appreciably higher g loading. The thrust bearing was more tenaciously secured to the steering column by welding it in place; in addition, the breakaway shaft was relieved on the housing and a ramp was built up on the internal shaft (as shown in Figure 47) to eliminate transmitting longitudinal loads along the column. To provide a larger platform to support the air bag, the wheel rim diameter was increased from 37 to 41 cm (14-1/2 to 16 inches). A strap 2.3 mm (0.090 inch) thick was welded along the full length of the spokes. To support the higher g loads and moments this revised wheel design could transmit to the hub, a steel colar was added to which the spokes were welded as shown in Figure 48.

3.9 Driver Environment

The environment afforded the driver of the RSV, and as a result to the other occupants, was investigated because of its direct relationship to the driver's ability to control the vehicle.[22] Such considerations as being able to see out of the vehicle directly or indirectly and maintaining that capability in adverse weather and at night bear a direct relation to the driving task. The information provided other drivers by the exterior lighting is also important, as is the control of the climate within the occupant

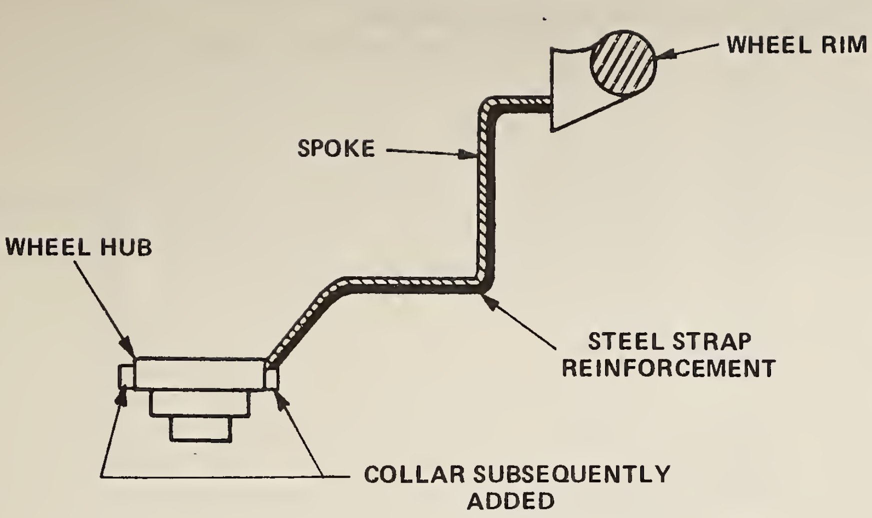


INTERMEDIATE SHAFT -
SIDE VIEW

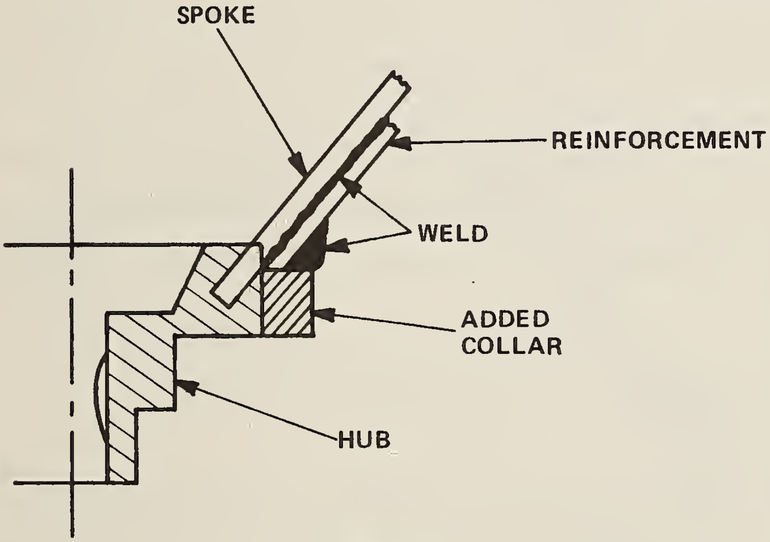


HOUSING -
SIDE VIEW

Figure 47 RSV BREAKAWAY SHAFT MODIFICATIONS



SKETCH NOT TO SCALE



HUB DETAIL

Figure 48 FINAL STEERING WHEEL

compartment to insure that driver capability is not compromised. These factors are discussed in the subsections below.

3.9.1 Visibility

Both direct and indirect visibility are discussed in References 1 and 3.

3.9.1.1 Direct Visibility

Results of a direct visibility study are shown in Figures 49 and 50. Figure 49 shows that the maximum obscuration angle through the A pillars is 4-1/2 degrees (which may be compared to the 6 degree acceptable limit proposed for such binocular obstructions). As illustrated in Figure 50, the RSV meets all the specifications for monocular vision, including an absence of obstructions in the ± 22 degree area directly ahead of the driver. In addition, the obstruction provided by each of the A pillars is less than the 11 degrees allowed. Also, for the zone 90 degrees to the right and rear of the driver, no single obscuration angle is greater than 16 degrees and the combined total of the three obstructions measures less than the 26 degree allowable maximum total value.

3.9.1.2 Indirect Visibility

Indirect visibility studies in Phase II showed that the base Simca 1308 mirrors would not provide a sufficient view to cover 95% of targets Q, SL and SR, (see Figure 51) as specified in the Recommended Specifications for Research Safety Vehicle Visibility System Design.[3] To meet the 95% target coverage specified would require a 217.17 x 73.66 mm (8.55 x 2.90 inch) mirror on the driver's side and a 134.62 x 73.66 mm (5.30 x 2.90 inch) convex mirror mounted on the right front fender, plus a carryover Simca 1308 inside mirror. The size and position of such outside mirrors were considered to be detrimental to both aerodynamics and pedestrian protection.

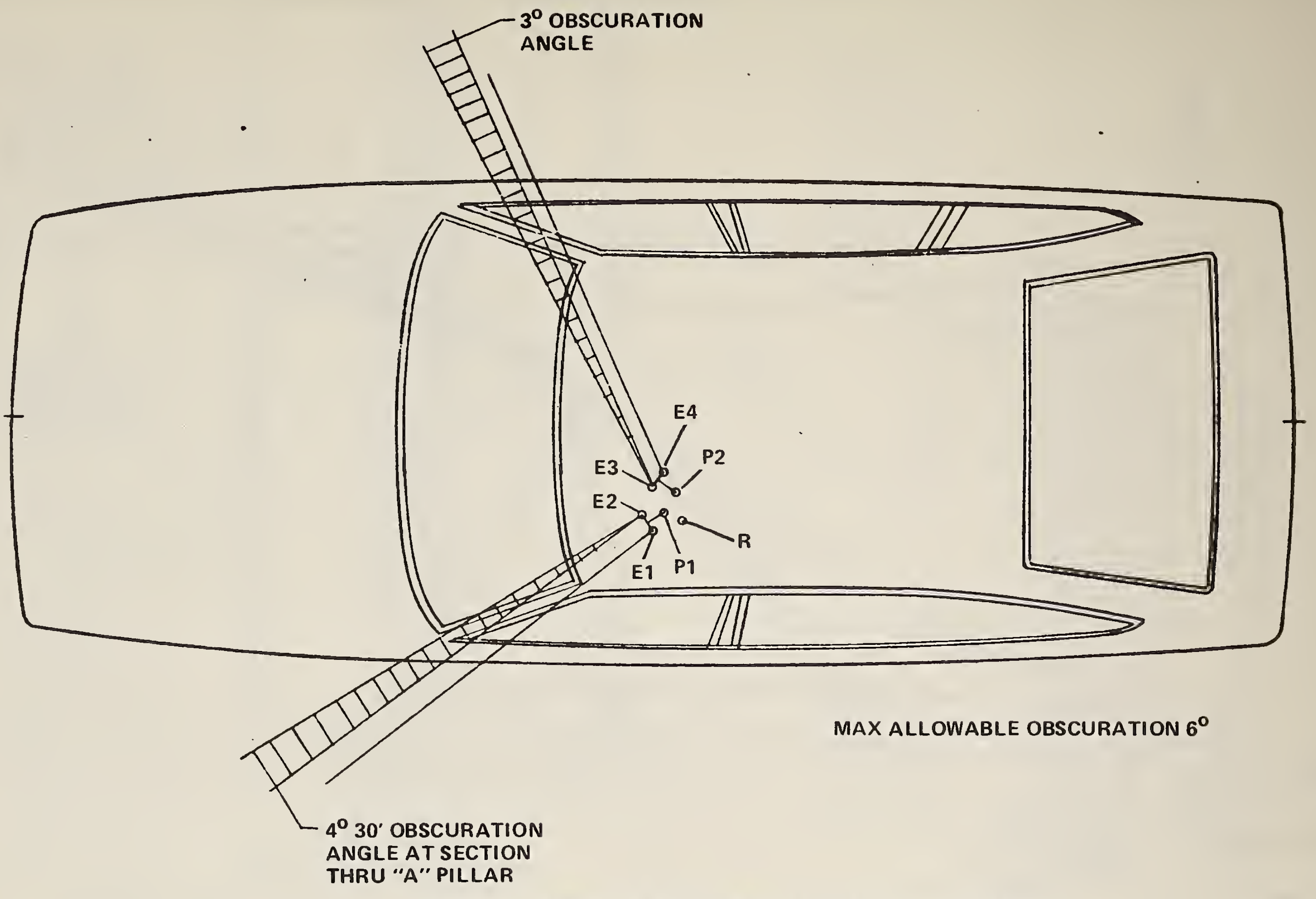


Figure 49 BINOCULAR VISIBILITY THRU "A" PILLAR

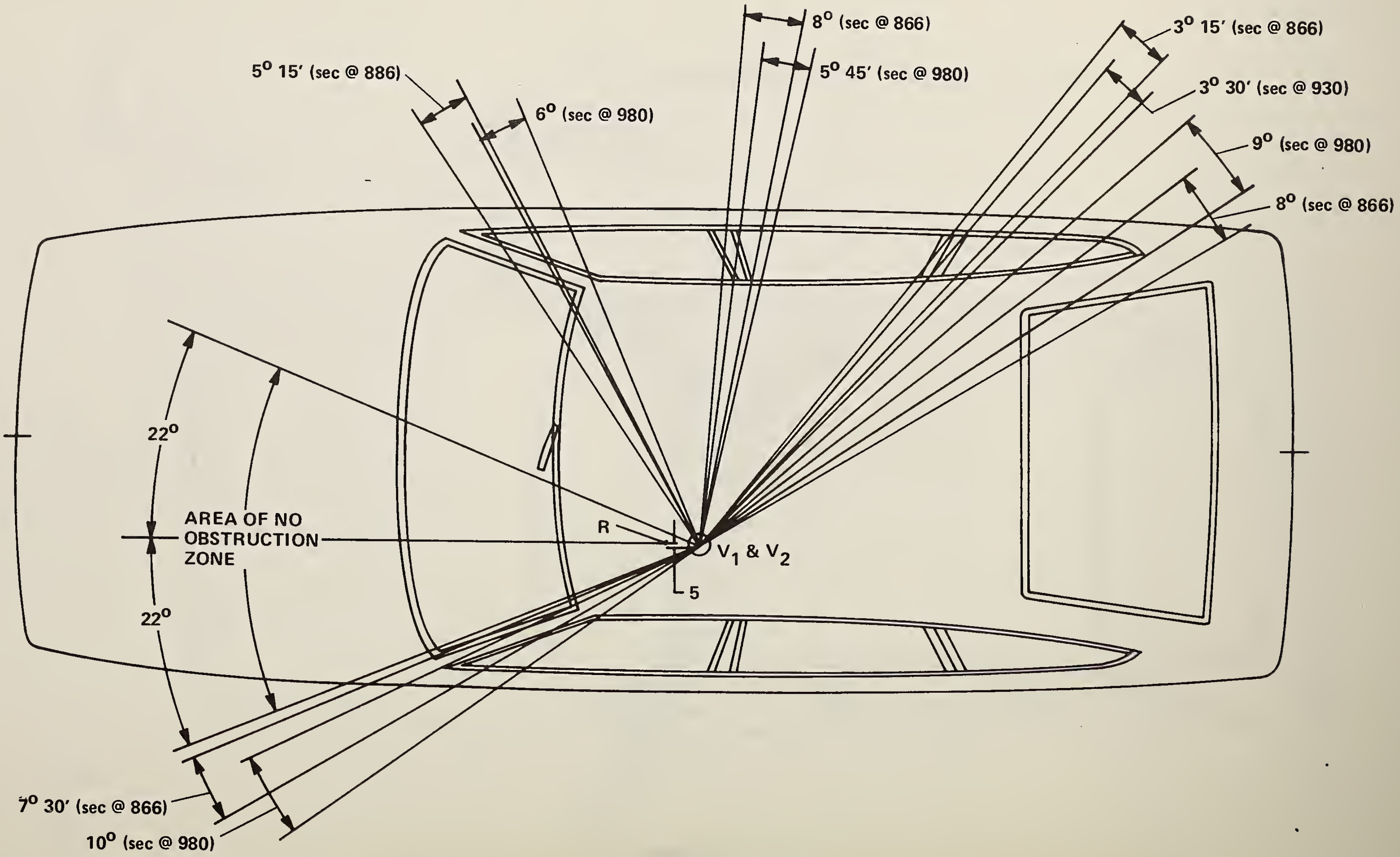


Figure 50 MONOCULAR VISIBILITY OBSTRUCTIONS

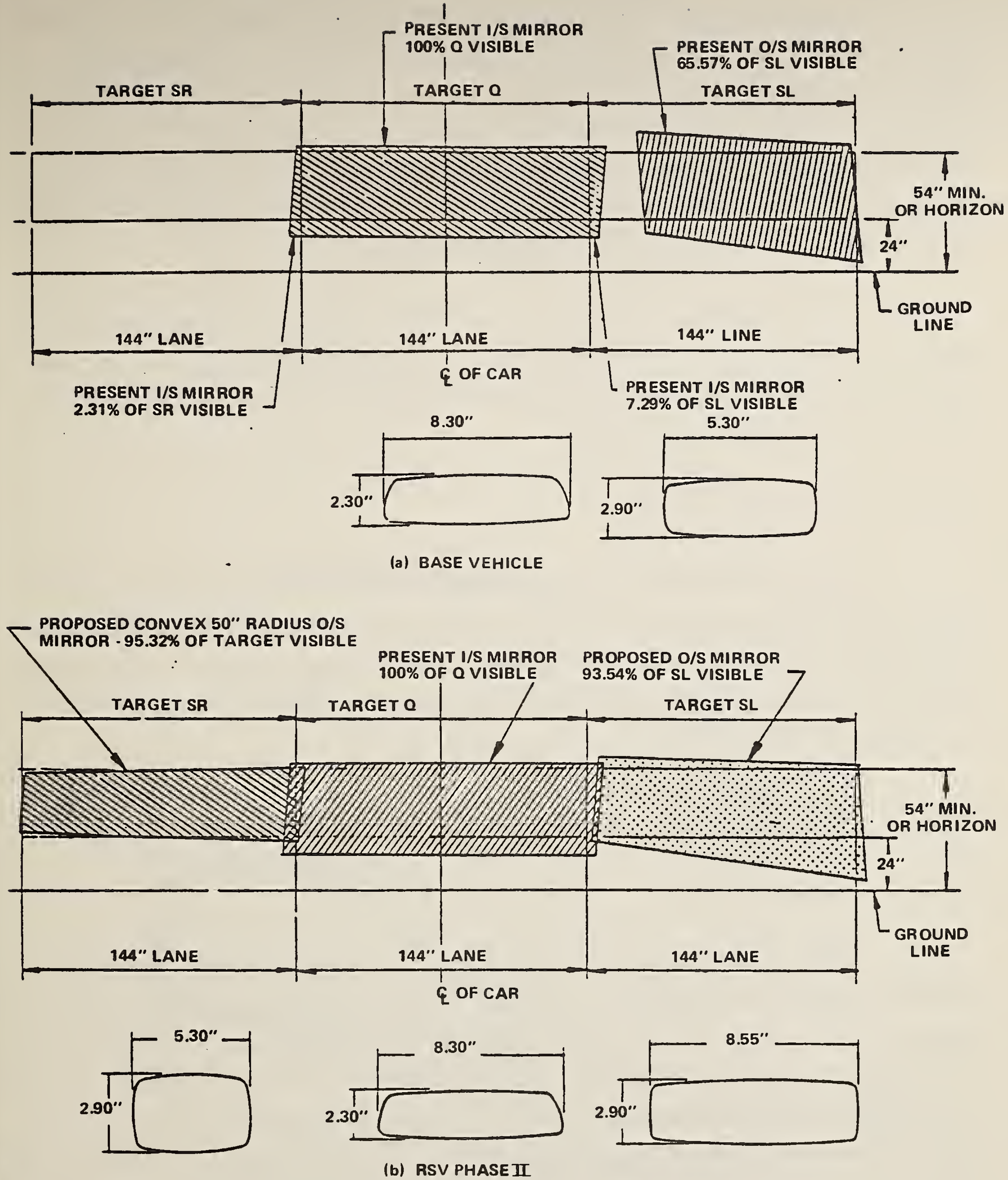


Figure 51 INDIRECT VISIBILITY – MIRROR TARGET PLANE

As shown in the picutres of the final RSV, Figures 2 and 3, outside mirrors are trapezoidal and mounted in plastic housings. This particular mirror, designed for a Chrysler 1979 subcompact car, is able to meet FMVSS No. 111 for left outside mirrors (see Figure 52). A convex mirror of 1524 mm (60 inches) radius is used on the right outside mirror. The inside rearview mirror utilizes a double jointed support (an improvement over the 1308 single joint support) which provides a breakaway feature.

In view of the earlier results, a full visibility study was not conducted in Phase III; it is believed that the larger outside mirrors on both sides of the car will provide acceptable performance without penalty to drag (fuel economy) or pedestrian safety.

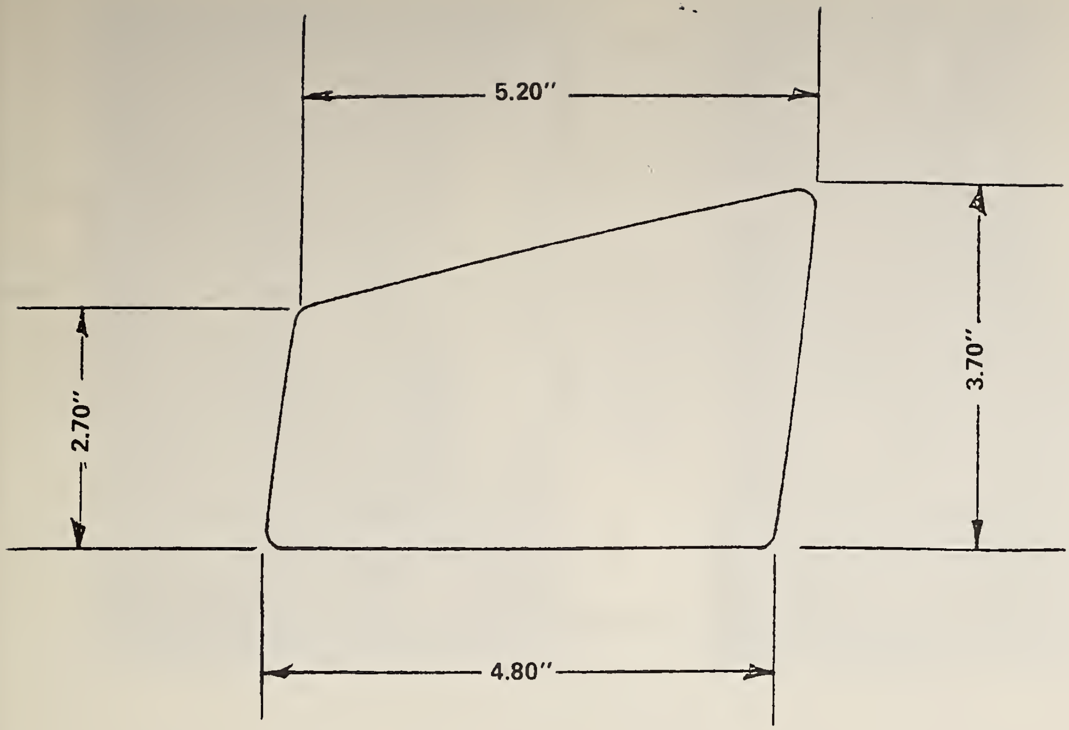
3.9.1.3 Wiper/Washer System

The wiper system is carryover Simca except that the wiper motor is rotated 120 degrees clockwise to avoid contact with the carburetor when these components "stack up" during front impact (see Figures 6 and 20). The washer system is carryover Simca except for the routing of hoses. See engine compartment packaging (Section 3.2.1) for details.

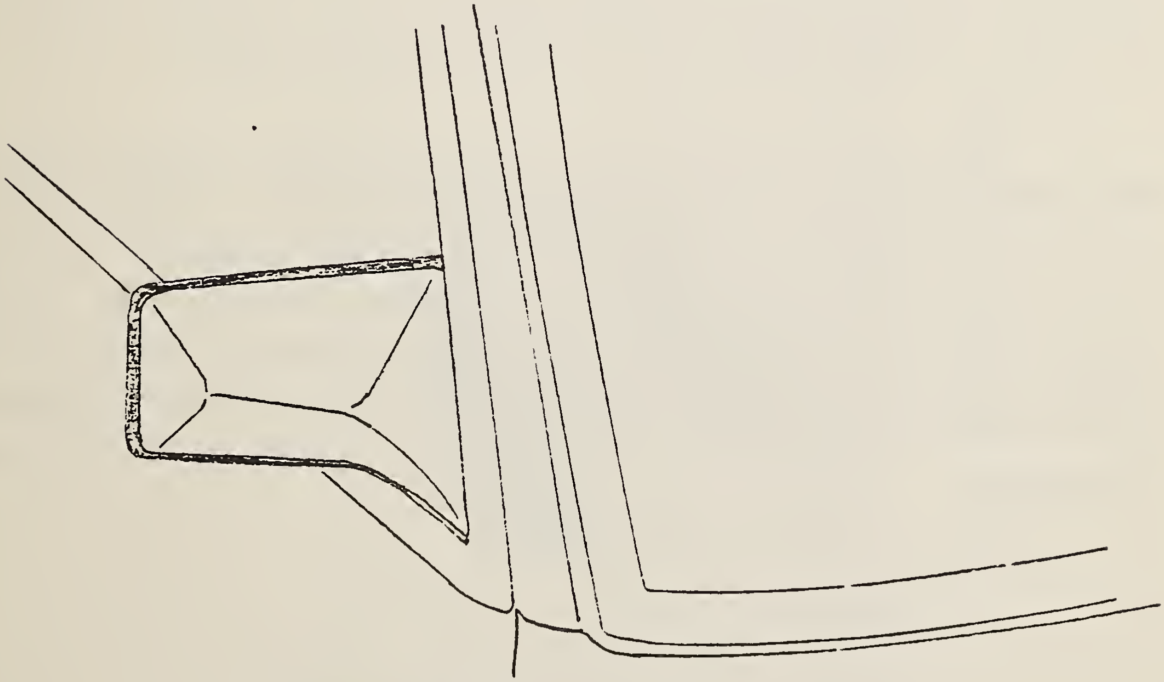
3.9.2 Lighting

3.9.2.1 Headlamps

CIBIE of France designed and built the plastic lens, single beam, unsealed rectangular headlamp of 114 mm x 165 mm (4.5 x 6.6 inches) shown in Figure 53. The goal of this lamp, although not in complinace with FMVSS 108, is to provide sufficient light for the driver to see the road ahead as well as with present American high beams and at the same time improve vision to both sides of the road without being objectionable to other drivers. Driver evaluations have indicated improvement over the standard U.S. low beam system (particularly in adverse driving conditions) and improved vision to the left and right of the vehicle. The lamp has a less sharp cutoff than is the common



(a) MIRROR SIZE PHASE III



(b) HOUSING ON BODY PHASE III

Figure 52 OUTSIDE REAR VIEW MIRROR

practice in Europe but a more distinct one than in current U.S. lamps (see Figures 54 and 55). A CIBIE developed hydraulic headlamp aim compensator for dynamic adjustment could eliminate some of the objections about the "bounding" effect of the upper cutoff for both following and on-coming cars.

The lamp is equipped with a special H-4 bulb in which the high beam filament is replaced by a low wattage filament so that when the standard filament burns out, a small amount of light will still be emitted from the bulb to help define the vehicle at night.

3.9.2.2 Headlamp Covers

FMVSS 108 does not allow headlamp covers on any normal production car. The primary functions of the covers on the RSV are to reduce the aerodynamic drag, eliminate the possibility of collecting snow in front of the headlamps and present a smooth surface to pedestrians. A drag coefficient reduction of 3.6% for the headlamp cover was determined during full scale model wind tunnel tests.[20] The cover is made from polycarbonate plastic (General Electric, Lexan) with the most modern scratch resistant coating. The covers are shown installed on the RSV in Figures 2 and 21.

The cover is designed to pop out in low speed, no damage collisions and pedestrian impacts at or near the headlamp to prevent breakage. Their survival in 40-50 mph barrier crashes indicates their rebustness. Post-impact "snap-in" replacement must be refined and functional testing of the headlamp should be performed to determine if moisture condensation or dirt between the headlamp and its cover will be a problem. Since only preliminary testing was conducted at CIBIE, the effects of the cover on the light pattern should also be examined.

Figure 53 RSV PLASTIC HEADLAMP

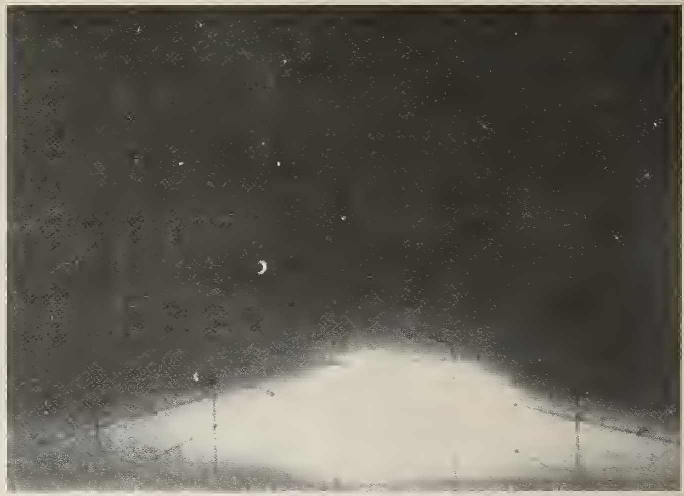


Figure 54 STANDARD TUNGSTEN SEALED BEAM LOW BEAM

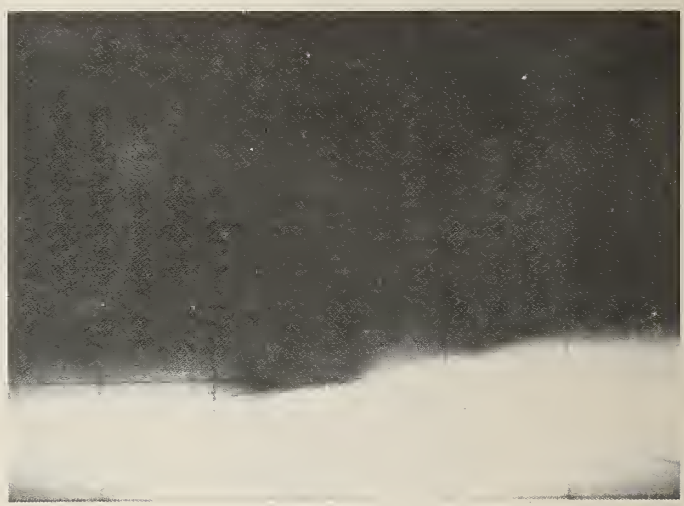


Figure 55 RSV HEADLIGHT BEAM

3.9.2.3 Exterior Lighting

In addition to the headlamps and headlamp covers as reported in the previous sections, vehicle exterior lighting will include front side marker lamps, front park and turn signals, rear high level taillights with combined side markers, conventional taillights, and a rear license plate light. These are shown in Figures 2, 3 and 27. Except for the high level taillights, all are standard production lamps used in the following locations:

park and turn signals	-	1978 Dodge and Plymouth Van
side marker lamp	-	used on all 1978 Chrysler Corp. vehicles
taillights	-	1978 Dodge Aspen
rear license light	-	1978 Chrysler New Yorker

The high level taillights were designed for the RSV by CIBIE to provide the ability for following drivers in heavy traffic to anticipate vehicle motion a number of cars ahead, particularly on multi-lane roads. DOT-supported tests of a single, high-level rear stop lamp on taxicabs in Washington, D.C. demonstrated the effectiveness of such a light by a dramatic reduction in rear end collisions. Four functions are incorporated: rear side marker lamp, taillight, brake light and turn signal. The rear side marker lamp does not fully comply with FMVSS 108 because the position is not at the rearmost practical location.

The high level taillights could possibly have been designed to admit elimination of the lower taillight. The resulting increase in space could then be made available for enlarging the rear energy-absorbing bumper to improve vehicle low-speed rear protection.

3.9.3 Air Handling Systems

3.9.3.1 Heater/Defroster

The baseline Simca heater/defroster system has been found to be a very efficient unit. The defrost function, however, is not capable of clearing the windshield area within the FMVSS allowed time limit. Time and budgetary limitations in Phase III did not permit modification or redesign of the heater/defroster system. Therefore, the final vehicles retain the Simca unit.[3] If design time and funding were available, modifications to the system would probably include installation of a more powerful blower motor, blocking off the side defroster ducts, and fitting larger ducting and air outlets. The ducting and outlets enlargements would be a major modification because available space is at a premium in the cowl area.

3.9.3.2 Air Conditioning

In Phase II, the base vehicle air handling module was used. In Phase III, with the change to the 1716 cc engine, air conditioning was added to the vehicle for consumer acceptance. An air conditioning evaporator has been packaged into a modified air handling unit. A sheet metal box is attached to the housing and sealed around the periphery. The heater controls will be modified to suit. In the A/C mode, the ram air vents are closed, and inside air is recirculated.

A new rear console and heat duct has been designed which replaces the Simca assembly and serves as a trim cover over the pyrotechnic gas generator and manifold of the occupant restraint system.

4.0 CHASSIS

RSV chassis parts are discussed in References 3, 22 and 23 and are shown in the drawings in Appendix B of Volume II.

4.1 Engine

The 1442 cc engine of the Simca 1308 was replaced in Phase III of the RSV program by the 1716 cc engine used in Chrysler's Omni and Horizon.[3,24] The decision to switch engines was based on several factors. First, the Simca engine had never undergone extensive emissions development in France, so meeting the improved emission targets for the RSV would have required a major development program. Second, even if the 1442 cc engine could be successfully "de-toxed", the anticipated loss in power would result in inability to meet the acceleration goals for the heavier RSV. Third, the Simca engine had never been mated to an automatic transmission which was a desired RSV option. Therefore, it appeared to be more reasonable to install a new engine rather than extensively redesign and redevelop the old one.

The 1716 cc Omni/Horizon engine (Figures 56 and Drawings 90010 through 90110 in Appendix B, Volume II) is a four cylinder, overhead camshaft power-plant featuring a cast-iron cylinder block and a aluminum cylinder head. The engine has electronic spark advance (ESA), a staged two-barrel carburetor, 8.2:1 compression ratio and, in California trim, produces 70 horsepower at 5600 rpm and 85 ft/lbs. of torque at 2800 rpm. The engine family description (Appendix C, Volume II) as supplied to the Environment Protection Agency provides further details of the engine features.

The initial emission targets for the RSV were .41, 3.4 and 2.0 grams per mile of HC, CO and NOx, respectively. These targets were later revised to the 1978 California emission standards of .41 HC, 9.0 CO and 1.5 NOx. This revision was made because Chrysler had never developed an engine specifically to meet the original targets and undue developmental expense without real

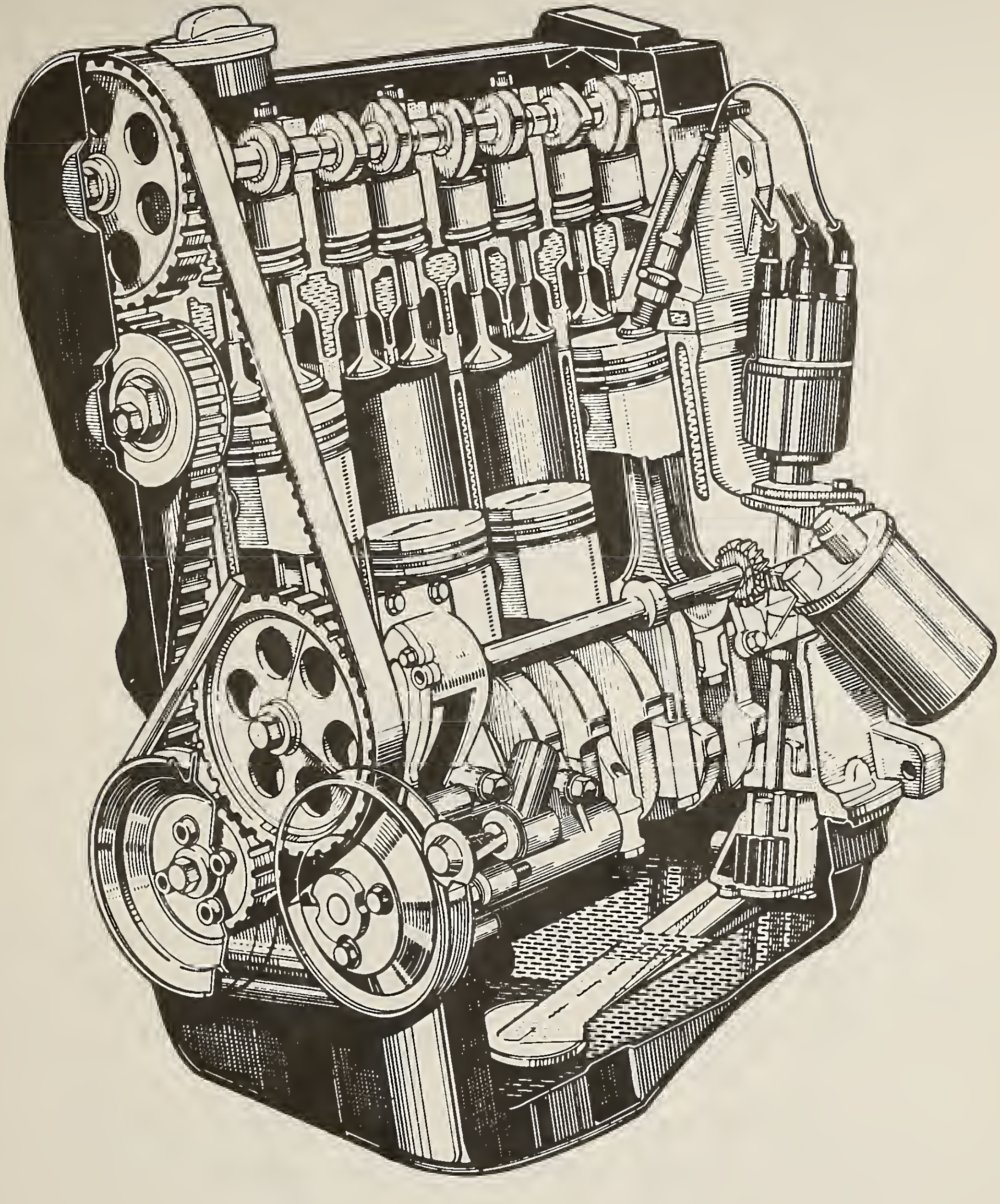


Figure 56 OMNI/HORIZON 1716 cc ENGINE

improvement in emissions characteristics might have been incurred. The Omni/Horizon California emission package (Figure 57) includes a close-coupled mini oxidation catalyst, main catalyst, air injection and exhaust gas recirculation. Evaporative emissions from the fuel tank and carburetor bowl are trapped by a charcoal canister.

In order to provide the compatibility of the final engine package with both original and revised RSV emission goals, a production Omni from the Chrysler engineering car pool was ballasted to RSV weight and tested on the EPA cycle at a 3000 lb. inertia weight and 4.5 hp dynamometer setting. Testing was conducted in "as received" condition with no attempt to optimize engine tune. EPA test cycles were run at odometer readings of 650 and 1450 km (400 and 900 miles) to evaluate repeatability as well as possible engine break-in effects. As can be seen from the data presented below, vehicle emissions are not only within the 1978 California standards but indicate compliance with the initial RSV program goals.

	Emissions		
Odometer	HC	CO	NOx
400	.253	2.46	1.174
900	.233	1.80	1.463

Because of the use of common components, the successful demonstration of production Omni's ability to pass the 50,000 mile emission durability test gives firm support to the belief that the RSV should be equally capable.

In mating the Omni/Horizon engine to the RSV, it was found that the engine accessory drive package would not fit the narrower engine compartment of the Simca 1308. Consequently, a new accessory drive package was designed. Provisions were made for optional power steering and air conditioning as well as the air pump required by the California emission control system. In addition to the standard accessory drives for the alternator and water pump (Figure 58), new mounting braketry was designed which incorporated rubber

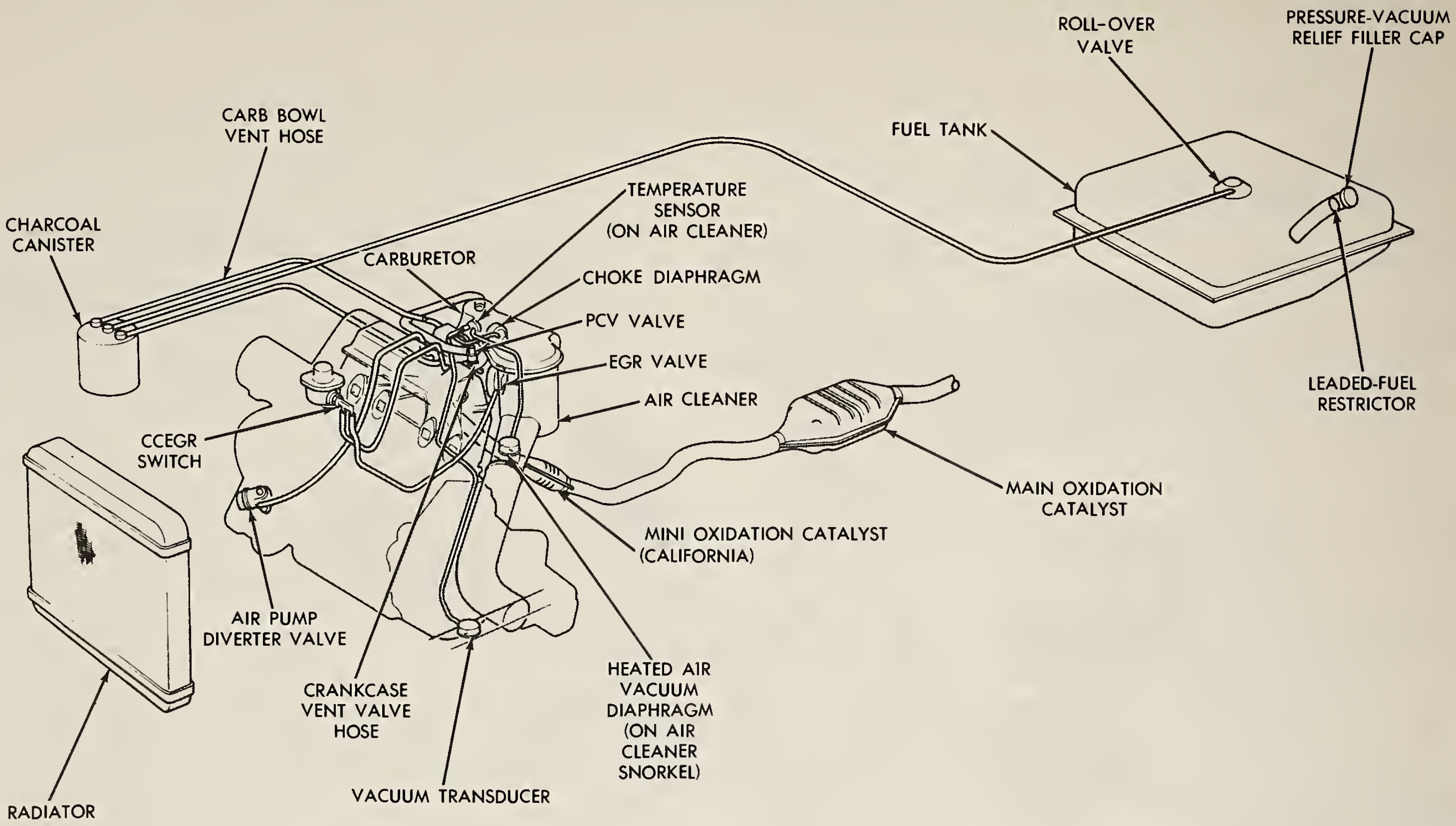


Figure 57 RSV EMISSION PACKAGE

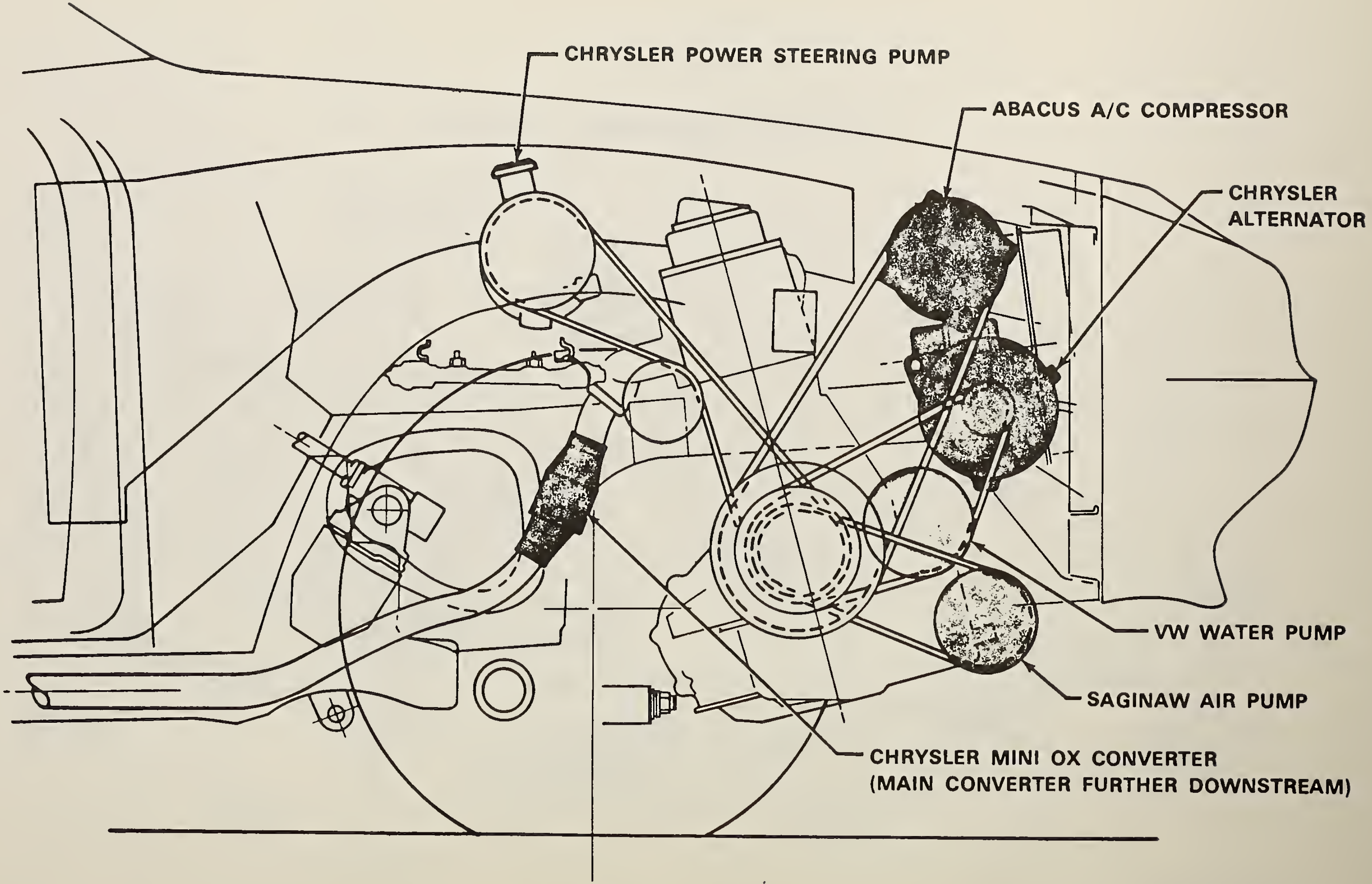


Figure 58 ENGINE COMPARTMENT & BELT DRIVE SYSTEM

isolators to preclude accessory damage due to engine vibration and reduce noise. The new accessory drive utilizes the first crankshaft sheave for the power steering pump, second sheave for the alternator and water pump, third sheave for the air conditioning compressor and fourth sheave for the air pump drive. In addition to the new accessory brackets, new pulleys were required for the crankshaft, water pump, and power steering pump. Installation of the power steering pump also required the addition of a "back-breaker" idler pulley in order to clear the Simca 1308 upper control arm.

As mentioned previously, the Omni/Horizon engine uses an analog computer (Figure 59) for electronic control of spark advance. Five sensors - a manifold vacuum transducer, hall effect pick-up (engine speed and crankshaft position), coolant temperature switch, throttle position transducer and idle stop solenoid - are used to provide inputs to the computer so that optimal spark timing can be determined. The ESA control module is packaged to fit on the left front fender shield and draw fresh air through the radiator yoke panel.

A new, four point engine mounting system was designed for the Phase III RSV. Voided, "X"-shaped rubber isolators from the three-point Omni/Horizon mounting system are used. A fourth rear engine mount (Figure 60) was added so that the front suspension crossmember would be loaded in frontal impacts and thus help prevent cowl/dash intrusion caused by rearward engine displacement. Two different engine locations are used in the RSV (depending on whether a manual or automatic transaxle is specified) because of the different spacing in input shaft to differential output flange of these transmissions. Thus, two different sets of engine mounting brackets were designed. The longitudinal and vertical body coordinates (in mm) from body "0" of each engine position are given below:

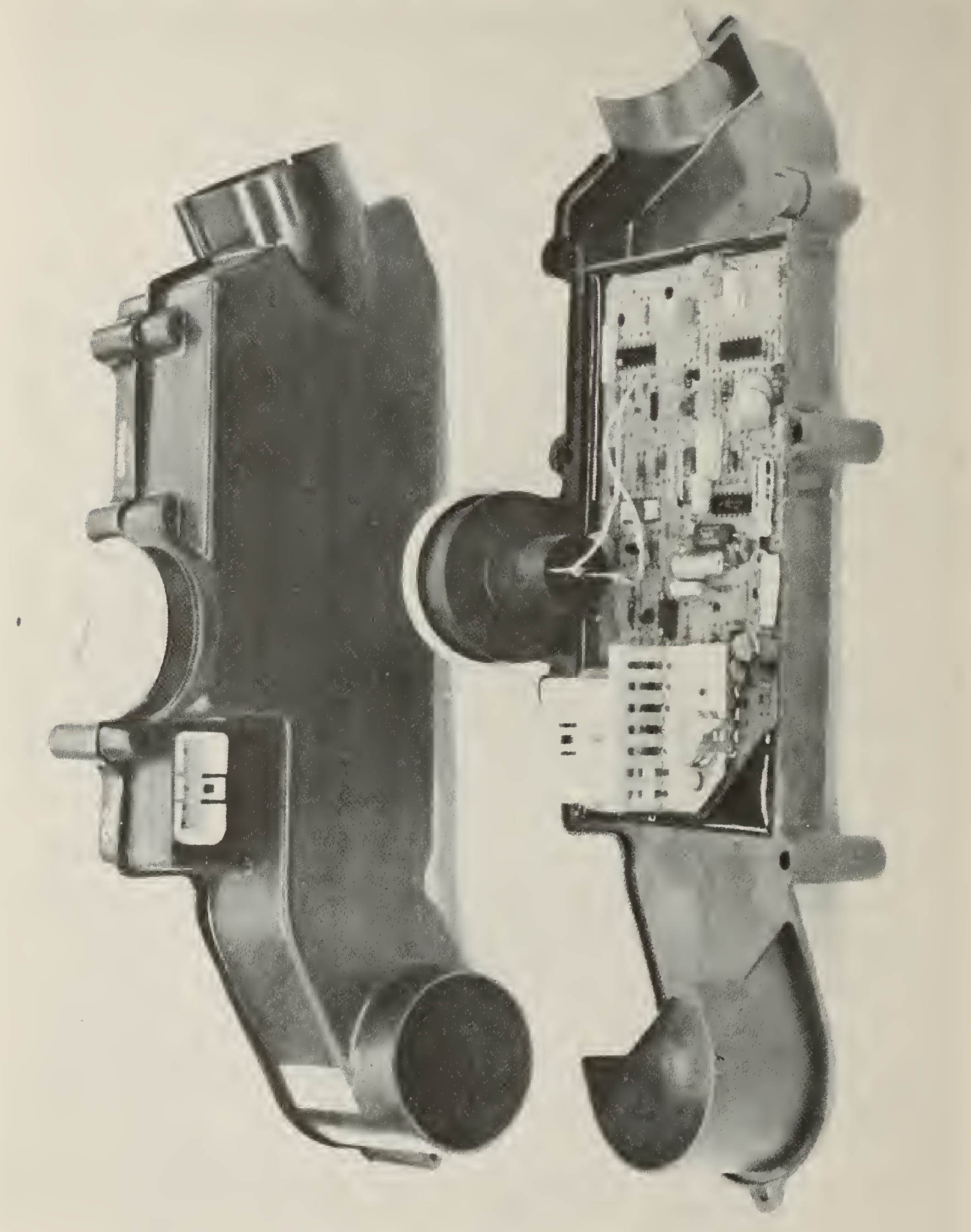


Figure 59 ELECTRONIC SPARK ADVANCE (ESA) MODULE

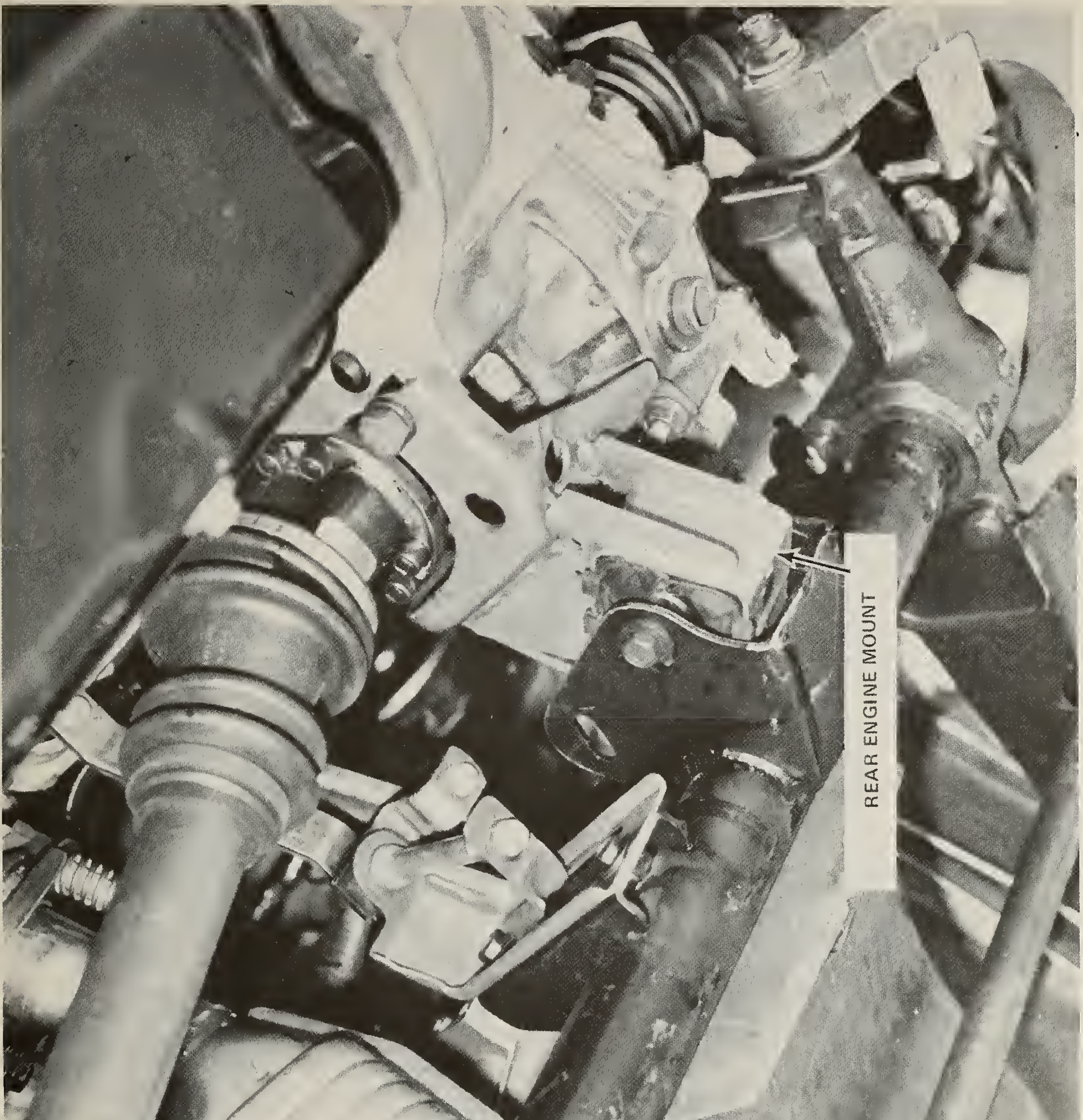


Figure 60 REAR ENGINE MOUNT

	Longitudinal	Vertical
Crankshaft		
• Automatic	-233.56	170.6
• Manual	-233.56	149.6
Differential		
• Automatic	-41.86	113.0
• Manual	-59.66	121.6

The overall engine installation package is shown in Figure 61. In this view, the evaporative emissions canister, battery, air cleaner, starter solenoid, ignition coil, and diagnostic connector can be seen.

4.2 Driveline

The decision to utilize the Omni/Horizon engine in the RSV also meant that a new driveline was required. In addition, it was decided to make provisions for both manual and automatic transaxles. These components are shown in Drawings 90130 through 90180 in Appendix B of Volume II.

The manual transaxle used in the Phase III RSV is the same as in Chrysler's Omni and Horizon. The transaxle combines the functions of a transmission, final drive, and differential into a single unit (Figure 62). It has four forward speeds and features a two-piece diecast magnesium case. Gear ratios are as follows:

First	-	3.45
Second	-	1.94
Third	-	1.29
Fourth	-	0.97
Reverse	-	3.17

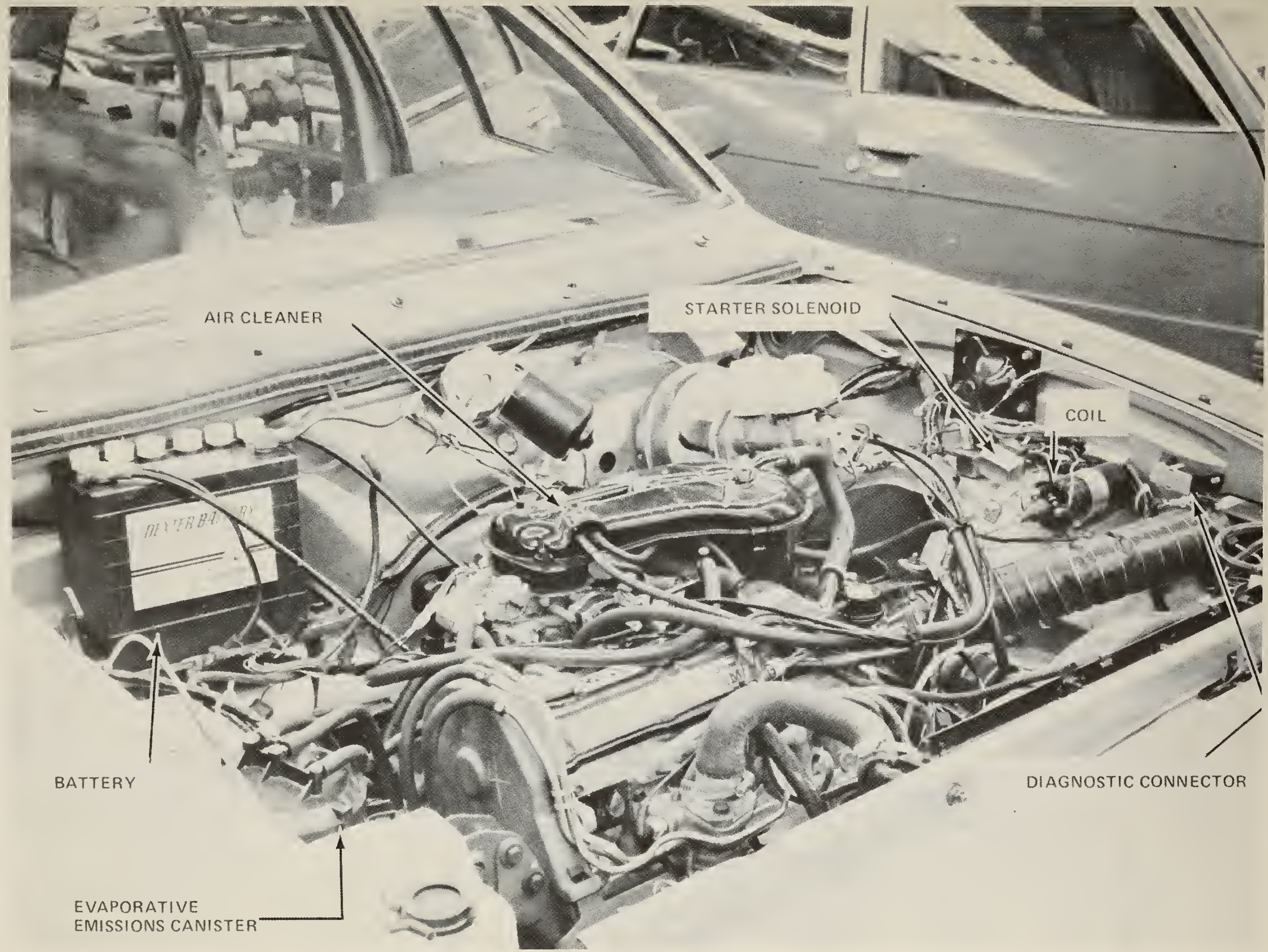


Figure 61 RSV ENGINE COMPARTMENT

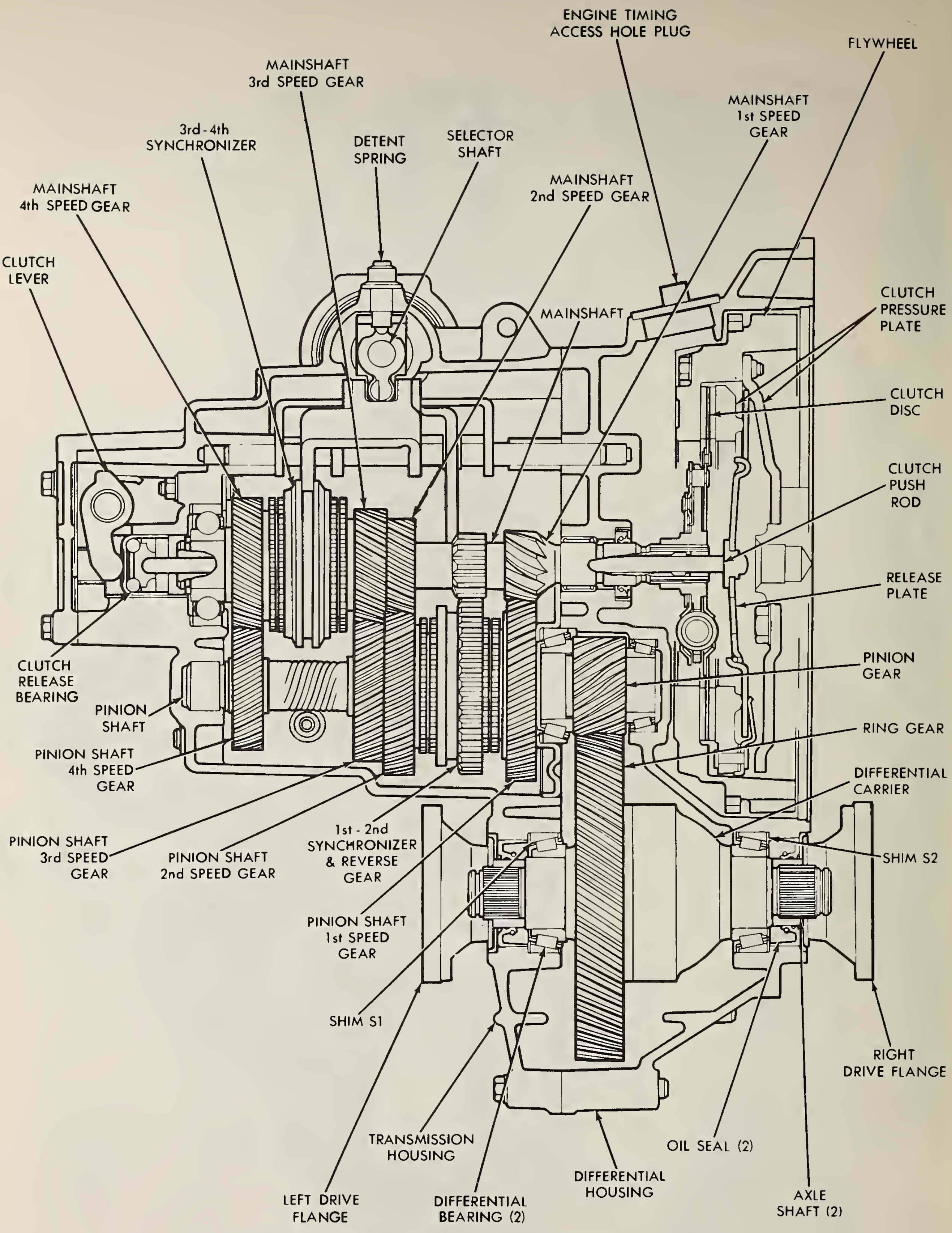


Figure 62 MANUAL TRANSAXLE SCHEMATIC

A 190 mm single plate clutch is used and a final drive ratio of 3.70 was chosen. Alternative 3.48 and 3.27 final drive ratios are available if different performance/economy tradeoffs are desired in the future. A new production-type clutch linkage was designed for the Phase III RSV. The design uses a new stamped clutch pedal and an Omni/Horizon type cable linkage (which represents both a cost and weight reduction over the Simca hydraulic clutch actuation system). A rework of the Simca dash and plenum was necessary to provide adequate cable travel for clutch actuation; these would be integrated into the primary stamping on a production design. Also, one of the windshield wiper links was reshaped to clear the plenum patch piece.

The four-bar manual shift linkage of the Omni/Horizon was adapted to the Phase III RSV. New mounting brackets and a revised actuation rod were designed.

Driveshaft adapters were designed to mate the outer, fixed-center, tri-pot constant-velocity joints of the Simca to the inner, sliding, tri-pot CV joints of the Omni/Horizon. Outer joint steer stops were incorporated in the steering knuckle design to limit the outer joint angle to 43 degrees and thus prevent exceeding the angular capability of the CV joint (see Section 4.5). With the manual transmission, the straight ahead running angles of the CV joints are approximately 12 degrees higher than that normally recommended. It was decided, however, to accept this design condition and the potentially shorter CV joint life rather than to redesign the entire RSV engine compartment. CV joint integrity should be demonstrated in the 40,225 km (25,000 mile) general endurance test.

The optional automatic transmission consists of a three-speed planetary gearbox and a torque converter enclosed in a one-piece aluminum case (Figure 63) and is the same unit used on the Omni/Horizon. Transmission gear ratios are as follows:

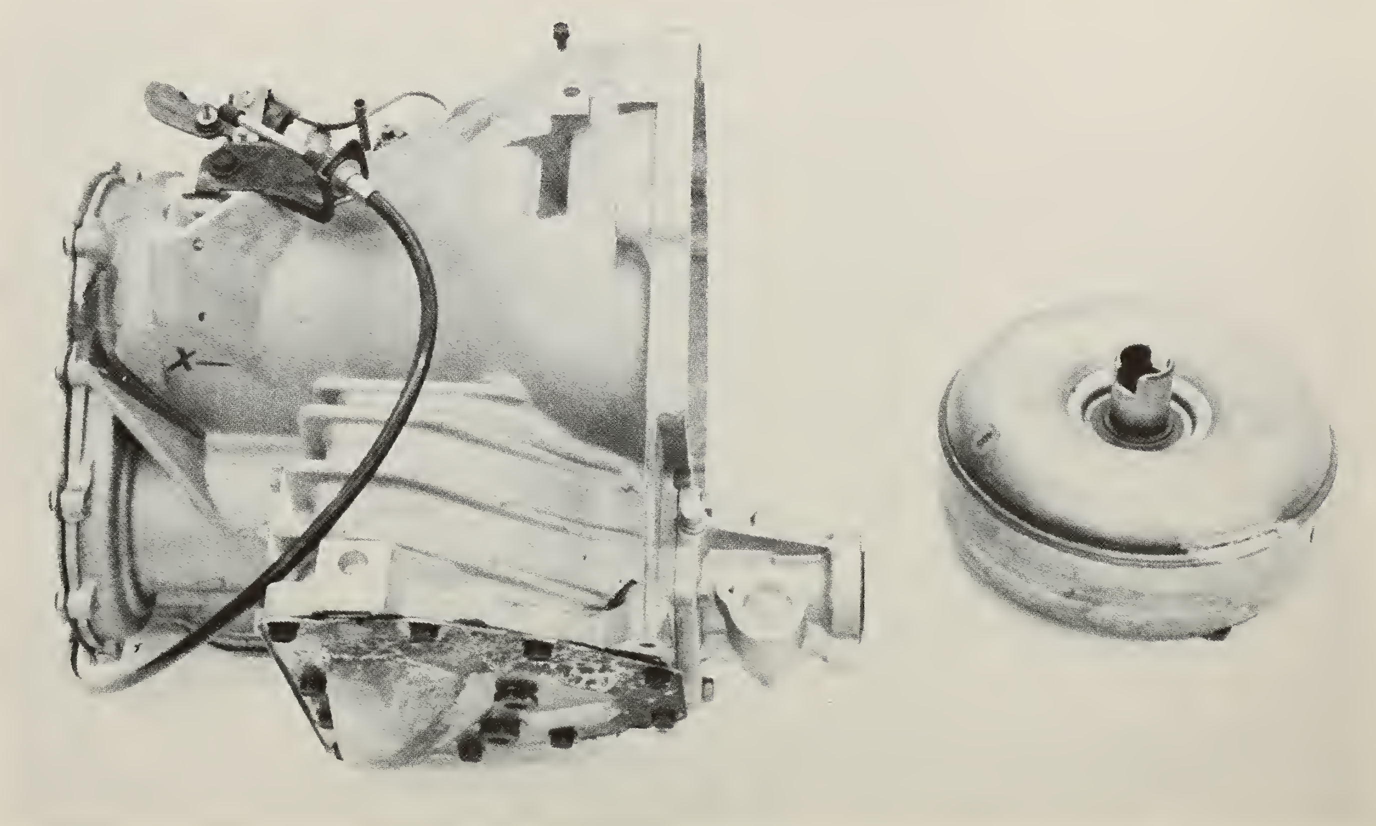


Figure 63 AUTOMATIC TRANSAXLE

First	-	2.47
Second	-	1.47
Third	-	1.00
Reverse	-	2.10

The final drive ratio is 3.74, although a 3.50 ratio is also available.

The shift mechanism for the automatic was adapted from the Omni/Horizon. A new actuation cable was designed to accommodate the new relative position between the transaxle and shifter. The carburetor to transmission kickdown cable is from the Omni/Horizon.

As with the manual transmission, new adapters for the halfshafts were designed. Straight ahead running angles for the automatic CV joints are approximately 7 degrees and, therefore, do not pose a problem.

4.3 Cooling System

The new Omni/Horizon engine installation in the RSV had considerable effect on the cooling system design. The Simca 1308 radiator used in Phase II was changed in Phase III because it could no longer accommodate the increased cooling requirements of the larger engine or the increased heat loads imposed by the automatic transmission and air conditioning options. As shown in Figure 64, the front overhang had to be increased and the hoodline raised in Phase III in order to accommodate the new larger radiator and air conditioning condenser. The Phase III RSV utilizes the 1991.7 cm^2 (308.7 in^2) cross-flow copper/brass radiator of the Omni and Horizon. The cooling system also contains a thermostatically controlled fan and a coolant recovery bottle (see Figure 65). When air conditioning is specified, an aluminum condenser is mounted in front of the radiator.

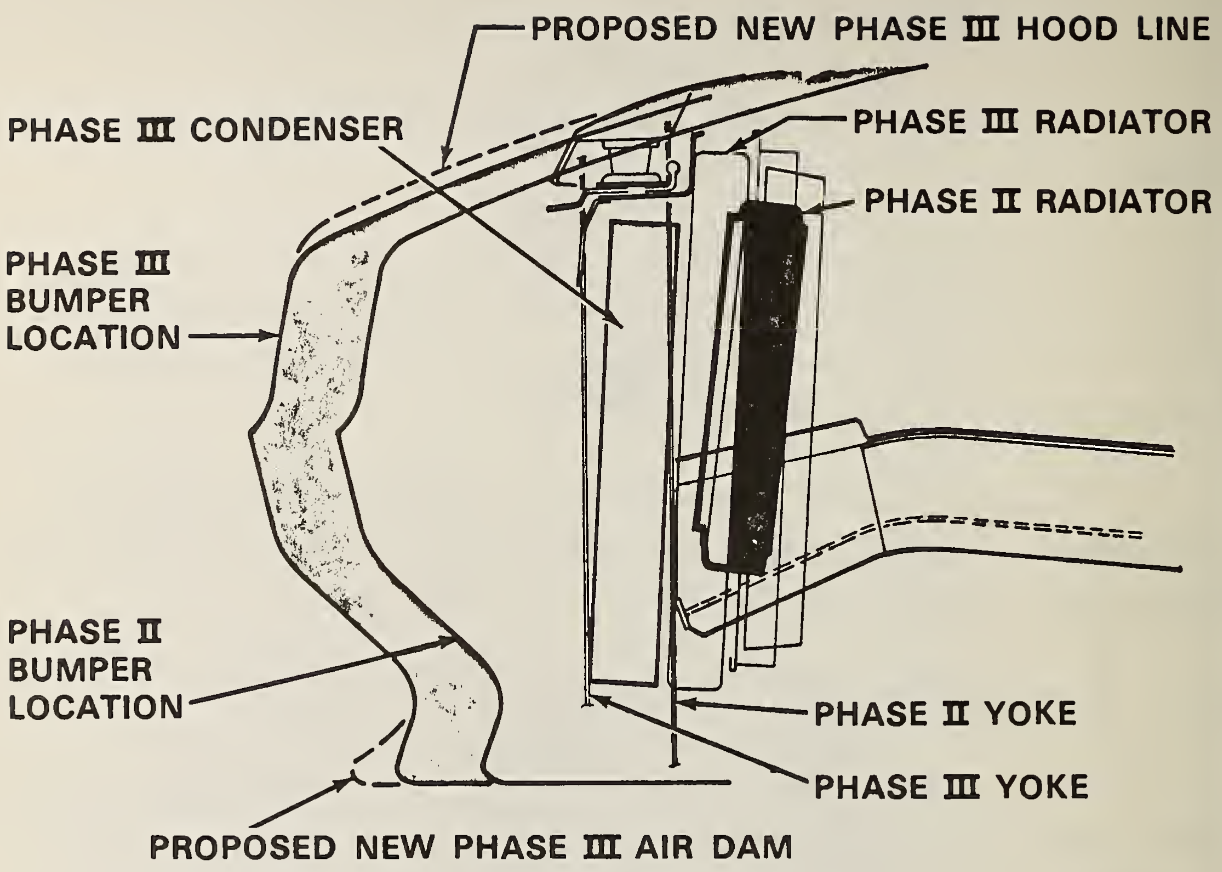


Figure 64 CHANGES IN RADIATOR POSITION, PHASE II TO PHASE III

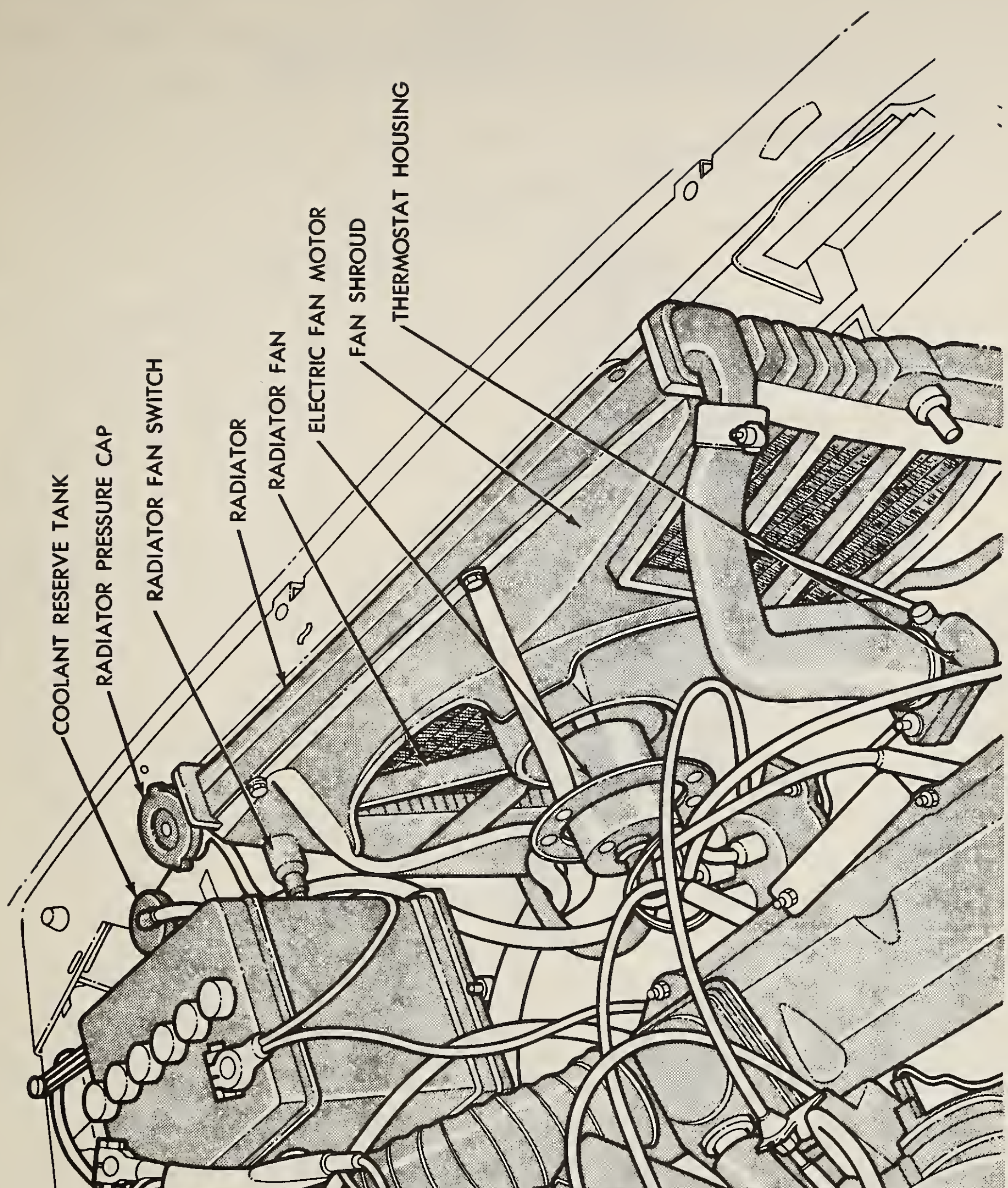


Figure 65 COOLING SYSTEM

The adequacy of this cooling system was demonstrated by tests conducted at Chrysler's Chelsea wind tunnel on the RSV mule car. Two basic cooling configurations were evaluated: (1) with both upper and lower cooling slots (987 cm^2 [153 in^2] inlet area), and (2) with the upper slots blocked (626 cm^2 [97 in^2] inlet area). Figure 66 shows the differences in ducting through the soft bumper. The incentive for eliminating the upper cooling slots was a potential 2.9% reduction in aerodynamic drag and a resultant increase in fuel economy. As shown below, five different test conditions were evaluated; the results are given in terms of temperature (in degrees F) below Chrysler's corporate goals. All tests were conducted at 43.3° C (110° F) ambient temperature, except the 88.5 kph (55 mph) - 6% grade test which was conducted under 37.8° C (100° F) ambient conditions:

Test Condition	Corporate Goal	All Fascia Open (153.2 $in.^2$)	Upper Fascia Closed (96.6)
Neutral Idle	260° F	-55°	-55°
3 mph - Simulated City Traffic	255° F	-48°	-48°
55 mph - Road Load	225° F	-40°	-22°
55 mph - 6% Grade	250° F	-37°	-22°
80 mph - Road Load	240° F	-34°	-27°

The manual transmission RSV mule car was well within corporate goals with both 153 $in.^3$ and 97 $in.^2$ inlet configurations; however, the extra inlet area does provide superior cooling performance at speed. This superior performance is needed when the projected heat loads for air conditioning and automatic transmission are included. For the worst case (55 mph - 6% grade) test condition, the projected heat load for A/C and an automatic transmission is an additional 41° F. This additional heat load raises the 153 $in.^2$ inlet configuration to a point slightly above the corporate goal (but within bogey), while the 97 $in.^2$ configuration would be approximately 20° F over goal. It was, therefore, decided that all RSV front bumpers should have both upper and lower cooling slots. Conceivably, in mass production the RSV could be offered

PHASE III RSV
FRONT BUMPER COOLING DUCTS

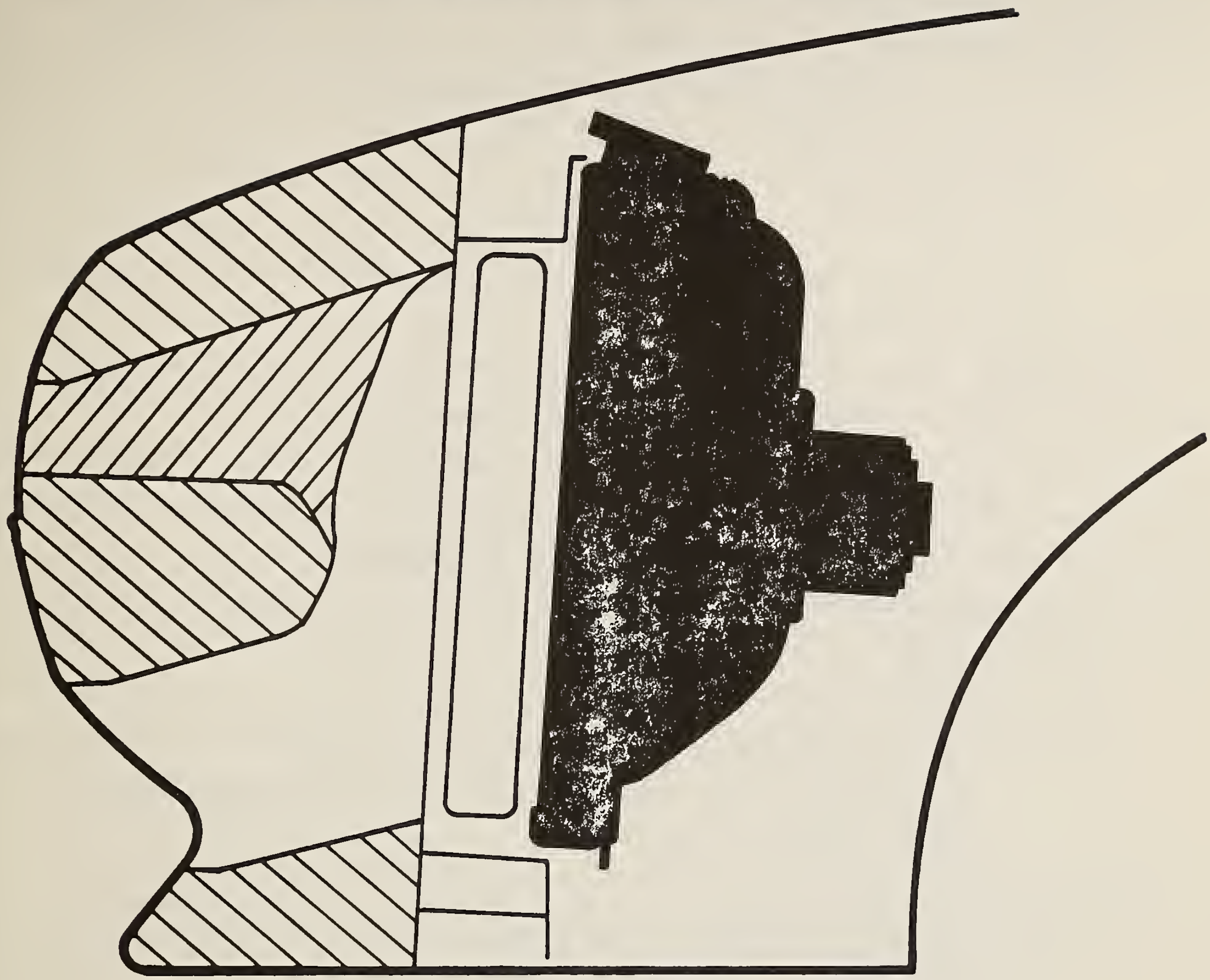


Figure 66 RADIATOR DUCTING

with two front ends: (1) a standard low drag bumper fascia, and (2) an optional fascia with additional cooling slots when both A/C and automatic transmission are specified. Further testing to quantify precisely the actual additional heat load imposed by A/C and automatic transmission options on the RSV could reveal a heat load less than currently estimated. Such tests, while beyond the original program scope, are highly recommended.

4.4 Steering System

The RSV uses the rack and pinion steering system of the Simca 1308. With the wheelbase stretch in Phase II, the steering system had to be extensively modified. This included repositioning of the rack. Further changes were made in Phase III in order to reduce the turning circle from 13.7 to 11.6 meters (45 to 38 feet), provide a proper toe pattern for handling considerations, prevent a possible linkage over-center condition on the inside wheel in a turn, and limit the working angles of the outer constant velocity joint at the outside wheel in a turn. The primary steering geometry changes are described below:

- The steering rack was relocated down 40.9 mm (1.61 inches) and forward 20 mm (.79 inch) and the inner tie rod ends moved 10 mm (.39 inch) inward.

- The outer tie rod end was lowered 41 mm (1.61 inches) and moved inboard 2.8 mm (.11 inch).

- Steering rack travel was reduced from 83 mm (3.27 inches) to 76 mm (2.99 inches).

- Front suspension rebound travel was limited to 82 mm (3.23 inches).

- Rebound steer stops were incorporated to limit inner and outer turn angles (see Section 4.5).

These geometry changes necessitated the use of modified racks (Figure 67), lengthened tie rods and modification of the Simca 1308 steering knuckle. The latter modification entails shortening of the steering arm, insertion of an adapter block, and reattachment of the tie rod end through a rather complex welding and heat treatment procedure (Figure 68). On a production car, an all new casting would be used. Relocation of the steering rack also caused revision of the center tunnel reinforcement, side rail mounting holes and side rail-to-tie rod clearance opening. The toe curve geometry is shown in Section 4.5 (Figure 71) at ten times scale. Note that toe is essentially unaffected by suspension travel.

Provision for an optional power steering system on the RSV has been made. A modified Burman power steering rack (Figure 67) was provided by Chrysler/France. This rack required relocation of the mounting brackets, modification of the tunnel reinforcement and floor pan, and the design of a new steering column intermediate shaft. Hydraulic power is supplied by an Omni/Horizon power steering pump mounted on a new rubber-isolated two-piece bracket. A new idler pulley was also designed so that the power steering drive belt could be routed to clear the Simca 1308 upper control arm. The power steering installation also required a new engine timing belt in order to provide adequate clearance to the P/S belt line.

Another major revision to the steering system was the incorporation of a "fall-apart" intermediate steering shaft (Figure 69). In the event that a frontal impact is so severe as to cause rearward displacement of the steering rack, the intermediate shaft is designed to decouple so that no rearward movement is imparted to the steering wheel. Decoupling is accomplished by forcing the locating pin down a ramp after approximately one inch of travel. The intermediate shaft has been found successfully decoupled in all frontal high speed impact tests of the RSV. The steering control components are shown in Drawings 90300 and 90310 in Appendix B of Volume II.

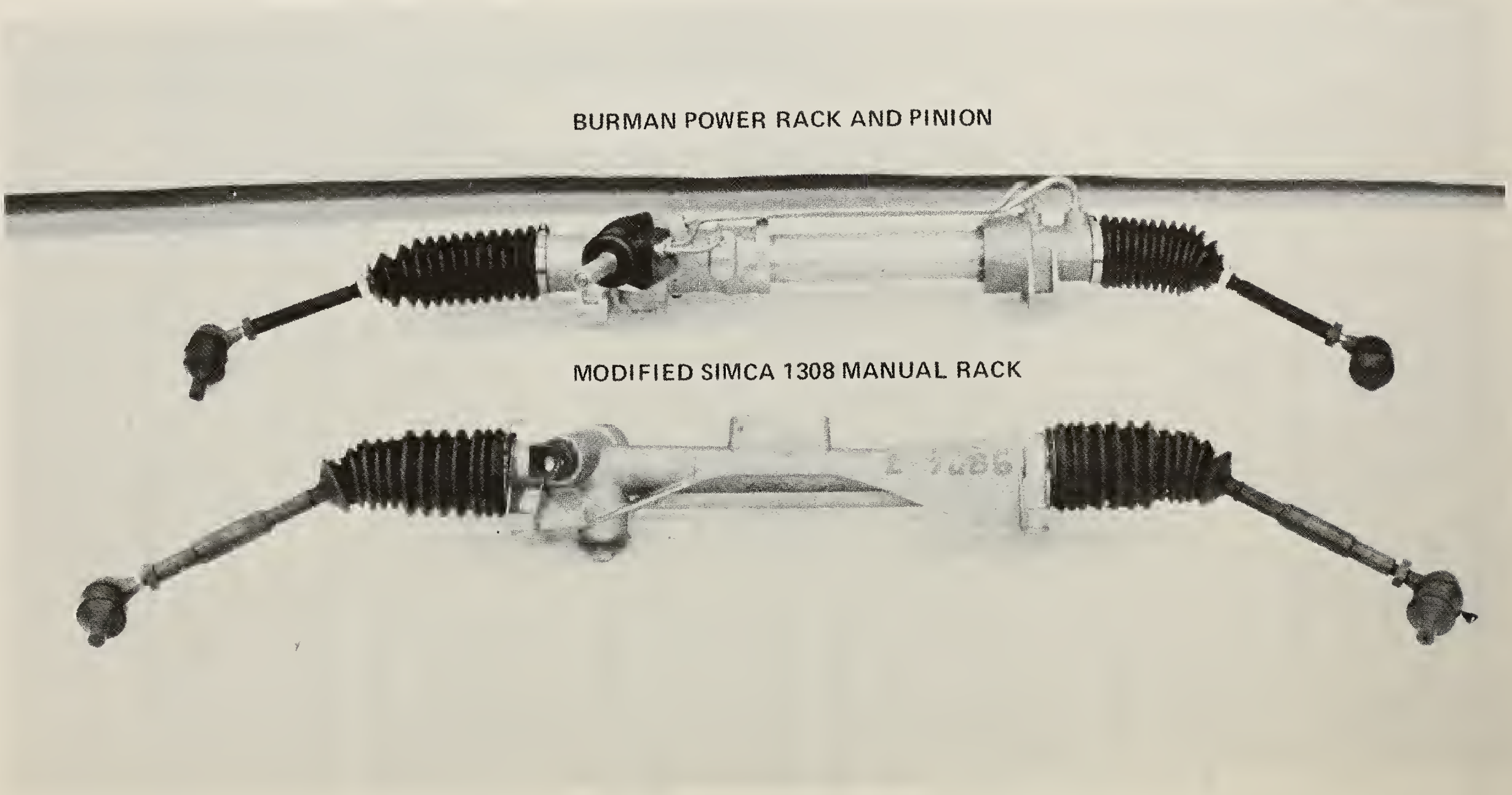


Figure 67 MODIFIED STEERING RACKS

Figure 68 STEERING KNUCKLE MODIFICATION

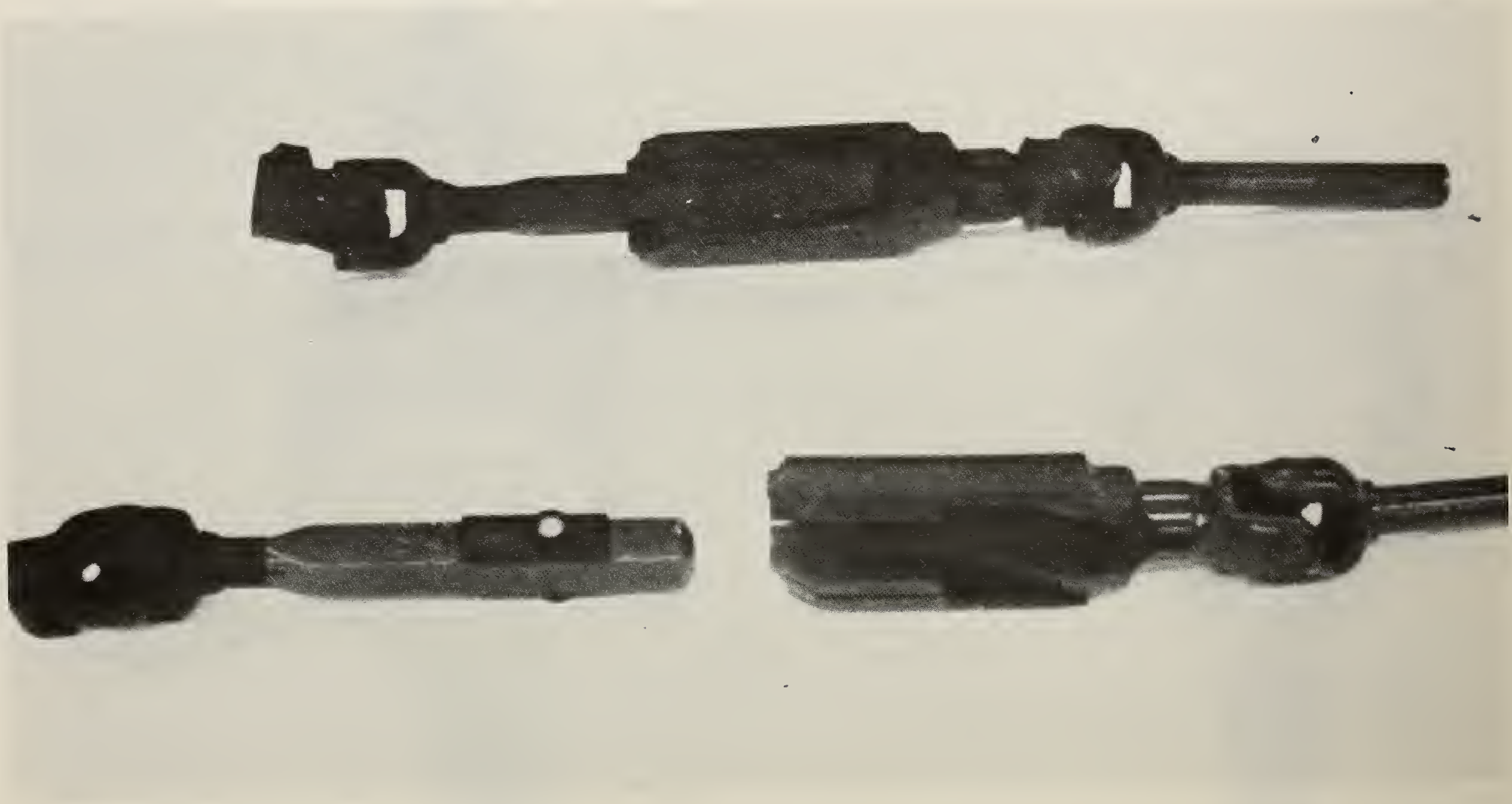


Figure 69 DE-COUPLING INTERMEDIATE STEERING SHAFT

4.5 Suspension System

The base Simca front suspension (Figure 70) is of the double wishbone type sprung by torsion bars. Suspension geometry is essentially unchanged for the RSV except that front rebound travel was limited to 82 mm (3.23 inches). Camber, caster and toe curves (given in Figure 71) are typical of an unequal length double wishbone suspension.

Although the suspension geometries are similar, the front suspension components have been extensively redesigned. One of the first changes made for the RSV was to eliminate the upper control arm crossmember, which in France is used primarily to assist in vehicle assembly. Handling and braking tests conducted with the crossmember removed indicated that the vehicle structure in this area had adequate strength.[3] Removal of the crossmember required the design of a reinforcement to mount the upper control arm directly to the front longitudinal. The advantages of this change are reduced vehicle weight and improved engine compartment packaging space. In addition to elimination of the upper crossmember, the following front suspension components were redesigned:

- Lower Control Arm
- Upper Control Arm Pivot Bar
- Front Swaybar
- Front Torsion Bar
- Torsion Bar Anchors

A new, fabricated, lower control arm was designed to cope with the increased RSV loads. In order to be more consistent with U.S. design and construction practices, a stamped and welded box section A-frame replaces the cast control arm of the Simca 1308 (see Figure 72). Also, steer stops have been welded to the control arm. These prevent linkage over-centering and limit CV joint angles as described in Section 4.4. Stress analyses indicate that the new control arm will withstand 5 g jounce and washout (3 g vertical,

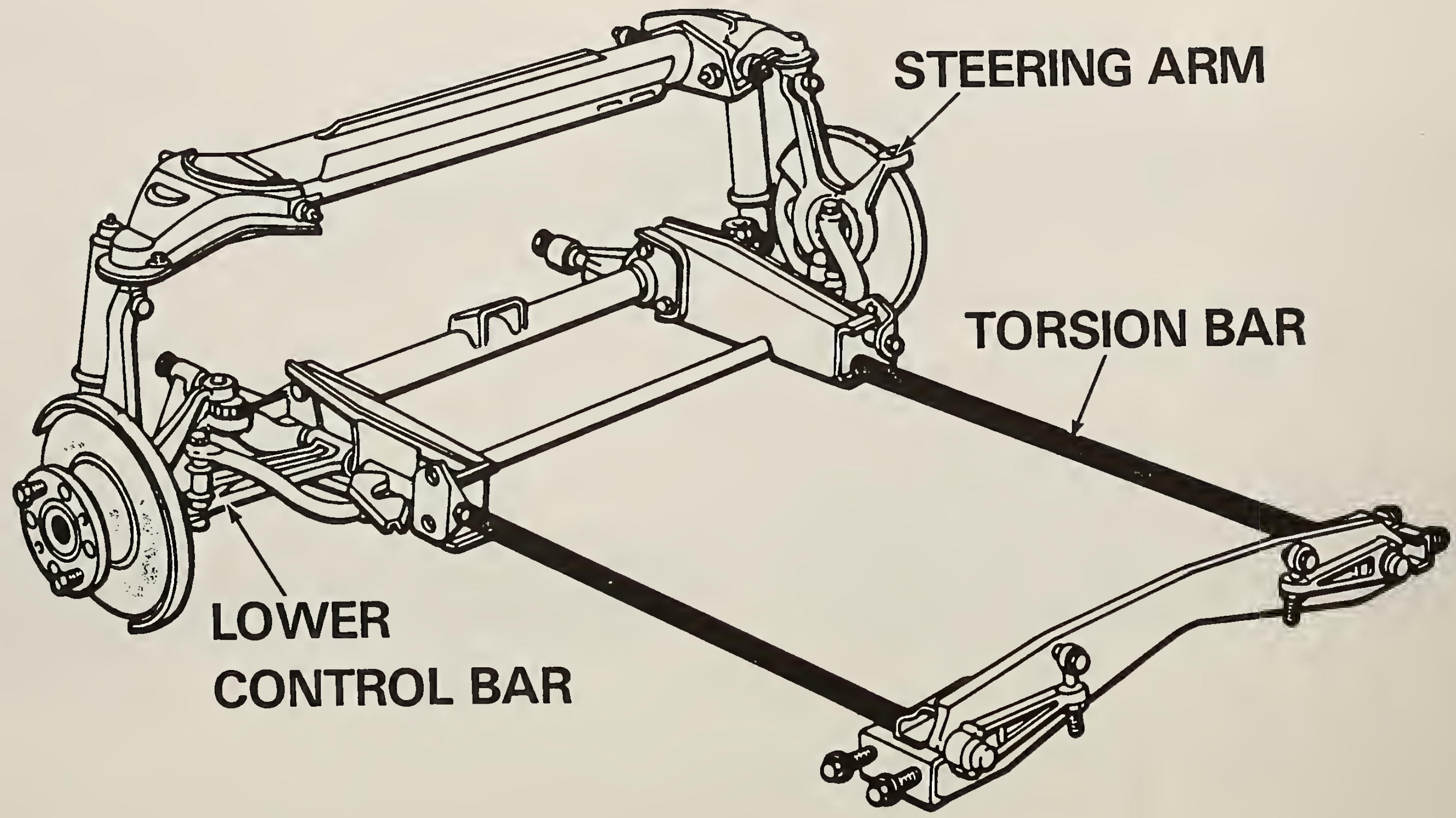


Figure 70 SIMCA FRONT SUSPENSION

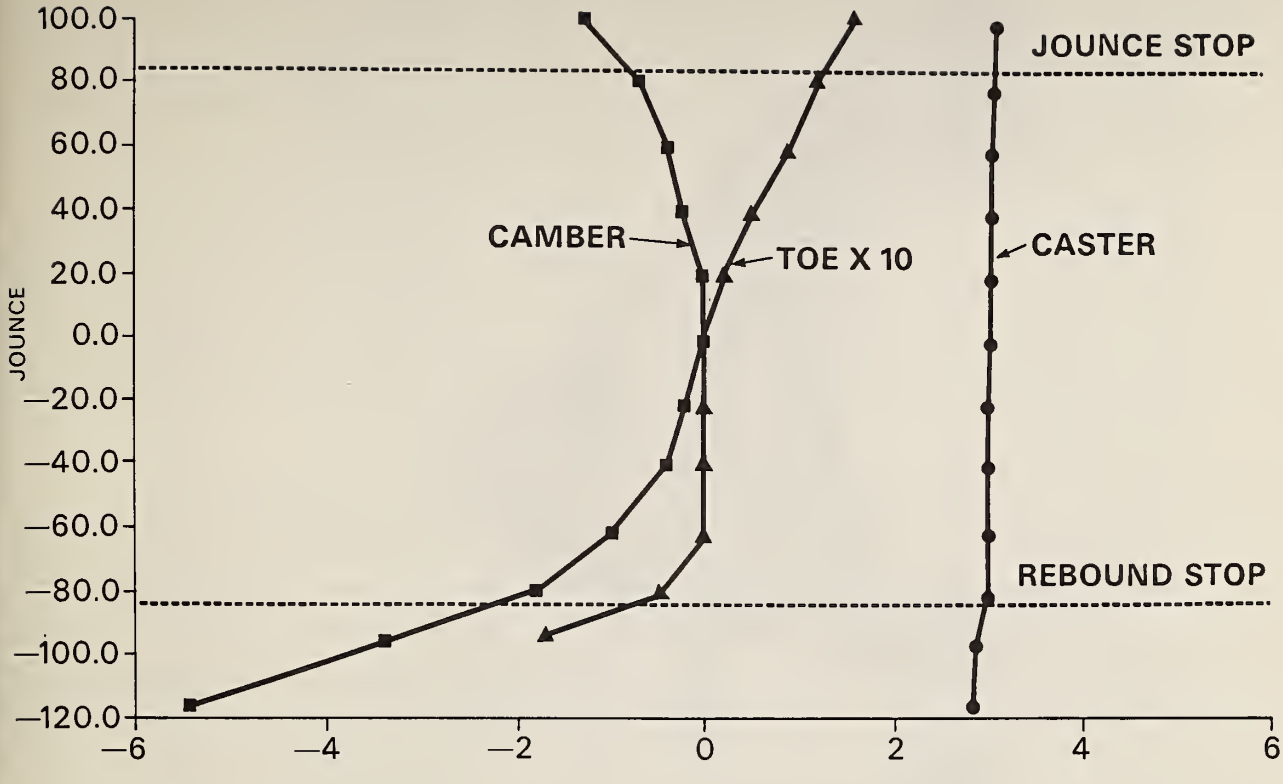


Figure 71 RSV FRONT SUSPENSION GEOMETRY

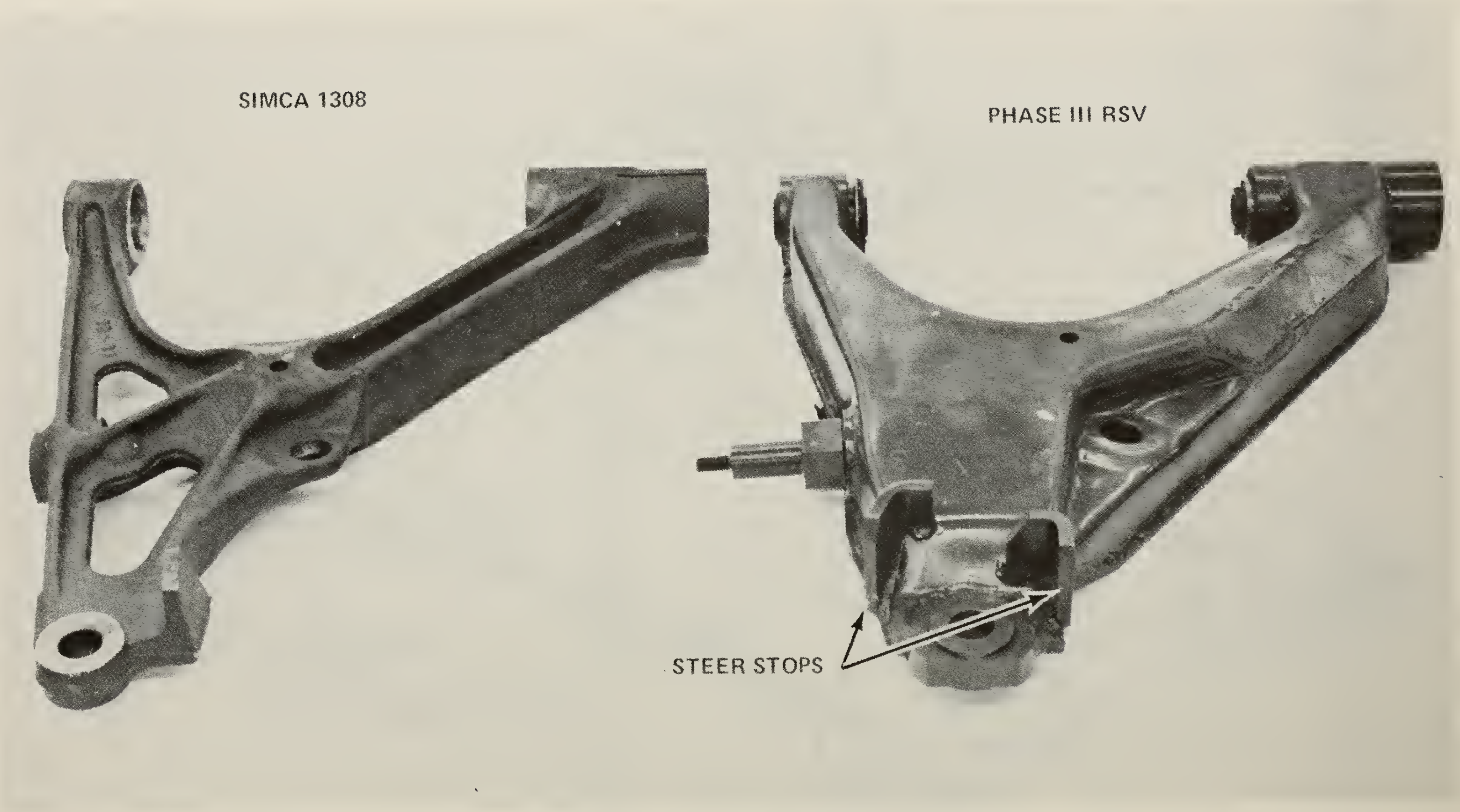


Figure 72 FRONT SUSPENSION LOWER CONTROL ARM

2 g braking) loads, assuming a front static weight of 449.9 kg (992 lbs.) per wheel at the three-passenger design load. This criterion is consistent with U.S. production design standards. The new design yeilds a 0.91 kg (2 lbs.) weight reduction and also represents a cost reduction in domestic production.

A new upper control arm pivot bar and attachment bracket were designed to use existing Volare/Aspen hardware and mate with the standard Simca 1308 bushings and upper control arm (Figure 73). This new type of pivot bar attachment represents an improvement in manufacturability, assembly and adjustment over the standard Simca system.

The standard solid Simca front swaybar was replaced by a new 25.4 mm (1 inch) O.D., 2.4 mm (.095 inch) wall tubular bar (Figure 74) in order to save approximately .91 kg (2 lbs.). The swaybar was also recontoured to provide clearance for the exhaust system and lower control arms. The tubular swaybar provides a 3.5 N/mm (20 lbs./in.) increase in roll rate; its projected effect on RSV handling is discussed in Section 4.5.1.

The increase in wheelbase of the RSV over the base Simca enabled the use of an existing Chrysler U.S. production torsion bar. This bar, 21.8 mm (.86 inch) diameter and 1039 mm (40.9 inches) in length, provides a front wheel rate of 19.0 N/mm (108.5 lbs./in.) and results in a 1.08 Hz front suspension ride frequency on an air conditioned RSV. This frequency falls within the original RSV target specification. Shear stresses in the torsion bar are sufficiently low to indicate an acceptable fatigue life of over 250,000 cycles.

The rear torsion bar anchor (Figure 75) was redesigned to accommodate the new torsion bar hex size of 31.8 mm (1.25 inches). This increased size was required in order to insure adequate endurance life. The new anchor design reduces complexity and weight and provides a safer failure mode than the Simca 1308 design. The adjustment bolt is now in compression which results in only partial suspension collapse in the unlikely event of a bolt failure

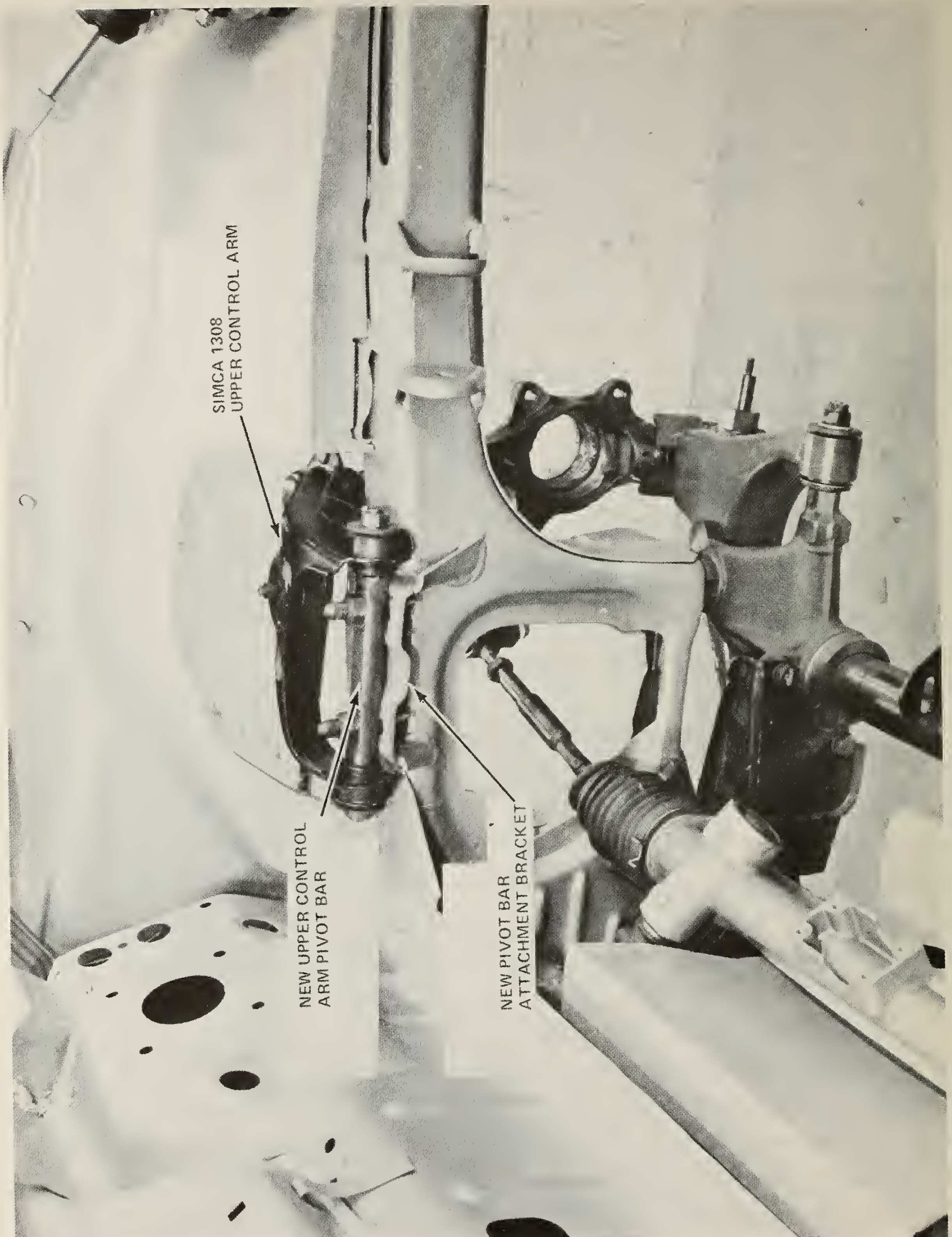


Figure 73 RSV UPPER CONTROL ARM ATTACHMENT

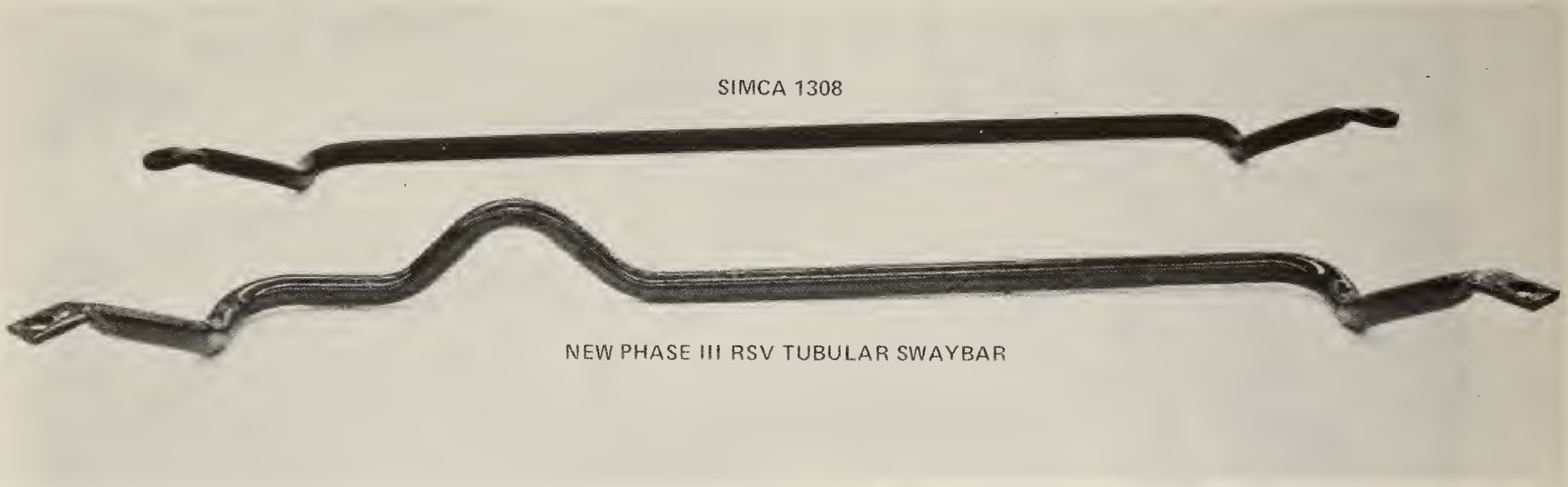


Figure 74 FRONT SWAYBAR

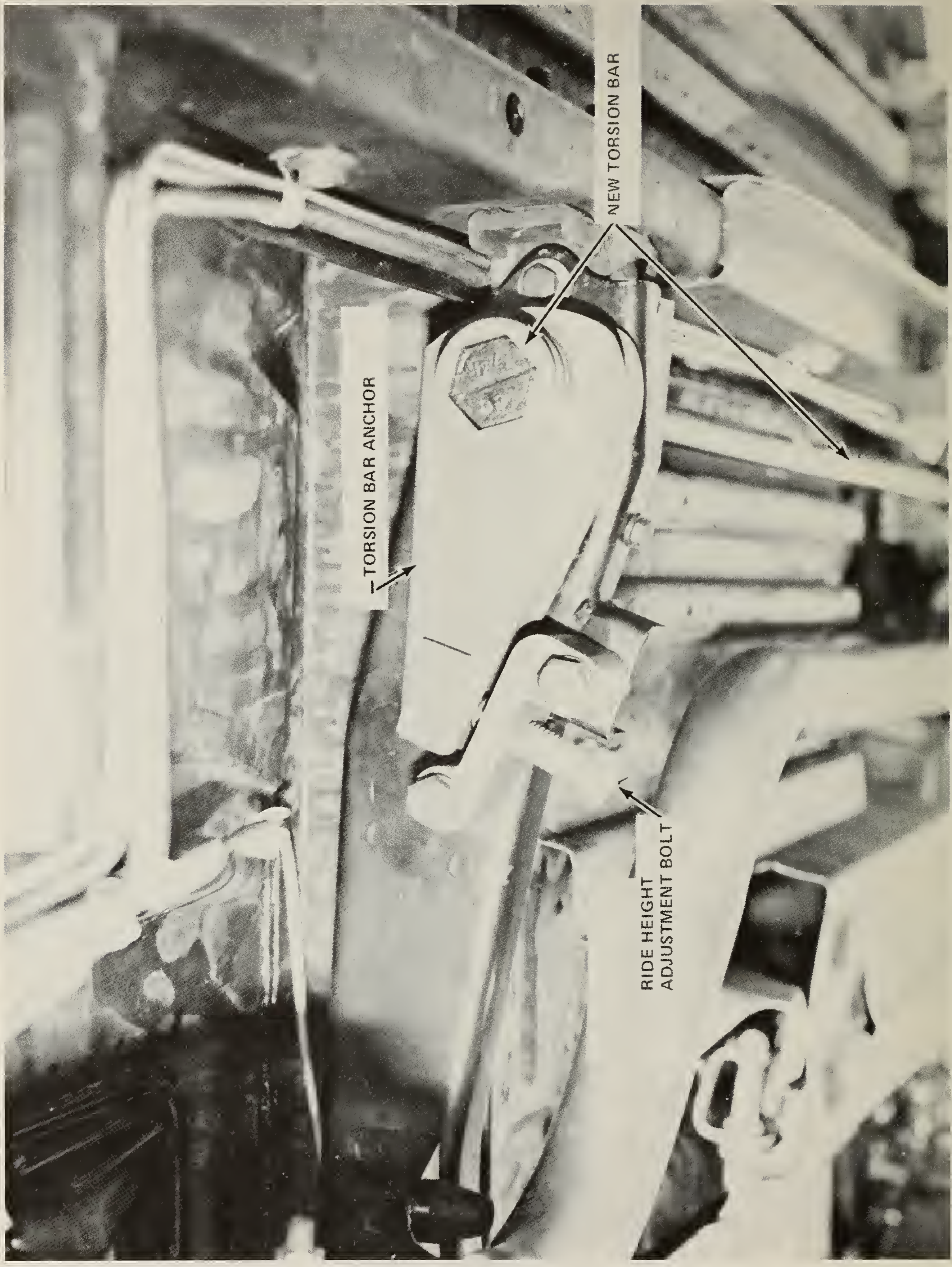


Figure 75 RSV REAR TORSION BAR ANCHOR

rather than the total loss which could occur with the tension type adjustment bolt used on the Simca.

The rear suspension layout (Figure 76) of the RSV is essentially carried over from the Simca 1308. It is a fully independent trailing arm suspension with coil springs and a light swaybar. The characteristic French "tail-high" attitude of the Simca is such that, at the increased RSV design loads, a more conventional U.S. vehicle attitude is achieved without a change in the springs while maintaining adequate suspension jounce travel. At a design load of 282.1 kg (622 lbs.) on the rear with a three passenger load, the standard Simca 1308 coil springs provide a ride frequency of 1.27 Hz. This rear ride frequency is within the target set for the RSV.

Additional views of the suspension system components are shown in Drawings 90200 through 90290 in Appendix B of Volume II.

4.5.1 Vehicle Handling

Throughout the RSV program, computer handling simulations were used to evaluate the effects of changes in suspension parameters. The Chrysler handling program enabled making evaluations of whether or not the RSV would meet the specified handling criteria and incorporating modifications before the RSV was available for actual handling tests. In particular, the effects of flatproof tires and the new, stiffer, tubular front swaybar were of interest.

Using force and moment data generated by Goodyear, it was found that conventional and flatproof tires exhibited similar response characteristics, well within the handling criteria, as shown in Figures 77 and 78. In the transient yaw maneuver, the flatproof tires exhibited slightly quicker peak response, probably because of their somewhat higher cornering stiffness. The tubular front swaybar increases the front roll rate by 3.5 N/mm (20 lbs./in.), so its effect on RSV handling was compared to that of the standard Simca solid

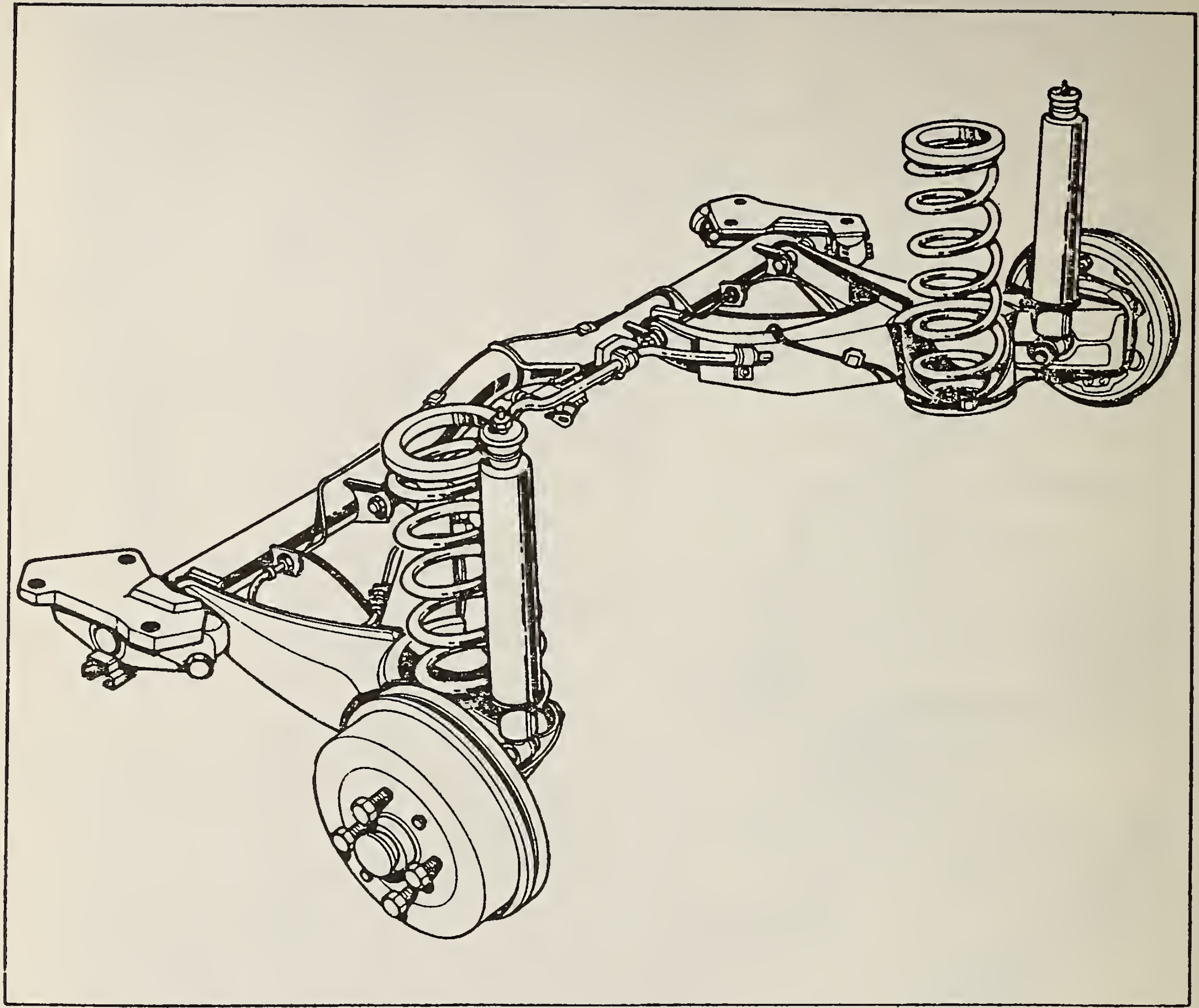


Figure 76 SIMCA INDEPENDENT TRAILING ARM REAR SUSPENSION

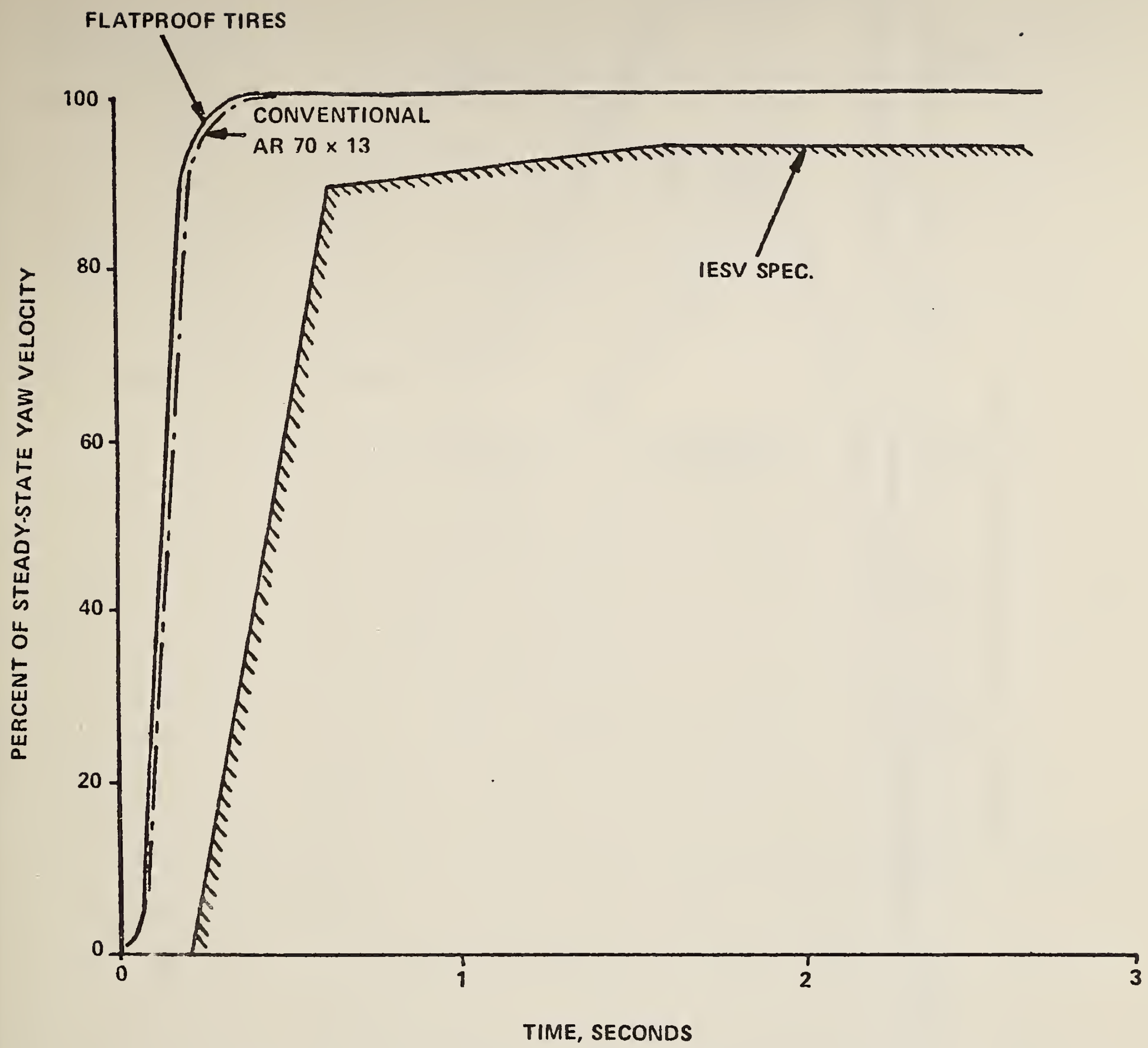


Figure 77 CALCULATED TRANSIENT RESPONSE, 25 MPH, 0.4 G CONVENTIONAL VS. FLATPROOF TIRES

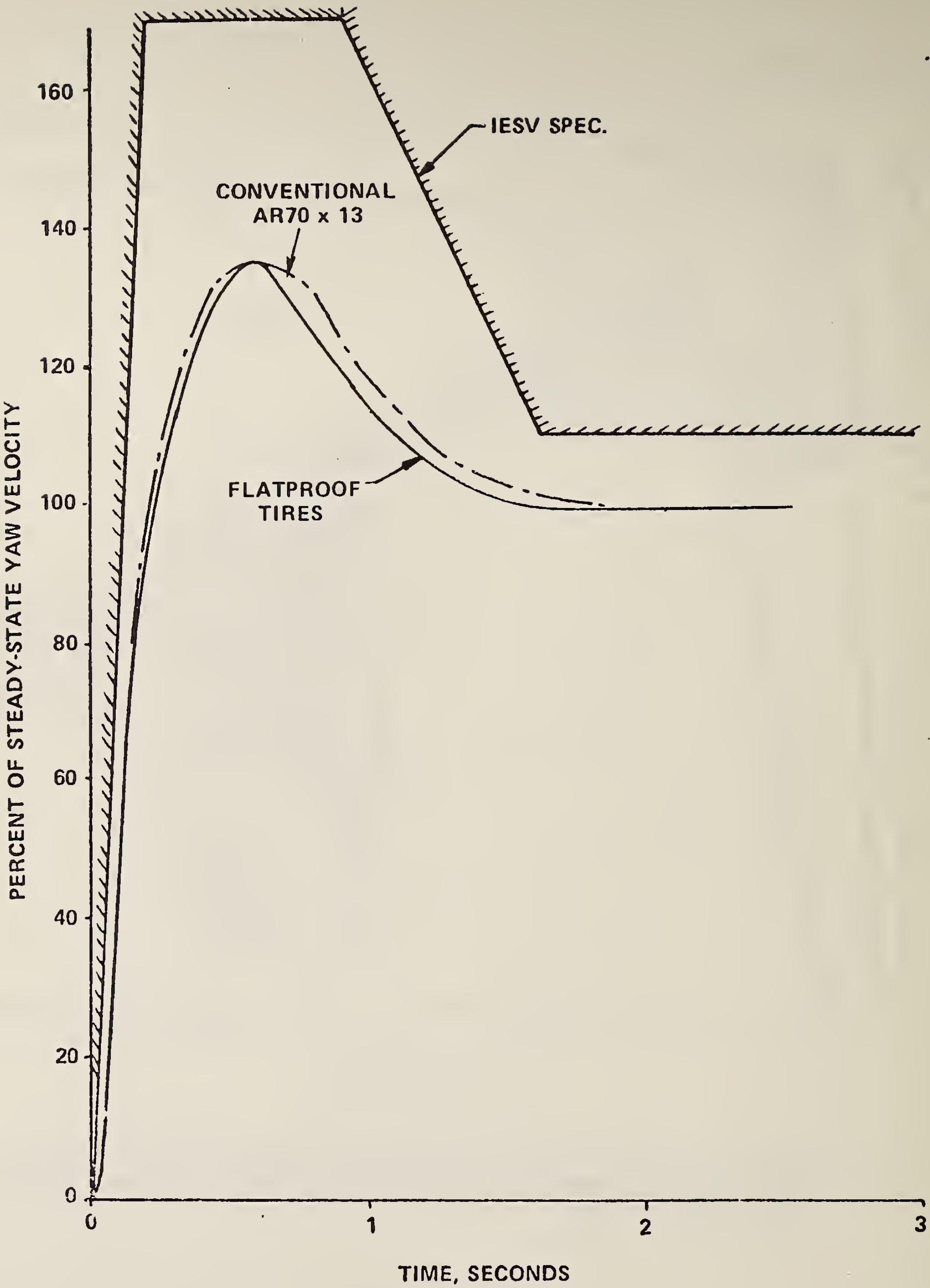


Figure 78 CONVENTIONAL VS. FLATPROOF TIRES CALCULATED TRANSIENT RESPONSE, 70 MPH, 0.4 G

swaybar. The understeer gradient was increased slightly for lateral accelerations greater than .4 g and the transient yaw response time was reduced slightly (Figures 79 and 80). This condition was considered acceptable and a decision was made to incorporate the weight saving tubular swaybar in the RSV. Subsequent testing of the RSV mule car at Calspan with flatproof tires, but without the tubular swaybar, confirmed that the RSV would easily meet all handling criteria.[17] In fact, subsequent Calspan handling tests on the final RSV showed completely satisfactory handling responses in all aspects. These tests were later verified in Italy and Japan.

Since the RSV can be driven with a deflated tire, an attempt was made to calculate the effects on vehicle handling while operating in this mode. Flatproof tire force and moment data were obtained from Goodyear at zero psi, (in order to simulate a blow-out where there would be no pressure build up) and at 4 psi (to simulate a small leak with internal pressure generation due to heat build up). Although the Chrysler handling program cannot cope with different tire properties for each side of the vehicle, simplified calculations were made to estimate RSV handling with either one front or one rear tire deflated. Generally, the calculations show a marked increase in understeer when the front tire is in this condition and neutral steer with a deflated rear tire at design loads (three passengers, no luggage). At 4 psi inflation pressure, the effects are somewhat less severe than for zero psi. Normally, a vehicle is insensitive to lateral load transfer from 0 to 0.3 g lateral acceleration since the outside tire compensates for the effects of reduced vertical load on the inside tire; however, this is not the case with a flat tire, particularly when it is on the outside of the turn. As the inside tires loses vertical load, the required slip angle tends to increase because the flat tire does not increase cornering capability with vertical load. Qualitative transient analysis indicates that with a flat front tire the response might be more rapid, but the vehicle would be much less sensitivie, requiring larger steering inputs. With the outside front tire flat, the RSV would probably meet both 25 and 70 mph transient yaw response criteria. With a flat rear tire the response would be large but

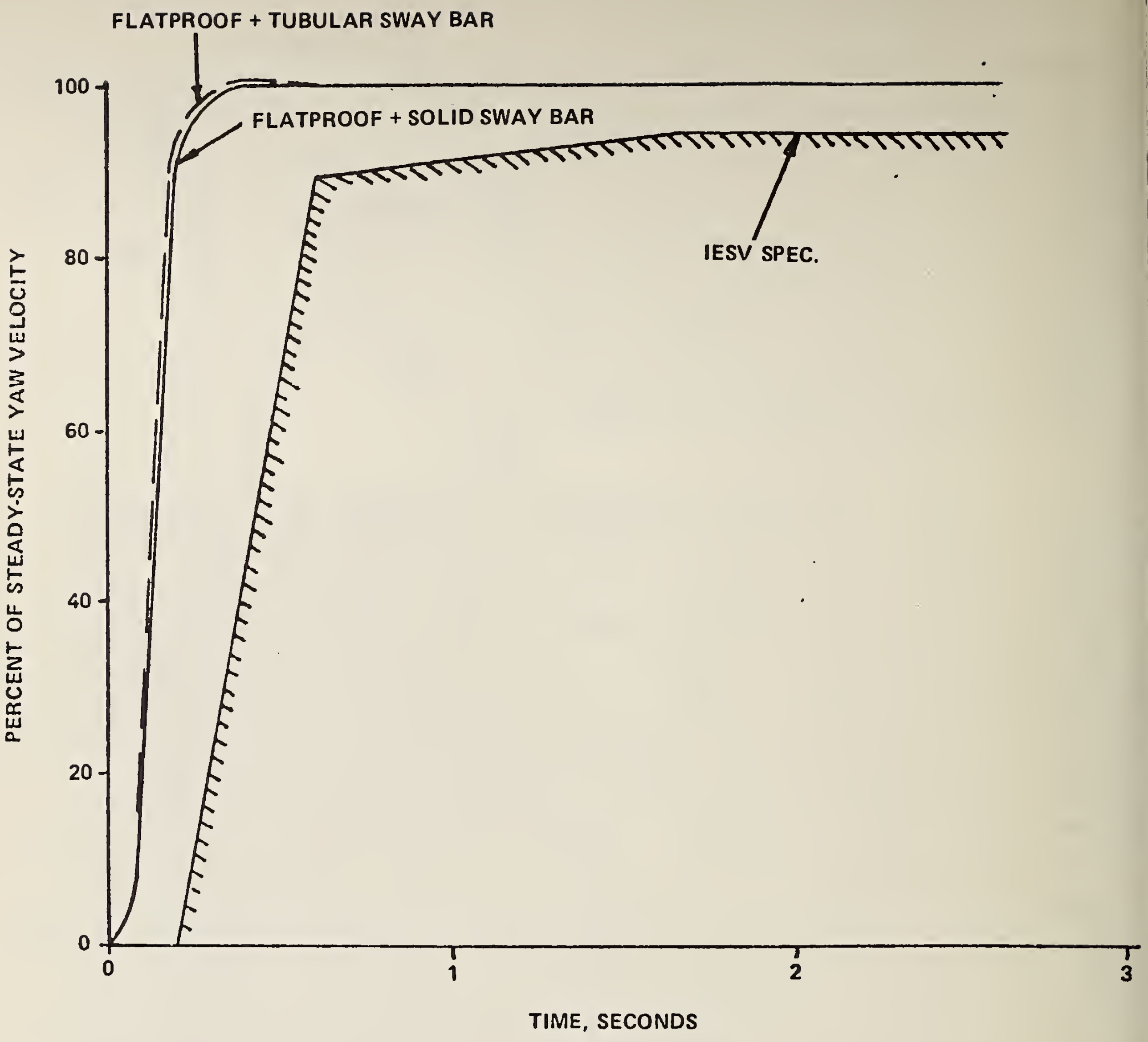


Figure 79 SOLID VS. TUBULAR SWAY BAR CALCULATED TRANSIENT RESPONSE 25 MPH, 0.4 G

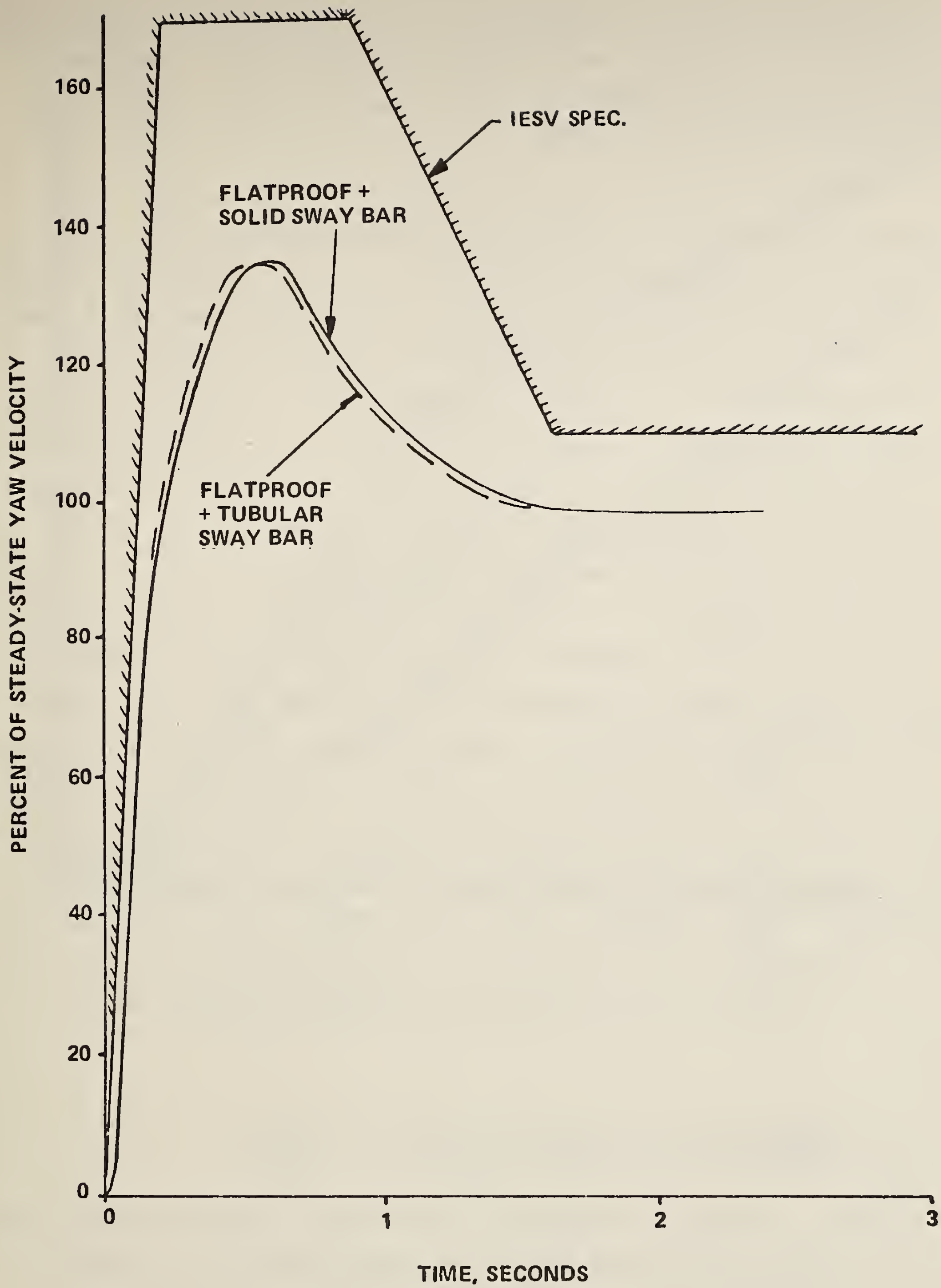


Figure 80 SOLID VS. TUBULAR SWAY BAR CALCULATED TRANSIENT RESPONSE 70 MPH, 0.4 G

sluggish and might not be able to meet the 25 mph RSV performance requirements. At maximum payload the situation would tend to be aggravated. Subsequent subjective testing of the RSV mule car with either the front or rear tire deflated confirmed these trends.[17,18]

Rather than testing the RSV for wind gust sensitivity, it was decided to calculate gust response using cornering compliance and aerodynamic side force and yaw moment data in a two degree-of-freedom mathematical model. Calculations according to the IESV specification response to a 80.45 kph (50 mph) crosswind for a 20 foot exposure at 48, 80 and 113 kph (30, 50 and 70 mph) assuming the steering wheel is fixed in the straight ahead position were made. At 48 kph (30 mph) the course deviation two seconds after gust onset was equal to the IESV specification while at 80 and 113 kph (50 and 70 mph) the deviation was within the prescribed boundary, as shown in Figure 81. For comparison, the response of a four-door Volare was also calculated. As can be seen in Figure 81, RSV response is superior to the Volare, primarily because the front wheel drive configuration locates the vehicle c.g. closer to the aerodynamic center of pressure. These calculations are probably conservative since aerodynamic properties were measured at yaw angles no greater than 12 degrees whereas aerodynamic side-slip angles of up to 59 degrees were calculated. At high side-slip angles there is usually a tendency for the center of pressure to move rearward, which would reduce the yawing moment on the vehicle and consequent course deviation. Based on the calculations, it was decided that the expense of testing the RSV for gust sensitivity was not warranted.

4.6 Brake System

Braking for the RSV is supplied by essentially carryover Simca 1308 components. The brake system consists of a vacuum assisted split hydraulic circuit with disc brakes at the front and self-adjusting drum brakes at the rear. On the Simca, hydraulic pressure to the rear brakes is controlled by a height-sensitive pressure reducing valve mounted on the rear suspension. The

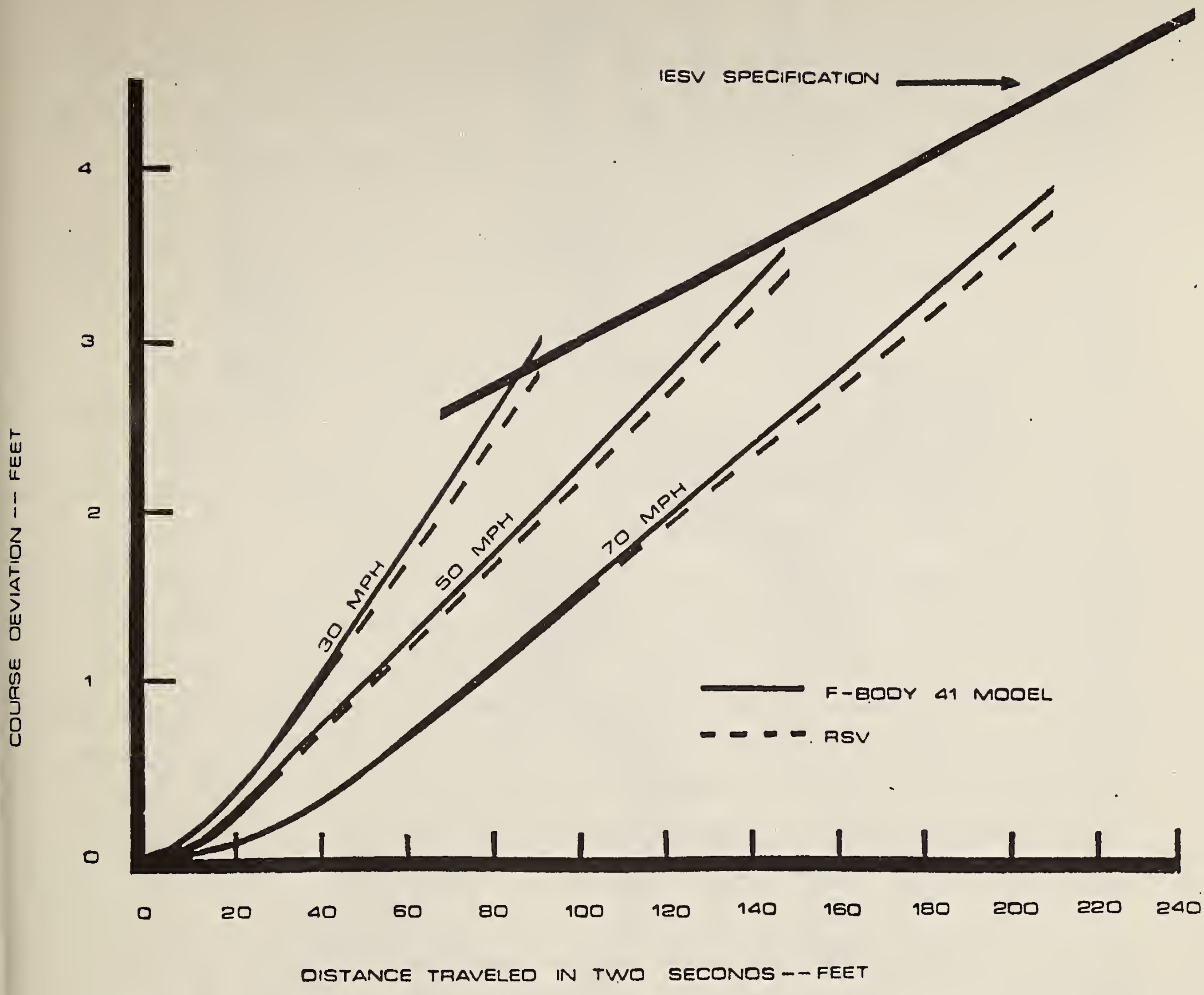


Figure 81 CALCULATED RSV GUST RESPONSE

valve proportions the rear brake effort to vehicle load, thus reducing the possibility of locking the rear wheels under a light load operating condition. The parking brake operates the rear brakes through a cable linkage.

Initial brake evaluations indicated the need for two important but relatively simple modifications to the RSV. First, the front/rear hydraulic split of the Simca was changed to a diagonally split system (Figure 82). This change reduced 96.5 kph (60 mph) stopping distances for a partially failed brake system from 145 to 100 m (475 to 329 feet). Second, the change to a diagonal split necessitated the addition of a second load-sensing, proportioning valve. Testing was conducted both with and without the proportioning valves operational. Light load 60 mph stopping distances with the valves functioning ranged from 49 to 53 m (160 to 174 feet) (limited by front skid). Stopping distances with the proportioning valves defeated ranged from 48 m (157 feet) to 51 m (167 feet) (limited by rear skid). While the RSV could meet the brake performance goals without the proportioning valves (a cost and 2 kg [2 lb.] weight saving), they were retained as an active safety feature since they provide additional vehicle control by utilizing front wheel skid as the limiting condition. Drawings 90320 through 90380 in Appendix B, Volume II, show the brake system components.

Complete FMVSS 105 brake compliance testing was conducted on the RSV mule car. As summarized below, all RSV and FMVSS 104 performance requirements were met with a substantial safety margin. The complete FMVSS 105 compliance report is included in Appendix D, Volume II.

Braking Mode	Specified Stopping Distance	Actual Stopping Distance	Margin
60 mph, Maximum GVW	190 ft	151 ft	-39 ft
60 mph, 1/2 System Failed	400 ft	329 ft	-79 ft
60 mph, Booster Failed	350 ft	192 ft	-158 ft
60 mph, Prop. Sys. Failed	250 ft	157 ft	-93 ft
Parking Brake, 30% Grade	90 lb	82 lb	-8 lb

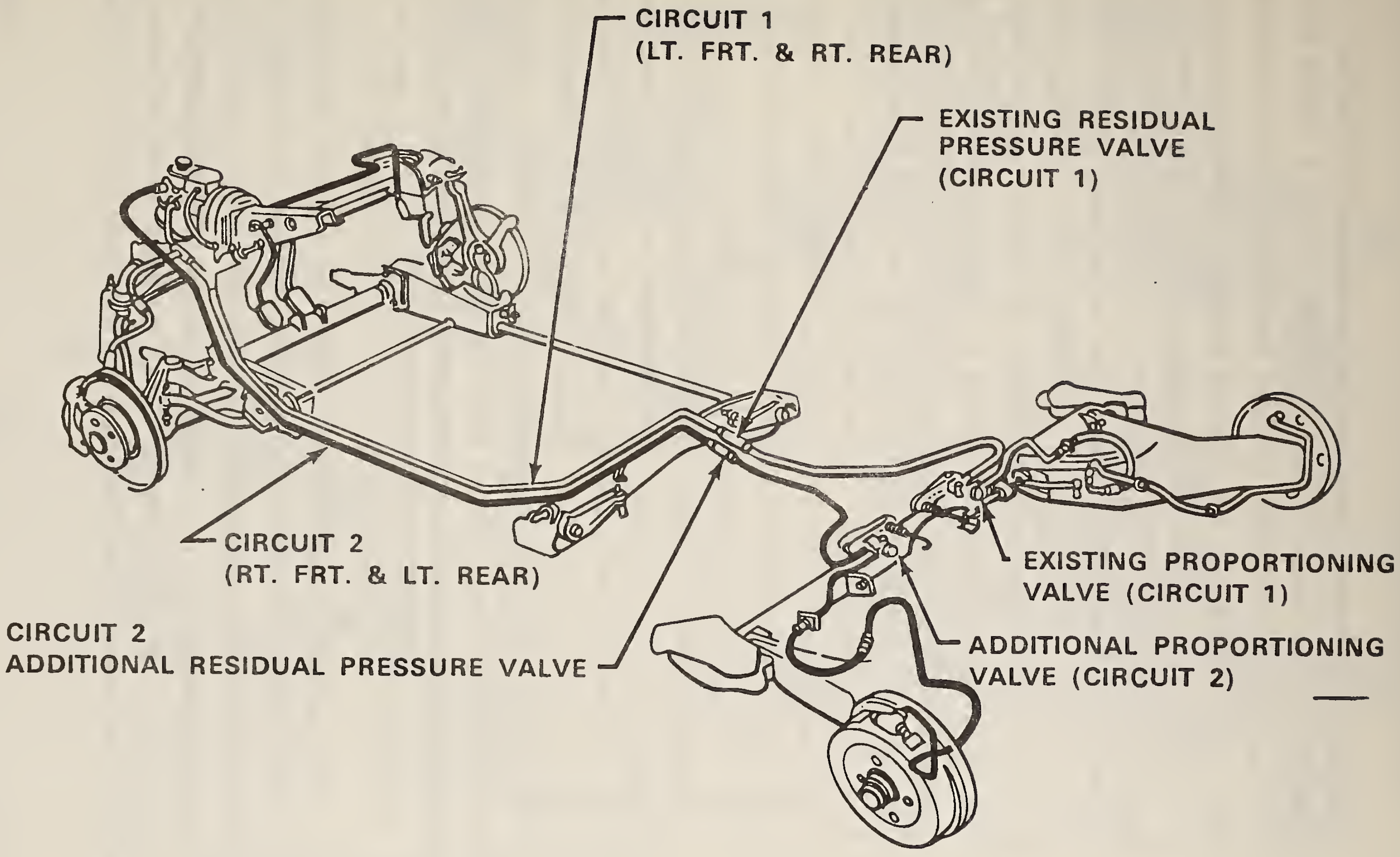


Figure 82 BRAKE LINE ROUTING FOR PHASE III RSV WITH DIAGONAL SPLIT SYSTEM

4.6.1 Anti-Skid Brake System

An anti-skid brake system was developed as an RSV option. It was felt that the additional vehicle control offered by such a system on low coefficient and split coefficient surfaces would be a highly desirable active safety feature. The anti-skid or Adaptive Braking System (ABS) developed by Bendix (Figure 83) utilizes four wheel-sensors and non-displacement modulators while maintaining the diagonal split feature of the RSV basic braking system. A four-wheel anti-skid system was chosen over a two-wheel system despite the added cost and complexity because a four-wheel system allows the driver to steer the vehicle even under maximum braking while negotiating a turn. The system uses individual wheel speed sensors to determine when wheel lock-up is about to occur. Although individual rear wheel sensors are employed, the control system logic is such that it will select the lower wheel speed for modulation of both rear brakes. This "select low" feature was chosen because previous Bendix experience indicated that such a system would provide vehicle control superior to individual brake modulation on split coefficient surfaces.

Hydraulic power, instead of a vacuum source, was chosen for the ABS system because of space and weight considerations as well as uncertainty of vacuum level and capacity with the Omni/Horizon engine. The hydraulic pump is driven by an electric motor and charges a bank of four accumulators to store energy for "closed center" operation. This allows the pump to be sized substantially smaller than would be required for an "open center" system and permits the peak flow demands to be met using only fluid accumulated previously during low demand periods.

The regulator is designed to insure that the anti-skid system provides no more hydraulic force than is being called for at the brake pedal. When the anti-skid electronic control unit determines that lock-up is imminent from wheel speed sensor data, it begins to control the two solenoids mounted in each modulator. Be energizing the decay solenoid, wheel cylinder pressure is vented to the reservoir and the wheel is then free to roll. Cylinder

RSV ADAPTIVE BRAKING

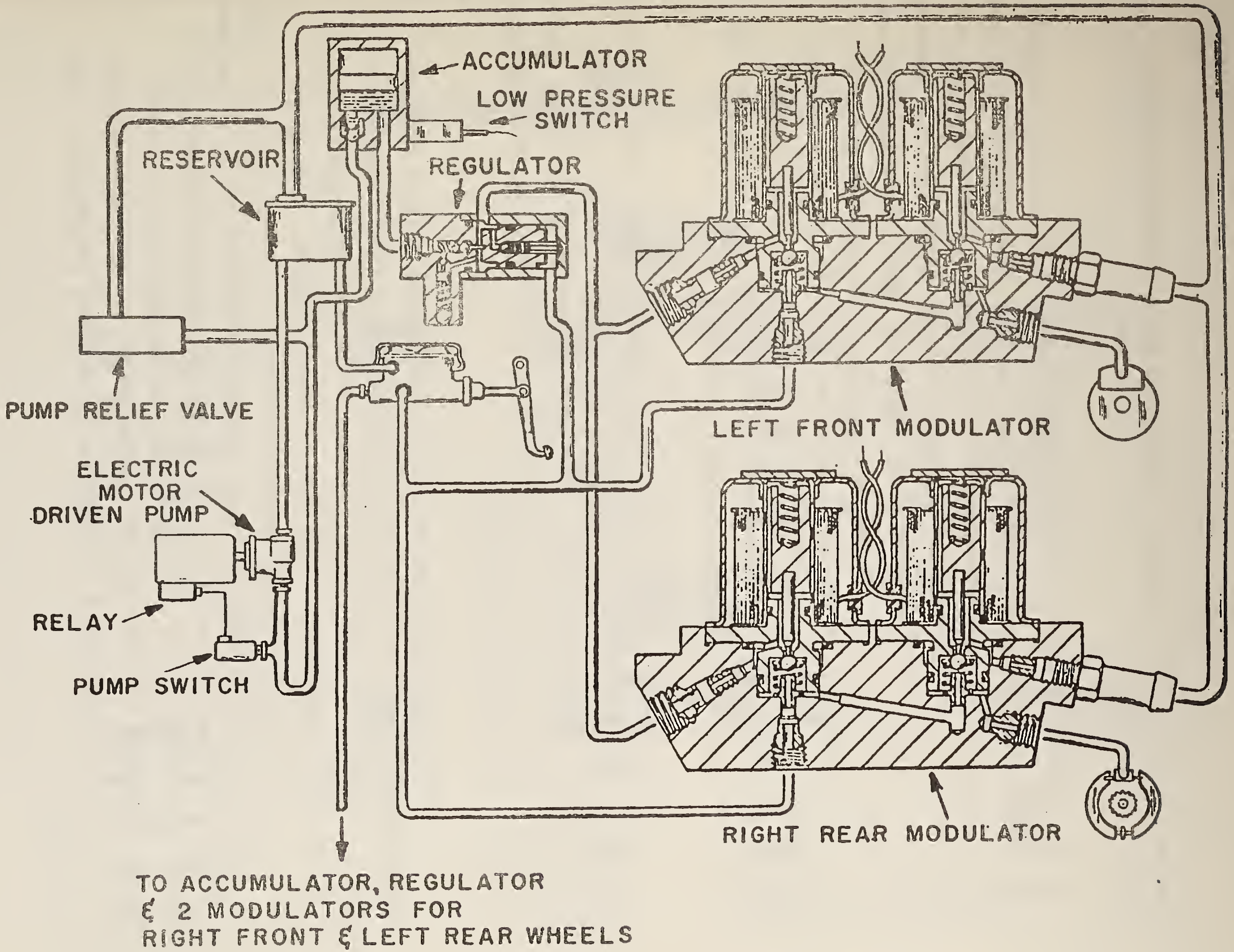


Figure 83 ABS SCHEMATIC

pressure can then be re-applied by closing the decay solenoid and opening the isolator solenoid.

Early in the anti-skid development program, two failures occurred which prompted changes in the system logic. In each case, the hydraulic pump began to operate continuously because of a stuck relay. The original circuit design was such that the excessive pressure could be relieved only by passing through the regulator and bleeding back through the master cylinder compensation ports. Unfortunately, the master cylinder seals tended to jam in the ports and cause the entire brake system to lock up. This failure mode was eliminated by installing a relief valve in the pump line so that excessive pressure would be dumped to the resevoir. In addition, new relays and pump switches were developed to insure system reliability.

The weight of the ABS system is approximately 18 kg (40 lbs.). This is partially offset by the potential to eliminate 2.3 kg (5 lbs.) of rear proportioning valves and bracketry. A production version of the system could save an additional 3.2 to 4.5 kg (7 to 10 lbs.) through the use of aluminum modulators and an engine-driven pump.

Initial testing of the ABS system installed on a Simca 1308 produced the results shown in Table 1. Note that under all test conditions, except dry asphalt, the ABS system provides substantial improvements in braking distances compared to stops with the wheels locked. Even on dry asphalt, the ABS system exhibited superior performance with the Michelin tires. There is only a slight degradation under this test condition with the Goodyear flatproofs. It should be pointed out that the differences in performance with the two types of tires are attributable to the different tire sizes, inflation pressures and friction-slip characteristics. The Bendix design goal is to have no more than a 5% degration in stopping distances with ABS on dry asphalt.

Table 1

SIMCA PERFORMANCE DATA WITH 4-WHEEL ABS

MICHELIN TIRES
155SR x 13

SURFACE	SPEED (MPH)	AVERAGE CORRECTED STOPPING DISTANCE (FEET) SYSTEM ON	LOCKED WHEEL	% IMPROVEMENT (+) OR % LOSS (-)
DRY ASPHALT	40	77.4	84.9	+ 8.8
WET ASPHALT	40	94.2	100.0	+ 5.8
WET JENNITE	45	212.1	252.9	+16.1
WET X-10	30	94.3	101.4	+ 7.0

GOODYEAR
FLATPROOF TIRES
P185/70 x 13

SURFACE	SPEED (MPH)	AVERAGE CORRECTED STOPPING DISTANCE (FEET) SYSTEM ON	LOCKED WHEEL	% IMPROVEMENT (+) OR % LOSS (-)
DRY ASPHALT	40	73.5	72.8	- 1.0
WET ASPHALT	40	79.8	88.8	+10.1
WET JENNITE	45	185.6	240.6	+22.9
WET X-10	30	81.8	94.0	+13.0

Subjective evaluations of the Adaptive Braking System indicated significant improvement in vehicle controllability under all braking conditions, particularly on split coefficient surfaces. Testing was also conducted with one of the front flatproof tires deflated to determine if this might somehow affect ABS performance. The vehicle remained completely controllable, much the same as if the tire were inflated. The only significant performance trade-off associated with a four-wheel anti-skid system is when braking on gravel-type surfaces, where the improved control is obtained at the expense of substantially longer stopping distances (up to 25%). On gravel surfaces, the effective friction coefficient is greater with a locked wheel because of the tendency for the gravel to form a bow wave ahead of the tire and thus impede motion on the road surface.

4.7 Exhaust System

The Phase III RSV exhaust system design, shown in Drawing 90190, Appendix B, Volume II, adapted the manifold ball joint, mini-oxidation catalyst, main catalyst, muffler and support hangers of the Omni and Horizon to the RSV chassis environment. New heat shields were designed to protect the floor pan and steering gear rubber boots from excessive heat. In order to maintain adequate clearances to the exhaust system, the tunnel-to-rail reinforcement and front swaybar were redesigned. Due to the higher engine location of RSVs with automatic transmissions, a new longer exhaust pipe and slightly different routing between the exhaust manifold and mini-ox converter was designed for that configuration.

While the mule car was undergoing cooling tests, thermocouple recordings were taken at all critical underhood and underbody areas. In addition to the cooling tests, an induced one-spark plug-malfunction idle test was conducted to aggravate catalyst temperature effects. Figure 84 shows floor pan thermocuple positions. Only the fuel tank surface temperature nearest the exhaust system was above goal. The worst case recorded was during 88.5 kph (55 mph) - 6% grade testing where the surface temperature was 41.7° C (107° F) over the 65.6° C (105° F) corporate goal. This situation was

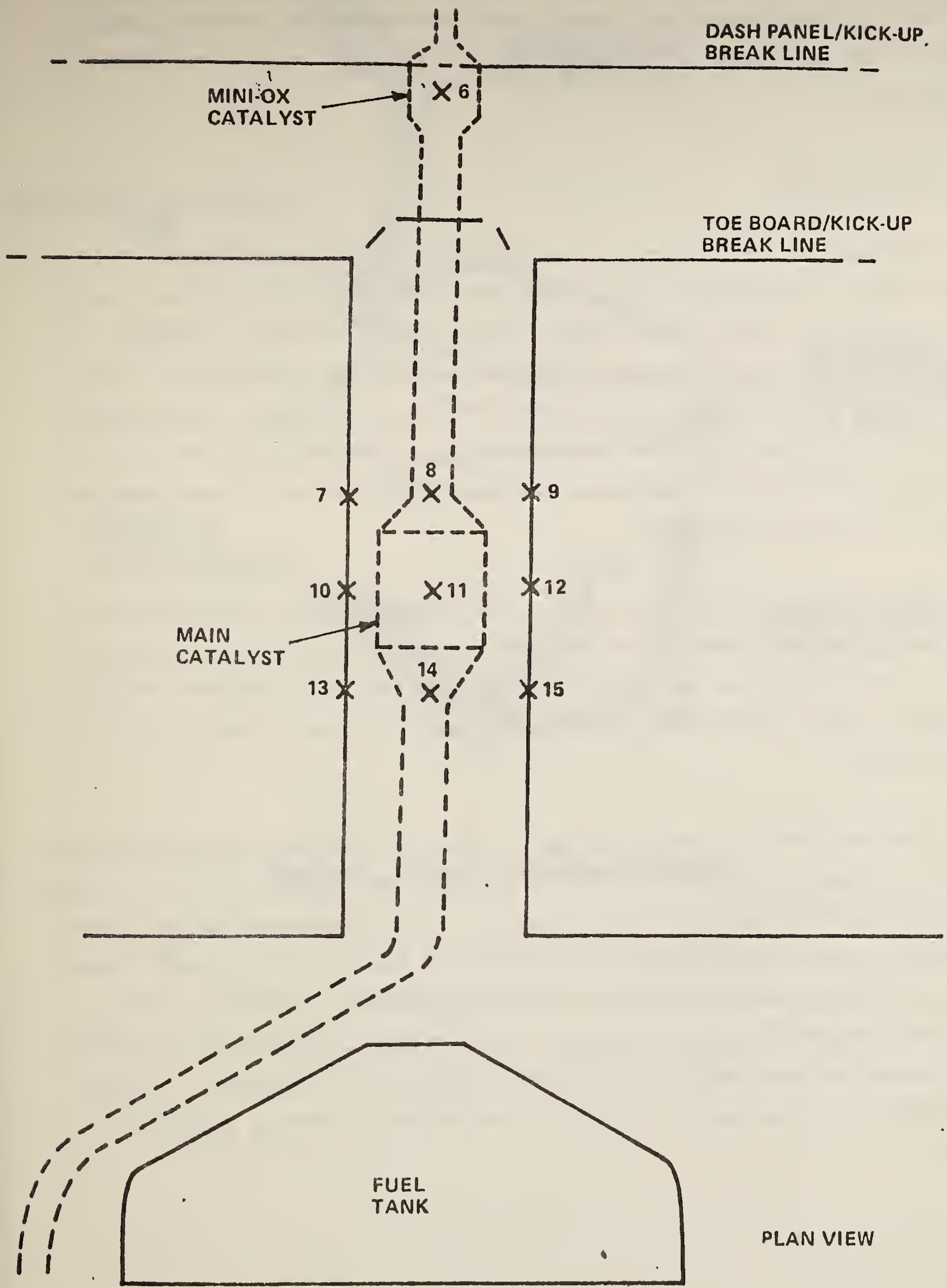


Figure 84 FLOOR PAN THERMOCOUPLE LOCATIONS

subsequently rectified by placing a heat shield located between the tailpipe and fuel tank. Temperature test results and corresponding corporate goals are given on the five pages of temperature test results included as Appendix E in Volume II.

4.8 Fuel System

The entire fuel system was extensively redesigned in Phase III of the RSV program. A new shorter fuel tank which avoided potential fuel tank damage by keeping it ahead of the rear primary impact zone was designed. This tank uses a rollover-vapor separator valve from the Omni/Horizon and a Simca sending unit for compatibility with the fuel level gauge. New attachment support straps were designed to provide better retention of the tank during impact than could be achieved with the flange mounted system used on the Simca 1308 (Figure 85).

The usable fuel tank volume for the final RSV fuel tank design is 10.5 gallons. Usable volume was determined by computing the total fuel tank volume and subtracting the largest air volume created by 16 degrees fore/aft and 14 degrees side-to-side tip angles (see Figure 86) and allowing for 2.7% expansion volume.

The RSV goal for vehicle range is that "sufficient storage shall be provided to achieve a distance of 220-250 miles at an average speed of 55 mph". Assuming that the EPA highway cycle is fairly representative of 55 mph steady state driving, the 37 mpg highway fuel economy of the RSV will yield a range of nearly 390 miles, well in excess of RSV requirements. Perhaps a more realistic assessment of vehicle range is the Chrysler Corporate goal of 250-300 miles based on seven-eights of the EPA composite fuel economy. For the 28 mpg composite fuel economy of the RSV, the range is then an acceptable 257 miles.

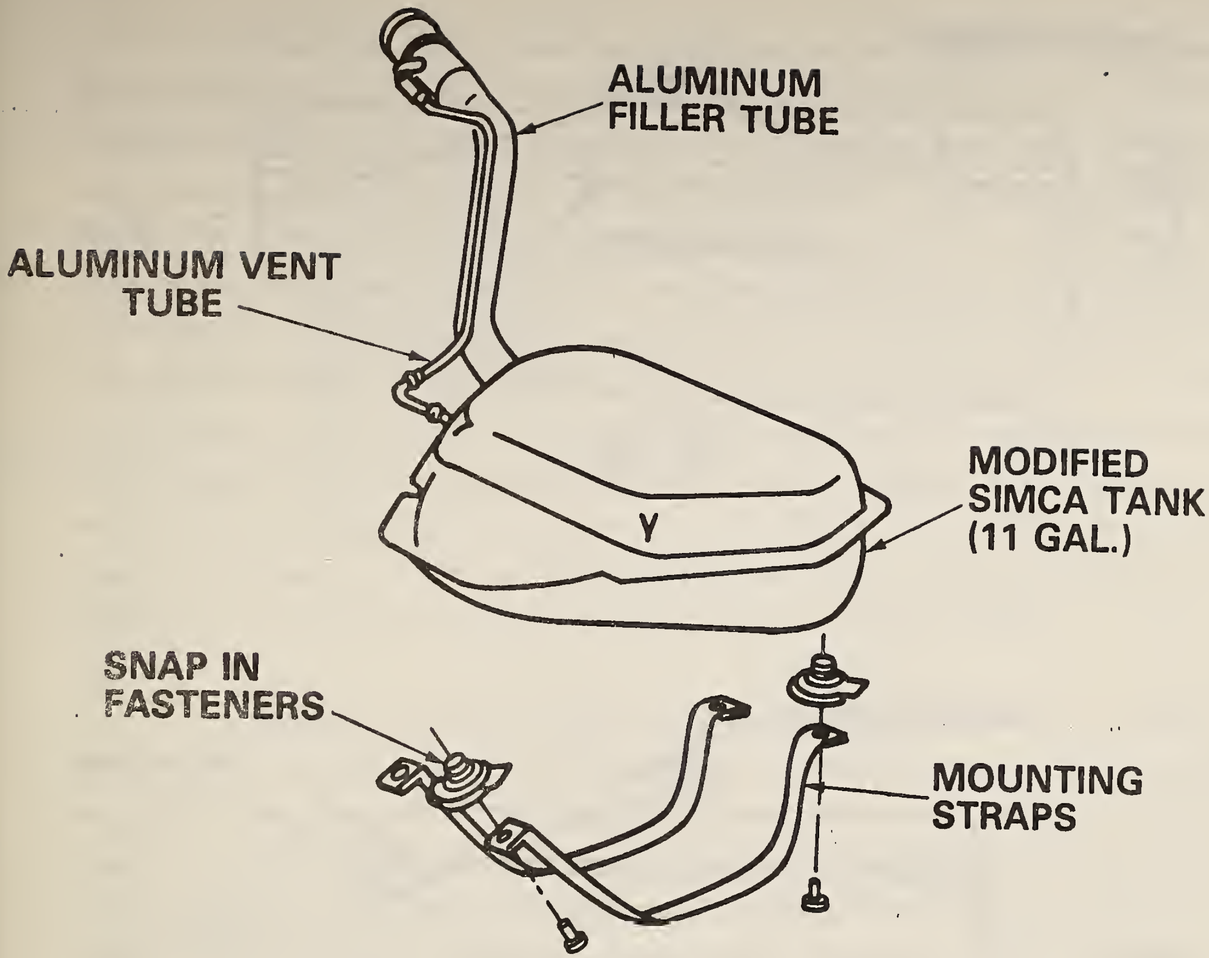


Figure 85 PHASE III RSV FUEL SYSTEM

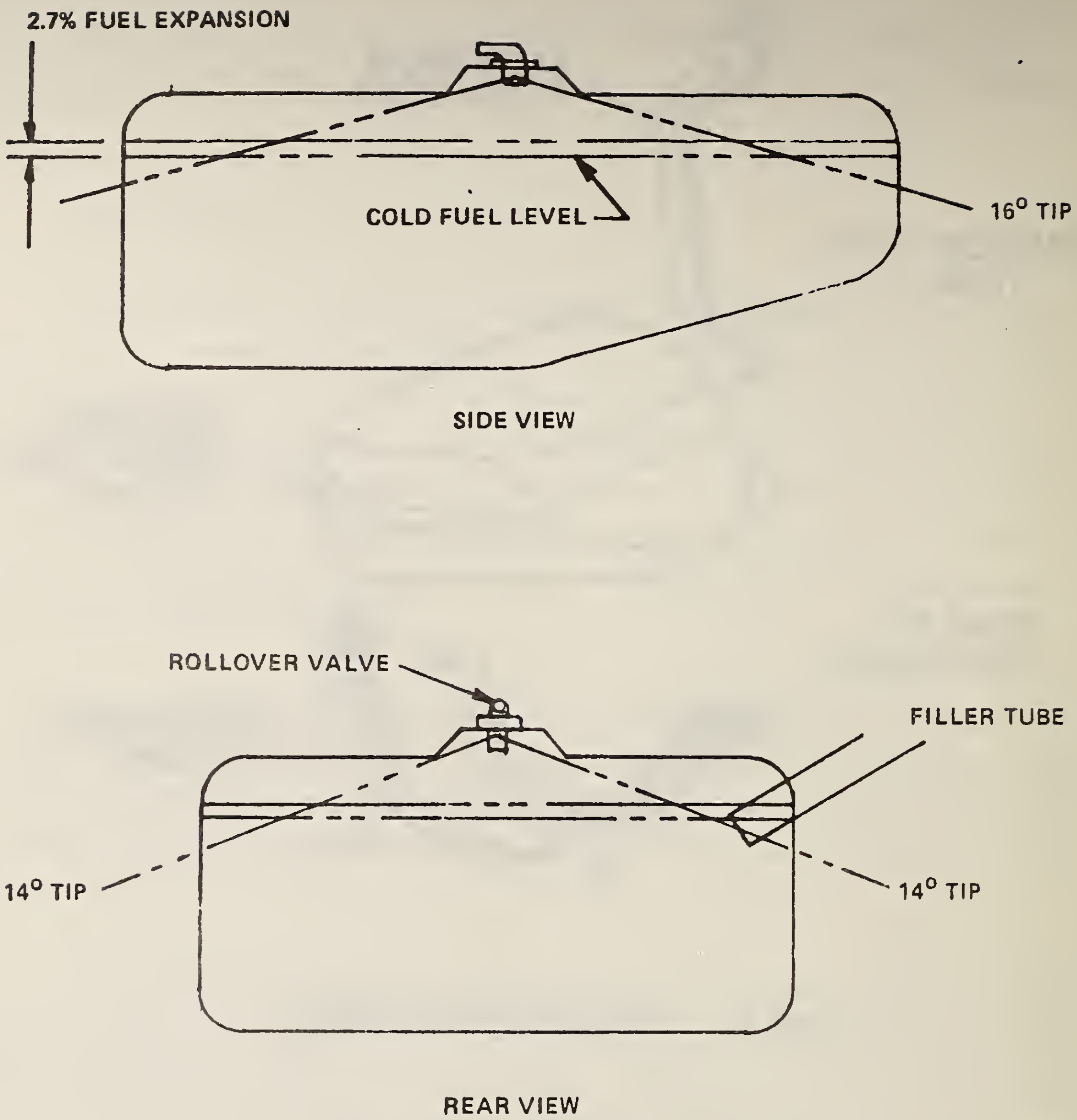


Figure 86 FUEL TANK VOLUME

A new fuel filler tube was designed to be located farther forward than on the Simca 1308 to improve rear impact protection. The fill tube is aluminum and has an external aluminum vent tube which must pass through the rear rail in order to maximize usable fuel capacity. The filler tube mounts inside the right rear wheelhouse with an exposed cap on the rear quarter panel. Since fuel filler cap disengagement was encountered during early moving barrier rear impact testing, the filler tube attachment to the rear quarter panel was redesigned as shown in Figure 87. The end of the filler tube is now attached by a plastic collar which will break away if any relative movement between filler tube and quarter panel takes place due to quarter panel buckling during rear impact. Flanges on the quarter panel inner and outer have been turned inward to present rounded surfaces to the cap; when the panel buckles, the tendency for it to "pry off" the filler cap is thereby reduced.

Completely new fuel line routings were designed for the Phase III RSV in order to adapt to the new fuel tank, different engine, and evaporative emissions control system. A fuel supply line runs from the tank to the fuel pump; the return line, running from the pump to the tank, also serves as a vapor separator to provide more precisely metered fuel to the carburetor for control of hydrocarbon emissions and to reduce the possibility of vapor lock. A third line runs from the vapor separator - rollover valve in the top of the fuel tank to a charcoal canister in the engine compartment. Figure 88 schematics show the vapor saver and fuel-vapor return system. Additional information is included in Drawings 90360, 90370 and 90390, Appendix B, Volume II. With the newly designed fuel tank, fuel tank support straps, fuel line routings, and Omni/Horizon rollover-vapor separator valve, fuel leakage during and after high speed impact, is less than the leakage rates defined in FMVSS 301.

4.9 Tire and Wheel System

Early in the RSV program it was decided that some type of flatproof tire should be an integral part of the RSV's safety features, both from an active safety standpoint and to eliminate roadside hazards associated with

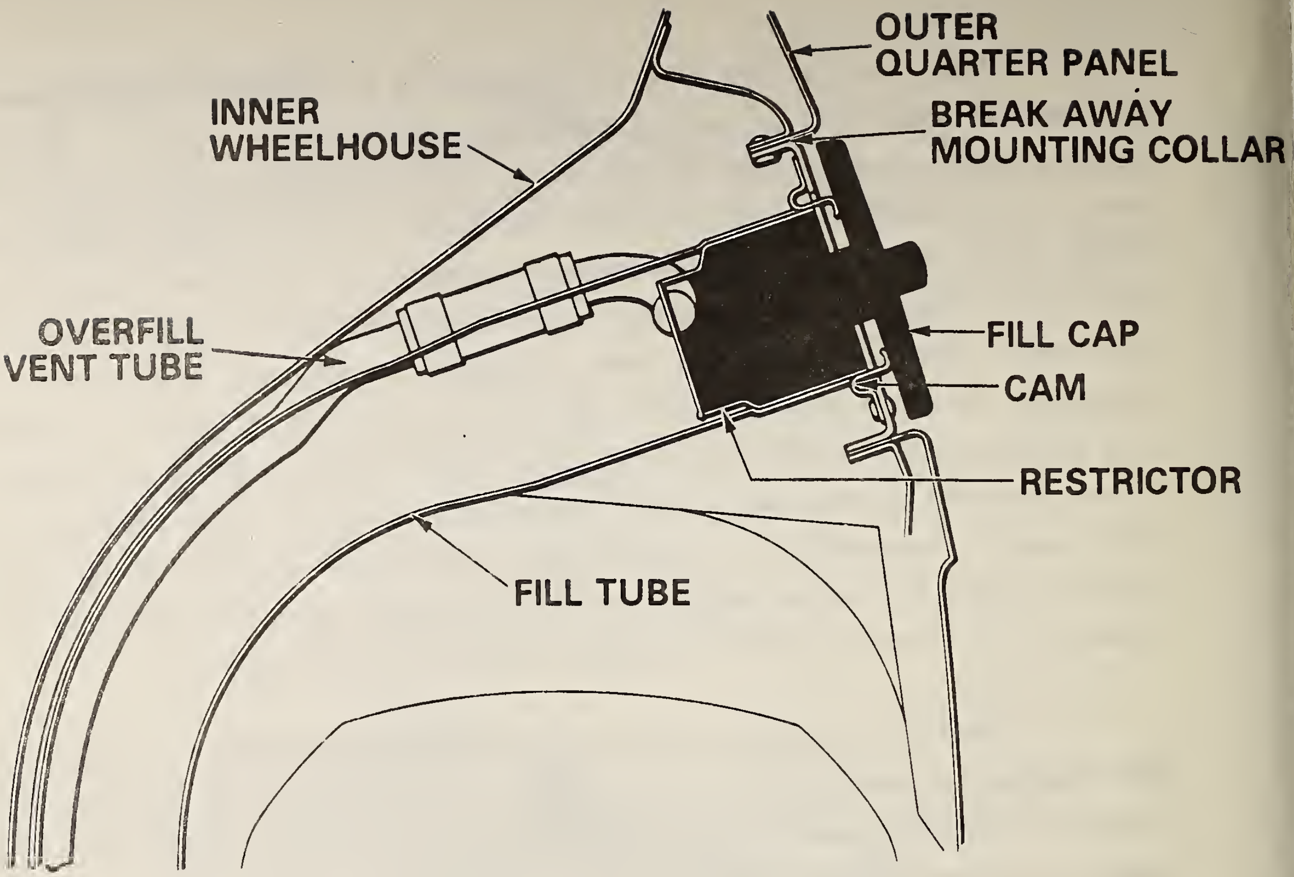
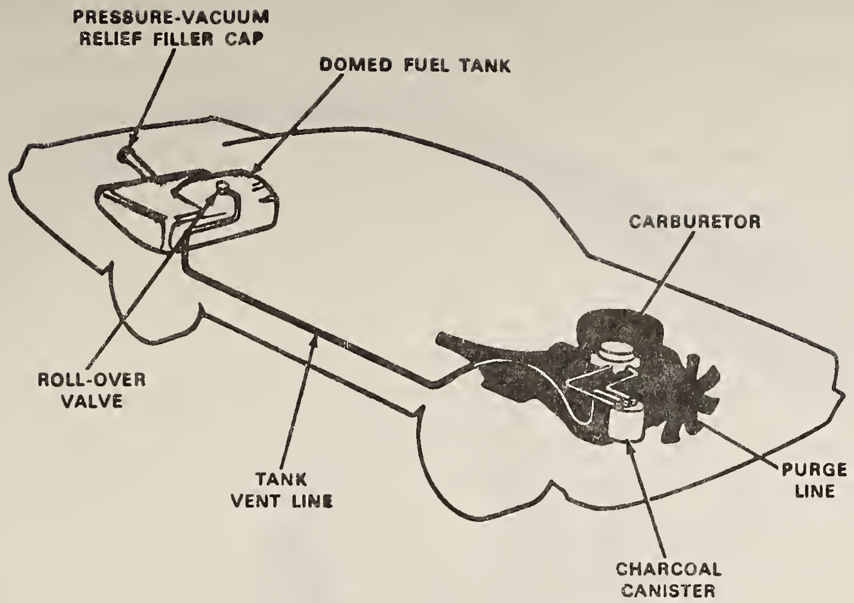
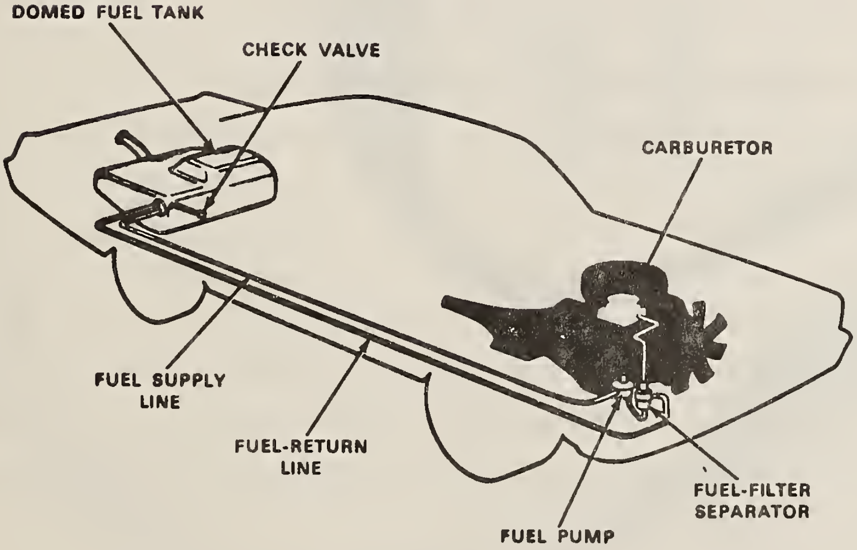


Figure 87 FUEL FILL SYSTEM



VAPOR SAVER



FUEL-VAPOR RETURN SYSTEM

Figure 88 FUEL VAPOR SYSTEM

changing a flat tire.[1,3,24] Initially, a P175/75R14 flatproof tire with an internal stabilizer was considered (Figure 89). Coolant release balls were incorporated in order to extend tire life while operating in the flatproof mode. However, when brake testing indicated the feasibility of returning to the 13-inch wheels, the stabilizer concept was abandoned since it is very difficult to assemble the stabilizer on 13-inch wheels using automated techniques.

A new, self-supporting flatproof concept replaced the old stabilizer design. Basically, the self-supporting flatproof tire developed for the RSV by Goodyear is a steel belted radial with stiffened sidewalls (Figure 90) such that at zero psi the wheel does not collapse onto the tread but rather settles one inch or less. Based on projected RSV load conditions, P185/70R13 tires with a 444.4 kg (980 lbs) capacity were chosen for the RSV. The standard 5J x 13 Simca 1308 wheels were retained for the RSV.

Initially, it had been planned to incorporate a coolant release mechanism in the tire to prevent tire degradation due to heat build up when operating in the flatproof mode. Unfortunately, the coolant release system was complex, heavy and expensive. Based on Goodyear testing conducted on P185/75R14 flatproof tires, both with and without coolant (Figures 91 and 92), it was decided to derate the 80 km (50 mile) deflated capability at 80 kph (50 mph) with coolant, to 64 km (40 miles) at 64 kph (40 mph) without a coolant. Note that substantially longer distances to failure can be achieved in the deflated condition if vehicle speed is reduced. One alternative to this approach would be to allow the driver the option of manually inserting the coolant after having been warned of a low pressure condition if greater capability were desired.

Another advantage of the flatproof tire concept is that it allows the elimination of the spare tire and jack mechanism so that usable luggage space can be improved. The elimination of the spare tire and jack more than offsets the weight increase associated with the thicker sidewalls of the flatproof tires.

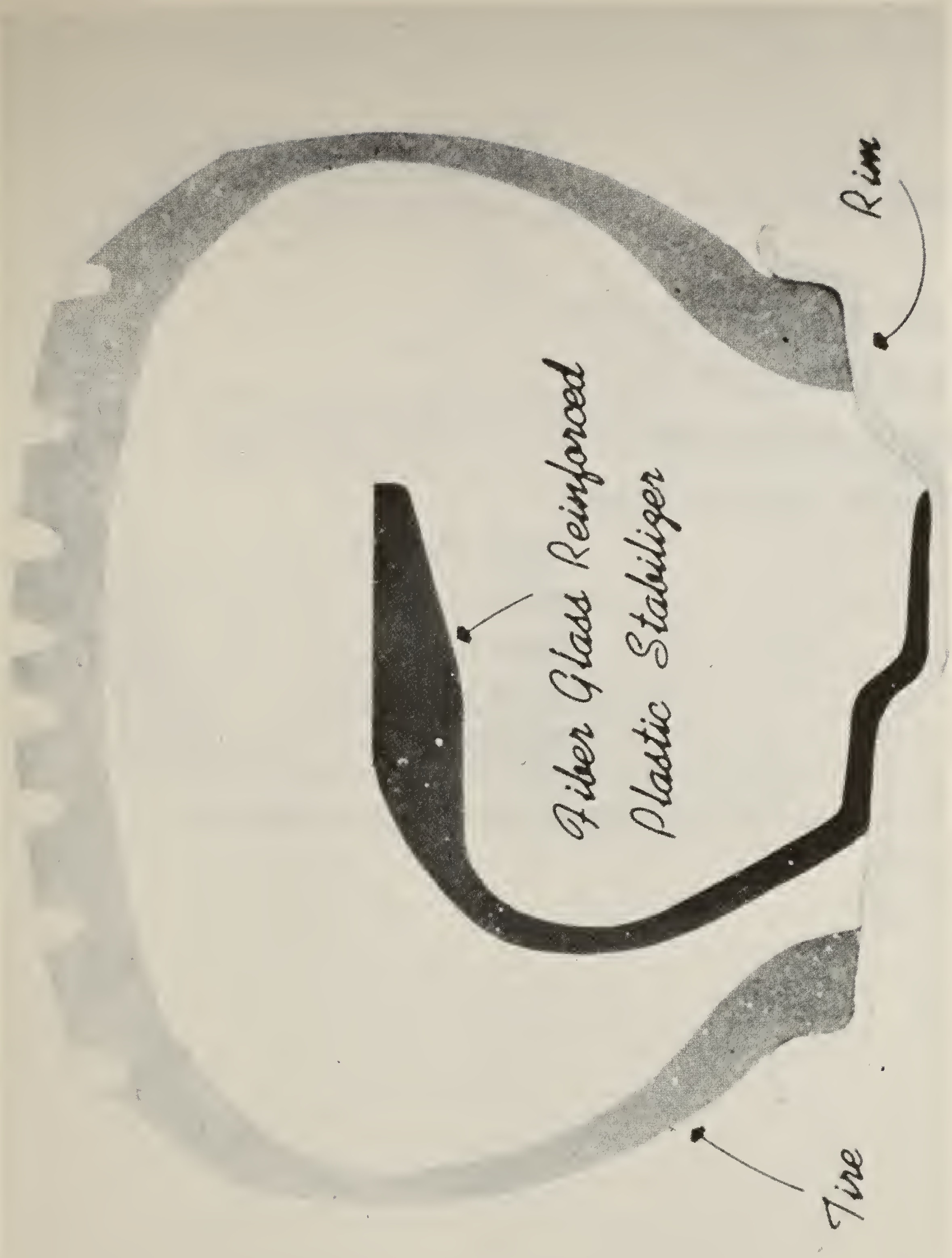


Figure 89 14 INCH FLATPROOF TIRE WITH INTERNAL STABILIZER

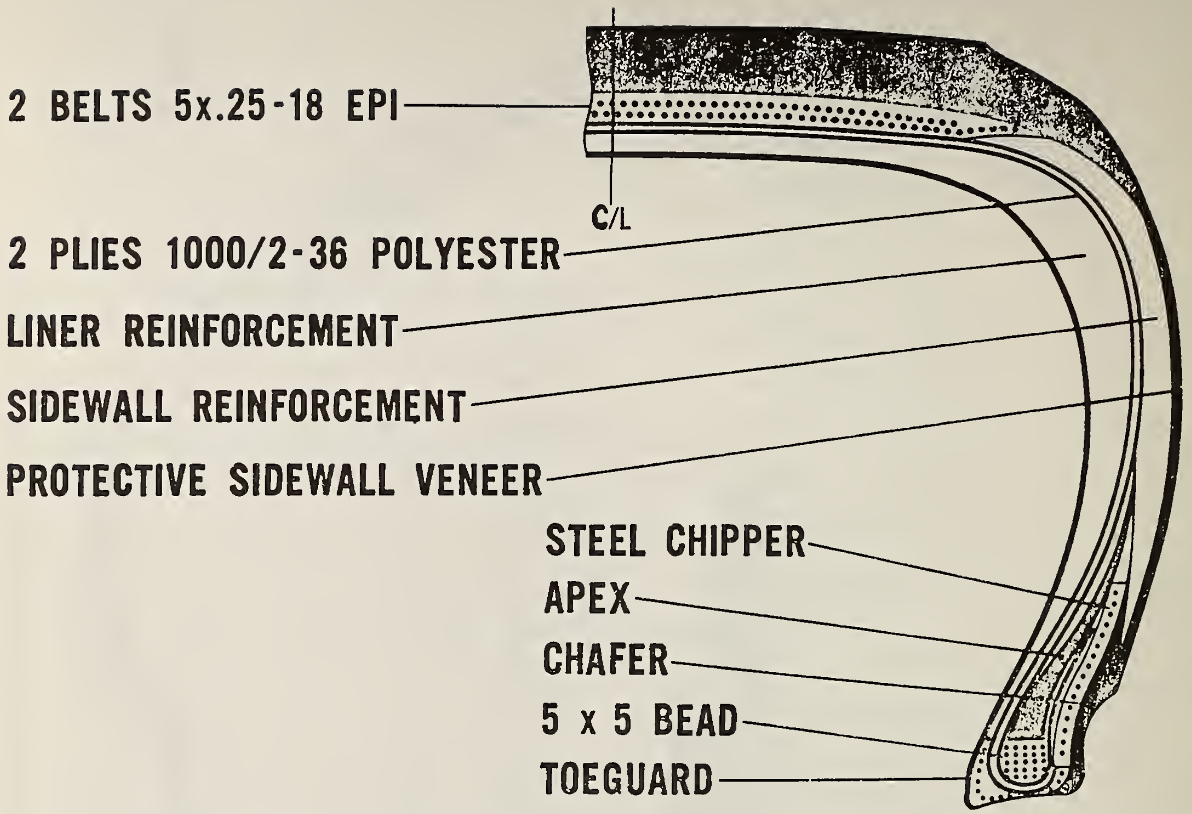


Figure 90 13" GOODYEAR SELF-SUPPORTING FLATPROOF TIRE

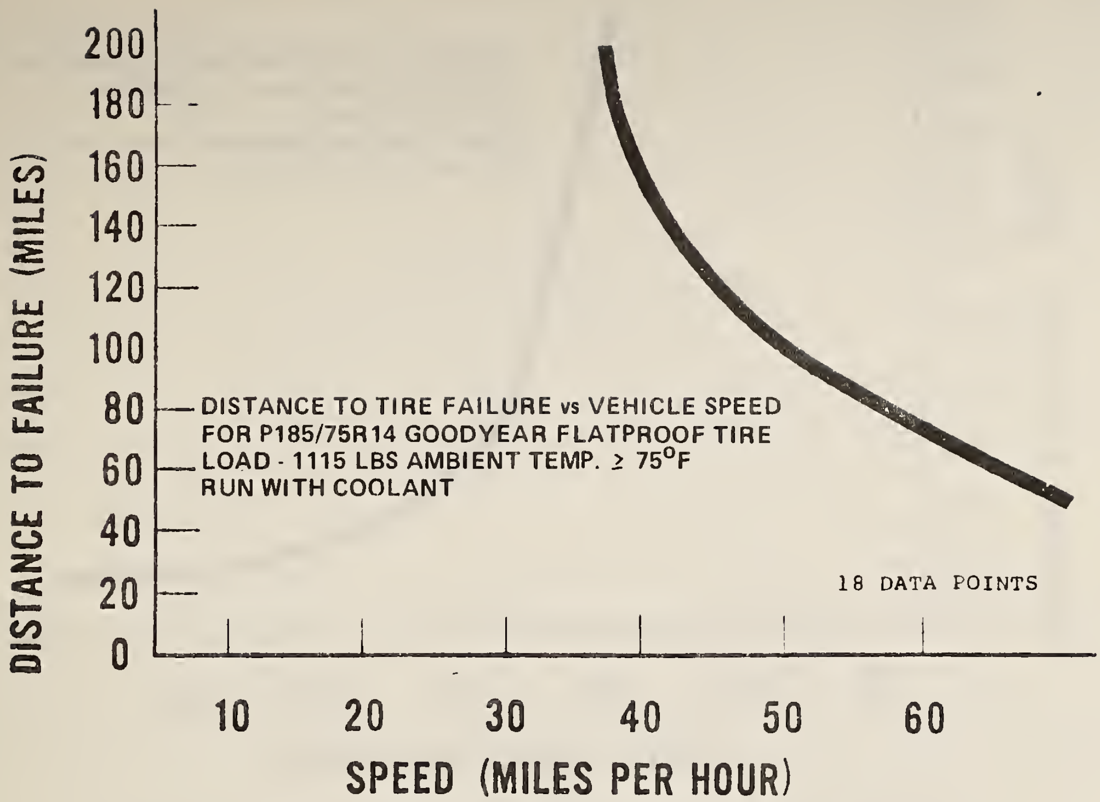


Figure 91 GOODYEAR FLATPROOF DATA WITH COOLANT

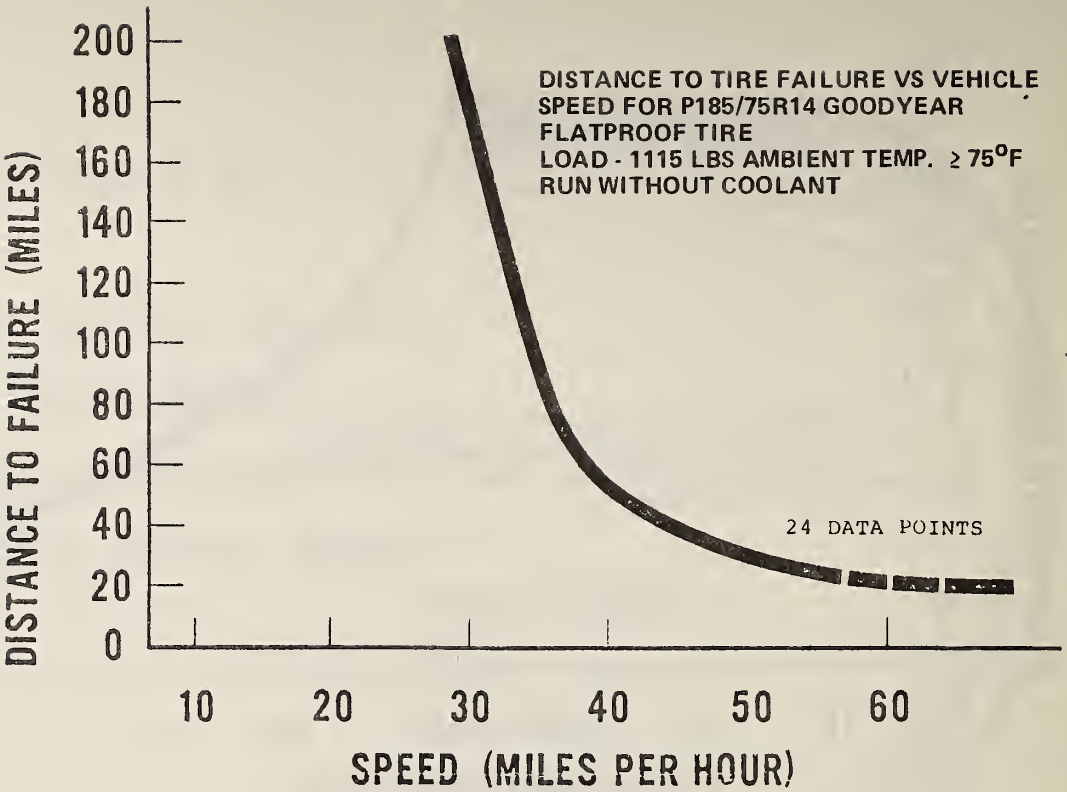


Figure 92 GOODYEAR FLATPROOF DATA WITHOUT COOLANT

The trend in tire design for the mid-1980s appears to be the development of tires with reduced rolling resistance which maintain an acceptable ride at increased inflation pressure. Consequently, it was decided to evaluate the effect of inflation pressure on rolling resistance by conducting coastdown tests at the standard 179 kPa (26 psi) ISO pressure and maximum load 241 kPa (35 psi) ISO pressure. The increased inflation pressure yielded a 3.4 to 4.4% reduction in road coastdown force required at 80 kph (50 mph) which converted to a 7.1 to 10.6% reduction in the rolls dynamometer setting. As a result of these findings, the decision was made to conduct all further RSV testing at the higher pressure 241 kPa (35 psi). It was assumed that the increased ride harshness associated with higher inflation pressures would be eliminated by new tire technology available by the mid-1980s.

Force and moment data were generated by Goodyear for the final P185/70R15 flatproof tires. The cornering coefficient (F), load transfer sensitivity (G), load sensitivity (H) and aligning torque coefficient (AT) for the flatproof tires and conventional P185/70R13 radials were supplied at both 207 kPa and 241 kPa (30 and 35 psi) inflation pressure. In addition, flatproof data at zero and 28 kPa (2 and 4 psi) were generated for simulations of vehicle handling while operating in the deflated mode. Results are summarized below:

Tire	Pressure	F (1°)	G (4°)	H (1°)	AT (1°)*
Flatproof	207 kPa (30 psi)	.2375 .2381	.2256 .2224	.1797 .1829	.0254 .0249
Flatproof	241 kPa (35 psi)	.2062	.2132	.1705	.0216
Flatproof	28 kPa (4 psi)	.1169 .1305	- -	.0222 .0173	.0245 .0253
Flatproof	0 kPa (0 psi)	.0678 .0538	- -	.0318 .0487	.0250 .0195
Conventional	207 kPa (30 psi)	.2042 .2119	.2809 .2774	.1071 .1217	.0297 .0280
Conventional	241 kPa (35 psi)	.1784	.2665	.1054	.0248

*Tire functions discussed in SAE Paper No. 670173, "Analysis of Tire Lateral Forces and Interpretation of Experimental Tire Data" by D.L. Nordeen.

In general, the flatproof tire exhibits cornering properties superior to its conventional counterpart. The higher inflation pressure, however, slightly degrades these properties. This loss may be attributable to a slight decrease in the area of the tire contact patch because of the greater pressure and perhaps could be overcome if the tire were initially designed to operate at 241 kPa (35 psi).

In order to distinguish the flatproof capability of the RSV tire, a new sidewall treatment was designed. The lettering and raised striping on the tire are red to provide the unique identification required. The styling of this sidewall has been carefully detailed to reflect the family type purpose of the vehicle (Figure 93).

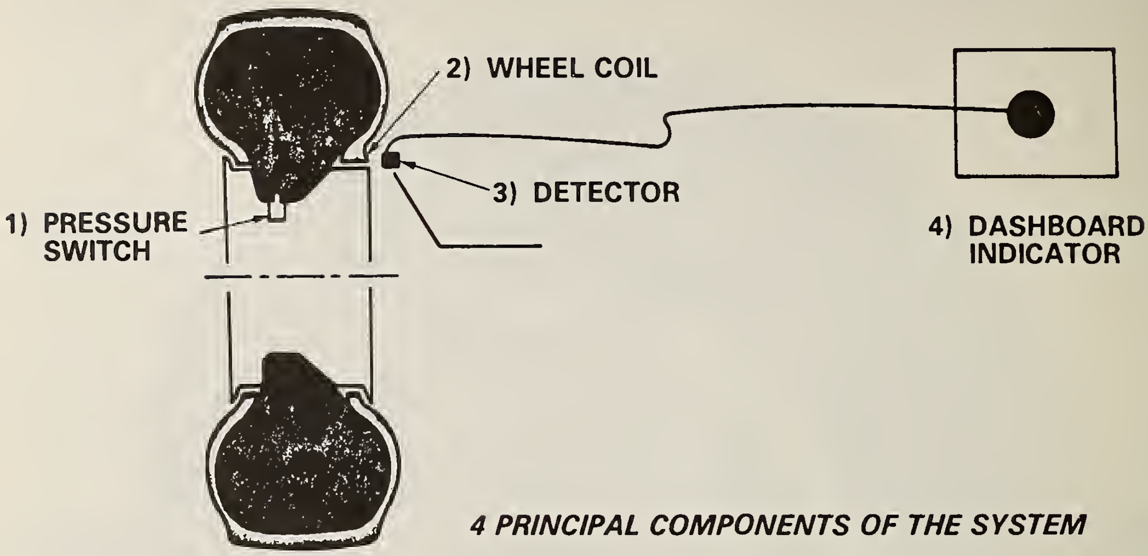
4.9.1 Low Tire Pressure Sensor Warning System

When traveling in a straight line in a vehicle equipped with flatproof tires, it is difficult if not impossible to discern that any tire has lost pressure. Therefore, a low tire pressure sensing system (Figure 94) was devised by the Motorwheel division of Goodyear to indicate through an instrument panel warning light that one or more of the tires has fallen below 117 kPa (17 psi) pressure. The system consists of a rubber booted pressure sensing switch extending through each wheel rim hole into the tire cavity, a passive wheel sensor adhesively attached to the rim bead lip, a solid state detector rigidly fixed at each wheel position, and an electronic processor which controls the dashboard indicator.

The low pressure warning system (Figure 95) operates by energizing the primary coil of the detector to create a high frequency magnetic field. As long as the wheel pressure switch is closed by tire pressure, the wheel coil creates a disturbance when passing through the field each revolution. The secondary coil then picks up this disturbance as a pulse and the electronic processor interprets these periodic pulses as an "OK" signal. If the tire pressure falls below 117 kPz (17 psi) the switch opens, breaking the wheel

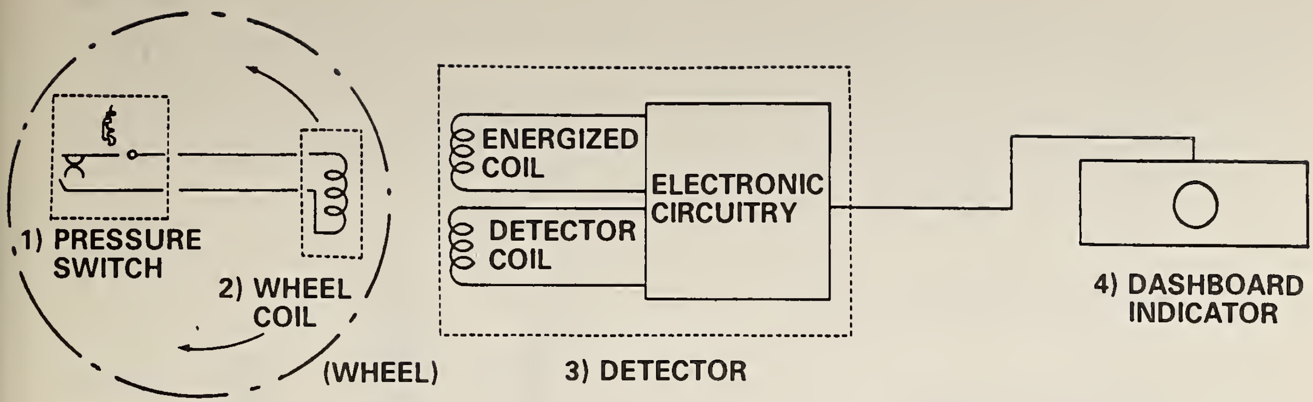
Figure 93 RSV FLATPROOF SIDEWALL STYLING

A SIMPLE, FAIL-SAFE ELECTRONIC SYSTEM THAT GIVES IMMEDIATE DASHBOARD INDICATION IF PRESSURE IN ANY TIRE DROPS BELOW A PREDETERMINED THRESHOLD LEVEL.



4 PRINCIPAL COMPONENTS OF THE SYSTEM

Figure 94 GOODYEAR LOW TIRE PRESSURE WARNING SYSTEM



OPERATION

- ENERGIZED COIL CREATES HIGH FREQUENCY MAGNETIC FIELD.
- WHEEL COIL CREATES A DISTURBANCE IN THE FIELD WHEN PASSING THROUGH EACH REVOLUTION, SO LONG AS PRESSURE SWITCH IS CLOSED.
- DETECTOR COIL PICKS UP DISTURBANCE AS A PULSE. ELECTRONIC PROCESSOR INTERPRETS PERIODIC PULSES AS A OK SIGNAL.
- IF TIRE PRESSURE FALLS BELOW PREDETERMINED THRESHOLD, THE SWITCH OPENS, BREAKING WHEEL CIRCUIT.

Figure 95 LOW TIRE PRESSURE WARNING SYSTEM SCHEMATIC

circuit. The electronic processor then senses that it no longer is receiving an OK signal and, therefore, activates the low tire pressure warning light within 30 seconds. The detectors, front and rear mounting brackets, and electronic processor are shown in Figure 96. The left rear detector is shown in its installed position in Figure 97.

4.10 Vehicle Aerodynamics

During the initial phases of the RSV program the main consideration for improved vehicle aerodynamics was as a qualitative influence on exterior styling, but no testing was conducted. However, when a fuel economy goal of 12.75 kg/l (30 mpg) was established for the RSV in Phase III, an aerodynamic drag reduction program was undertaken to quantify the potential for fuel economy improvements. Wind tunnel testing was conducted at the National Research Council facility in Ottawa, Canada using a Phase II RSV show car modified to the preliminary shape selected for Phase III. The RSV was evaluated for drag, lift, and yaw coefficients at various vehicle attitudes. In addition, the following aerodynamic aids were evaluated.

- Vertical Front Air Dam
- Front Spoiler Extension
- Adjustable Rear Spoiler
- Flush Headlamp Covers
- Aerodynamic Wheelcovers
- Partial Rear Fender Skirts
- Full Bubble - Type Rear Fender Skirts
- Flush Rear Quarter Windows
- Concave Front Wheel Fairings
- Convex Front Wheel Fairings
- Re-contoured A and D Pillars
- Reduced Cooling Inlet Area
- Aerodynamic Mirrors

Figure 96 LOW PRESSURE WARNING SYSTEM HARDWARE

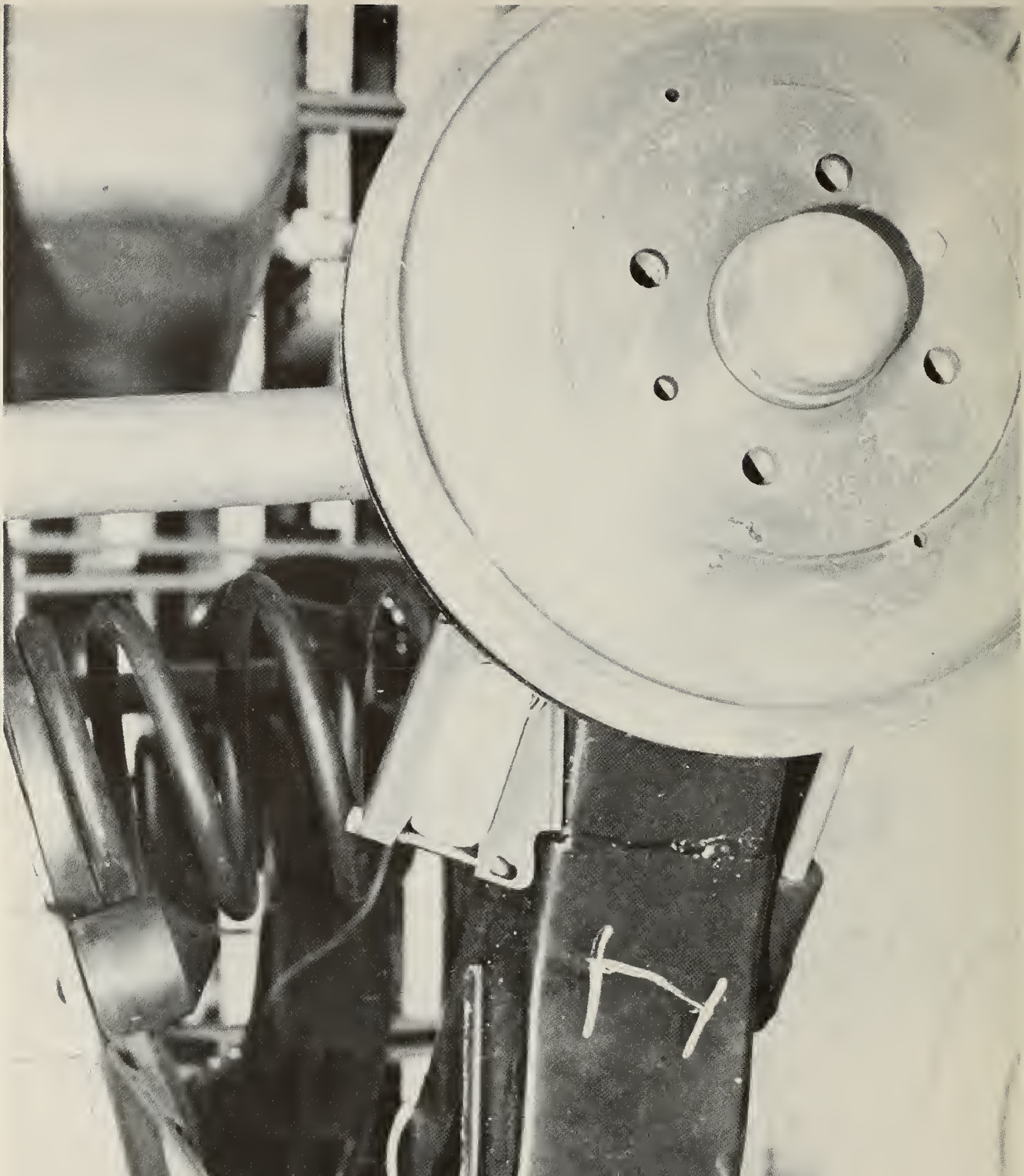


Figure 97 DETECTOR INSTALLED ON LEFT REAR TRAILING ARM

A chronological listing of all the test configurations is included as Appendix F in Volume II. The listing is a comparative table of drag coefficients as a function of test configuration with relative percentage comparisons made for the reader. Analysis of these data for the various aerodynamic configurations led to the following conclusions:

- The base Phase III RSV (Figure 98) exhibited a drag coefficient (C_D) of 0.474 compared to a C_D of 0.494 for the Simca 1308 from which it is derived.

- Incorporation of a rear spoiler (Figure 99) yielded as much as a 7% reduction in drag, while reducing lift approximately 37%. The magnitude of drag reduction, however, was not particularly sensitive to the size of the spoiler (Runs 42-45).

- Nearly a 4% drag reduction was achieved by simulating flush headlamp covers (Figure 100) (Runs 42-45).

- The smooth wheelcovers produced a 1 to 2% drag reduction, typical in magnitude for front wheel driver cars (Figure 101) (Run 52).

- A powered versus free-wheeling radiator fan did not affect the drag level (Runs 4 and 5).

- The air dam on the base car was found to be close to optimum. Of the three front air dam configurations investigated, only the vertical air dam (Figure 102) exhibited any promise of drag reduction. Approximately a 1% reduction in drag was achieved (Runs 24, 34-41, and 69).

Figure 98 BASE PHASE III RSV

Figure 99 REAR SPOILER

Figure 100 FLUSH HEADLAMP COVERS

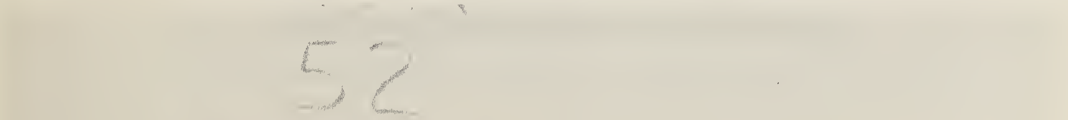


Figure 101 FLUSH WHEELCOVERS

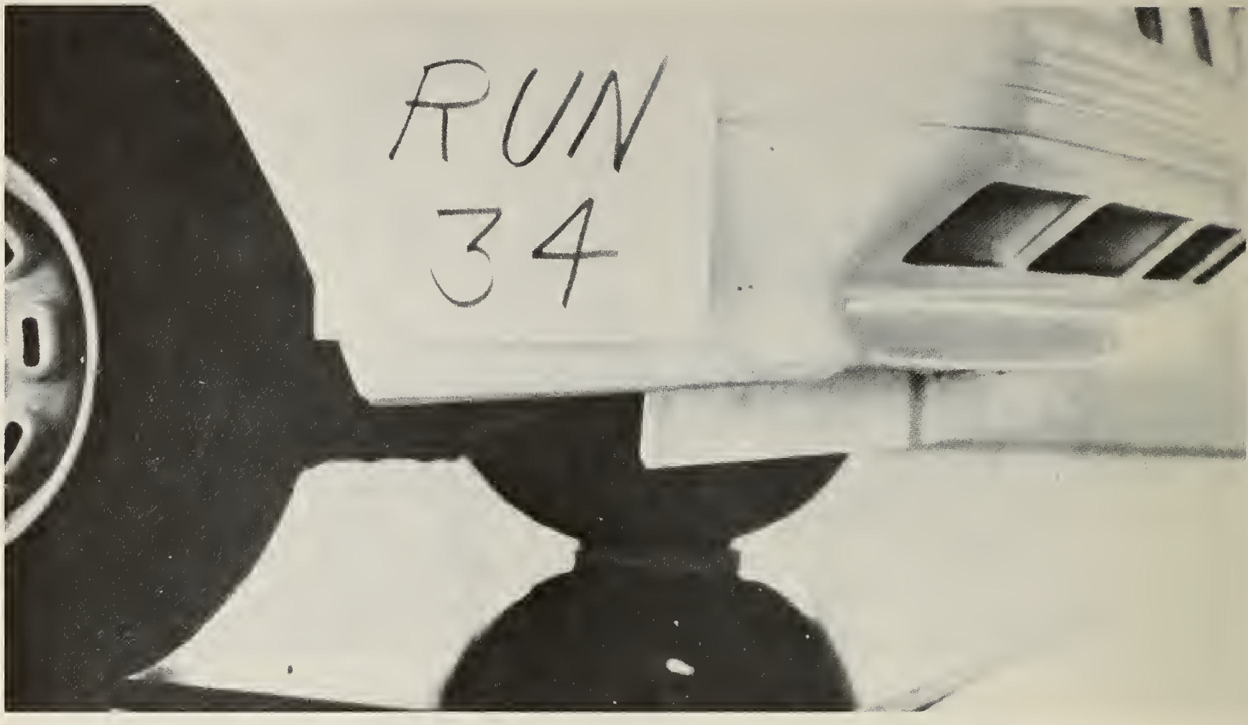


Figure 102 VERTICAL FRONT AIR DAM

- The RSV was relatively insensitive to vehicle attitude (Runs 6-10) until the vehicle was configured in a nose-up attitude which increased drag by approximately 3.6%. A tail-up attitude reduced lift, primarily at the front, and at the extreme -1.6° position increased flow through the radiator by up to 4%. Such a design attitude, however, would be visually unacceptable, especially in light of the small gains which might be achieved. Body attitude changes to create a more nose-down position increased the effect of the vertical air dam, improving drag reduction from 1% up to as much as 2.5% (Runs 34-36).

- Both the single standard Simca left-hand mirror and the dual aerodynamic mirrors (Figure 103) exhibited a drag penalty of less than 1% (Runs 6, 21, 22 and 28). However, a dual mirror system designed to meet the proposed DOT visibility guidelines (Figure 104) (Runs 18-20) created an additional 2.7% drag penalty. Of this, 1% was due to the size increase of the left-hand mirror over the standard Simca mirror, while the remaining 1.7% was due to the right fender mounted mirror (see Section 3.9.1.2).

- Simulation of the high level D pillar taillights (Figure 105) caused a 1.7% drag penalty (Run 25).

- The rather blunt Simca windshield molding did not appear to cause a drag penalty (Run 56). In any case, subsequent changes to the Phase IV RSV window retention system have smoothed out this area.

- Drag reduction increments from the rear fender skirts, flush rear quarter window, and front wheel fairings were marginally discernable, but did have a cumulative effect (Runs 56-64).

Figure 103 AERODYNAMIC MIRRORS

Figure 104 "FEDERAL" MIRROR SYSTEM

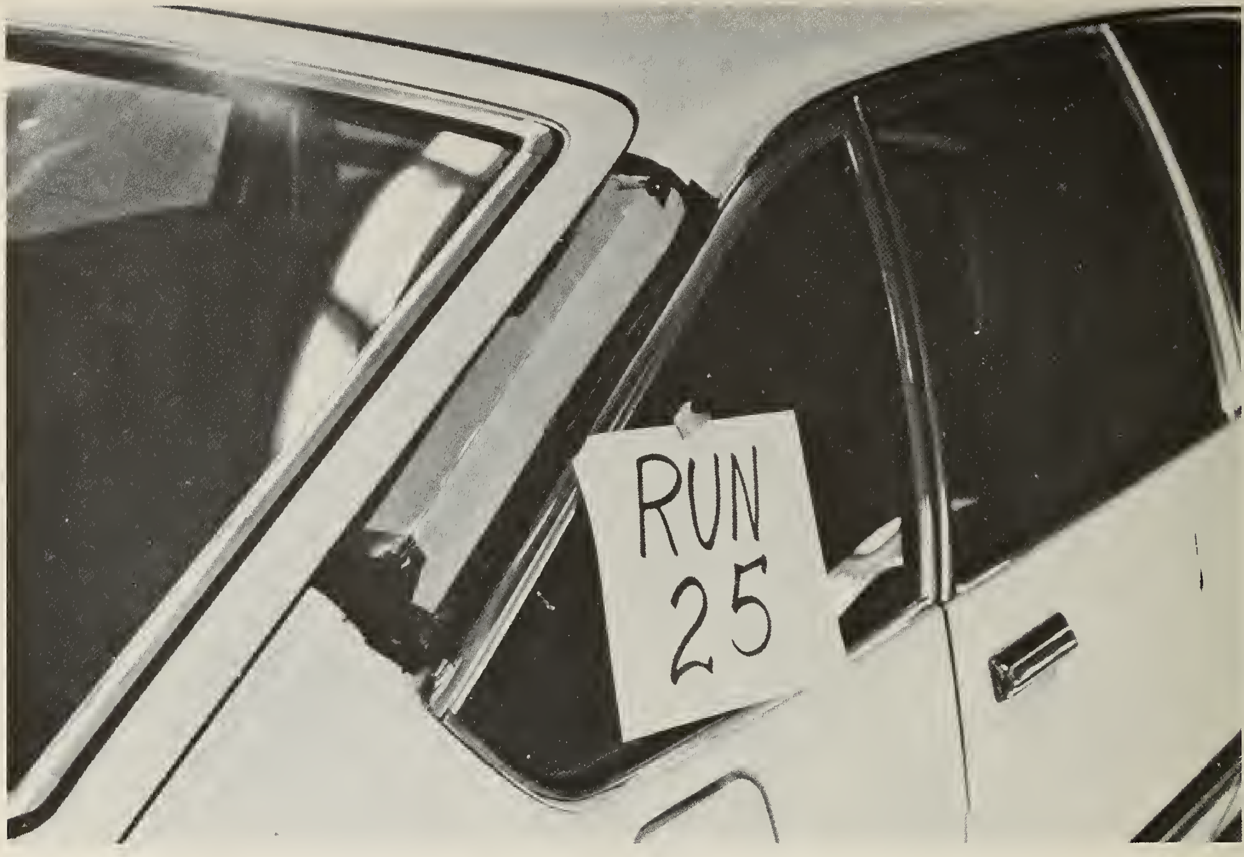


Figure 105 HIGH LEVEL TAILLAMPS

- As discussed in Section 4.3, cooling blockage studies (Figure 106) (Runs 72-74) indicated that further drag reductions could be achieved if the inlet area were tuned to match cooling requirements precisely.

The cumulative drag reductions achieved through the addition of the most effective aerodynamic aids are summarized below.

Conf.		Description	C_D	C_D%
1		Base Car	0.474	0.0
2	(1)	W/45 mm rear spoiler	0.438	7.8
3	(2)	W/headlamp covers	0.421	11.4
4	(3)	W/taped slot wheelcover	0.415	12.6
5	(4)	W/convex wheel fairing	0.413	13.1
6	(5)	W/faired drip molding & rear quarter window	0.412	13.3
7	(6)	W/rear wheel arch skirt	0.411	13.5
8	(7)	W/vertical air dam	0.408	14.1
9	(8)	W/center grille inlets only & aerodynamic mirrors	0.405	15.4

The final RSV styling reflects the more promising and feasible aerodynamic features identified by the wind tunnel tests. A rear spoiler was incorporated, the headlamps lowered into the hood surface and flush headlamp covers fitted, new "soft" aerodynamic wheelcovers were designed to fit flush against the tire sidewall, and the front fender flares and spoiler were recontoured to produce better flow around the sides of the car. In addition, aerodynamic mirrors and a vertical front air dam have been incorporated and the D pillar drip rail eliminated. Based on cooling inlet area efficiency test results, the radiator cooling slots were concentrated in the most effective location. The final RSV front styling was designed to be visually pleasing both with and without upper cooling slots (Figures 107 and 108). Drag coefficients for the final RSV styling are estimated to be 0.42 with all the cooling slots and 0.40 when the upper slots are eliminated.

Figure 106 BLOCKED OUTER COOLING SLOTS

Figure 107 RSV FRONT WITH UPPER COOLING SLOTS

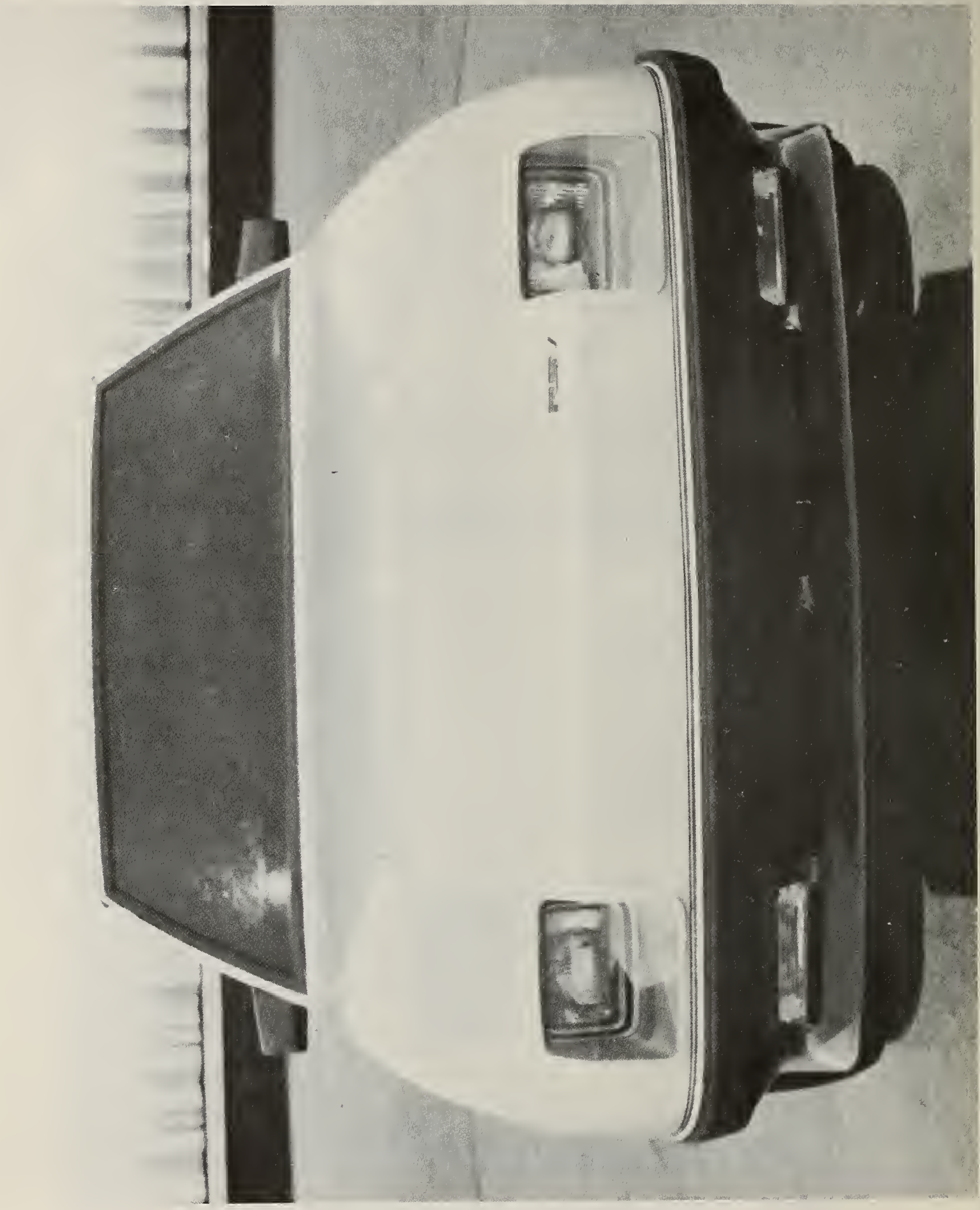


Figure 108 RSV FRONT WITHOUT COOLING SLOTS

Chrysler aerodynamicists feel that a drag coefficient of 0.385 might be achievable on the final RSV if all aerodynamic aids were incorporated and further development time alloted. However, final definition of the Phase IV RSV's aerodynamic characteristics was not part of the original program plan. It is strongly recommended that such testing be conducted and that various components such as wheelcovers, spoilers, mirrors, exterior trim, etc., be installed or removed to redefine their incremental effects. It should be pointed out that the predicted 0.384 C_D level is considered a barrier to further drag reduction by simple means. Flow visualization studies conducted at Ottawa indicate that the remaining problem areas (separated flow) are in the vicinity of the A and D pillars. Any improvement to the flow in these regions would require major re-contouring of the body surfaces.

4.11 Vehicle Performance

In order to insure that the RSV represented an optimum compromise between fuel economy, emissions and vehicle performance, computer simulations were used throughout the program to quantify the trade-offs involved.[3,22,24] The vehicle performance goals established for the RSV were as follows:

(1) Fuel Economy - The fuel economy goal for the Phase III RSV was a composite EPA rating of 12.75 km/l (30 mpg). Composite fuel economy is calculated using the following equation.

$$\text{Composite F.E.} = \frac{1}{\dfrac{0.55}{\text{Urban Cycle F.E.}} + \dfrac{0.45}{\text{Interstate Cycle F.E.}}}$$

(2) Emissions Performance - As discussed in Section 3.1, the goal was to meet the 1978 California standards of .41 HC/9.0 CO/.41 NOx.

The RSV performance goals are summarized below:

Description	RSV
0-5 sec. distance	27.4 m (90 ft.)
48.3 - 104.6 kph (30 - 65 mph) time	24 sec. maximum
80.45 - 120.68 kph (50 - 75 mph) direct gear	22 sec. maximum

Extensive computer simulations were conducted to model the relative effects of aerodynamic drag, tire rolling resistance, emissions control, final drive ratio, inertia weight class and various options including automatic transmission, power steering, and air conditioning. It should be pointed out that recent changes in EPA fuel economy test procedures have affected RSV fuel economy ratings. Specifically, in 1978 the fuel economy calculation was revised to reflect the actual mileage that the test vehicle traverses on the dynamometer rolls rather than the nominal test loop mileage. Fuel economy projections indicated that this would reduce city economy by 0.85 km/l (0.2 mpg) and increase highway economy by 0.04 km/l (0.1 mpg) for a composite penalty of 0.04 km/l (0.1 mpg). Accordingly, some of the fuel economy projections reported in early RSV status reports have been revised. The results of these computer projections are discussed in the following sections.

4.11.1 Aerodynamic and Rolling Resistance Effects

Initial studies on the effects of reducing aerodynamic drag were based on estimated dynamometer horsepower settings and compared to an EPA cookbook setting of 10.3 hp for a 3000 lb. IWC vehicle. Calculated projections of the variations in fuel economy and performance resulting from reduced drag coefficients are outlined below:

Aero Drag C_D	Rolls Dyno HP	Fuel Economy - mpg EPA Estimate City	Highway	Composite	Performance - mph 30-65 Thru Gear	50-70 Direct	Max Speed 5% Grade
--	10.3	22.9	31.9	26.2	13.4	14.6	72.4
.48	7.5	23.8	35.4	27.9	13.4	14.6	72.4
.45	7.0	23.9	36.1	82.2	13.2	14.2	74.0
.42	6.5	24.1	36.9	28.6	13.0	13.8	75.4
.40	6.2	24.1	37.4	28.7	12.9	13.6	76.4

In view of the significant aerodynamic drag reductions achieved through the wind tunnel development program described in Section 4.1, EPA coastdown tests were conducted on the RSV mule car at Chrysler's Chelsea Proving Grounds in order to determine more accurately the potential reduction in rolls dynamometer horsepower setting. Two configurations were selected for testing: The standard Phase III RSV (0.474 C_D) and a low drag 0.405 C_D version which included a vertical front air dam, rear spoiler, flush headlamp covers, flush wheelcovers, two aerodynamic mirrors and blocked upper cooling slots. In addition (as described in Section 4.9), coastdown testing was conducted at both 179 kPa (26 psi) and 241 kPa (35 psi) inflation pressures in order to quantify the effects of reduced tire folling resistance. The test results, when corrected for the latest EPA revisions to the test procedure, are as follows:

Configuration	Tire Pressure	Rolls HP Setting
Standard (C_D = 0.474)	179 kPa (26 psi)	5.7
	241 kPa (35 psi)	5.3
Low Drag (C_D = 0.405)	179 kPa (26 psi)	5.0
	241 kPa (35 pis)	4.5

From these data, it is obvious that significant reductions in the road coastdown load at 80.5 km/hr (50 mph) and corresponding EPA rolls dynamometer horsepower setting can be achieved by incorporating both the improved aerodynamics and the reduced tire rolling resistance. Because these horsepower settings were the lowest ever observed at Chrysler and in order to determine the effect of flatproof tire construction on rolling resistance, a second series of coastdown tests was conducted. Retesting was limited to a slightly degraded low drag configuration (no aerodynamic wheel covers) at 241 kPa (35 psi) tire inflation pressure. Tests of both conventional P185/70R13 and the Goodyear flatproof tires produced the following results:

Configuration	Road Coastdown Force Required @ 80.45 kph (50 mph)	Rolls HP Setting
P185/75R13 @ 241 kPa (35 psi)	372 N (83.6 lbs.)	5.22
Flatproof @ 241 kPa (35 psi)	386 N (86.7 lbs.)	4.96

In general, this testing verified the low horsepower settings previously established. These settings are based on achieving equal time to coastdown from 55 to 45 mph in both road and dynamometer tests. Although the computed road forces imply higher rolling resistance for the flatproof tires than for conventional tires, a lower dynamometer power absorber setting is required with the flatproof configuration. However, overall engine loading is higher with the flatproofs and lower fuel economy would be expected with that configuration. Future fuel economy and emissions tests, for which a dynamometer setting of 5 horsepower is recommended, will provide more data on this characteristic.

Subsequent computer projections show the relationship between dynamometer horsepower setting and resulting EPA fuel economy ratings:

Dynamometer HP	EPA mpg Estimate City	Highway	Combined
10.3	23.1	31.8	26.3
5.6	24.4	38.5	29.2
5.2	24.5	39.2	29.5
4.7	24.8	40.1	30.0
4.2	24.9	41.1	30.3

Note that there is a potential 4 mpg improvement in EPA combined fuel economy if the dynamometer horsepower setting is reduced from 10.3 to 4.2 hp. From these projections, it would be expected that a low drag version of the RSV with flatproof tires inflated to 241 kPa (35 psi) should come very close to meeting the goal of 12.75 km/l (30 mpg) EPA composite fuel economy.

4.11.2 Effect of Emission Control and Final Drive Ratio

The effect of the level of emission control on fuel economy and performance can be seen by comparing 1978 California and 49-State computer projections at a 6.5 hp dynamometer setting:

Emissions Package	Fuel Economy - mpg EPA Estimate City	Highway	Composite	Performance - mph 30-65 Thru Gear	50-70 Direct	Max Speed 5% Grade
49-State, 3.48 Axle	26.6	40.5	31.5	12.7	14.6	74.1
Calif., 3.70 Axle	24.1	37.1	28.6	13.0	13.8	75.4
Calif., 3.48 Axle	24.7	38.3	29.4	13.5	15.2	71.9

The reasons for the improved fuel economy and performance of the 49-State version are two-fold. First, the improved brake specific fuel consumption of the 49-State engine results in approximately a 7% increase in composite fuel economy. Second, the higher specific output of the 49-State engine allows the use of a lower numerical (3.48) axle ratio without sacrificing performance.

It is apparent that, if the RSV were equipped with a 3.48 axle, nearly a 3% improvement in composite fuel economy could be realized. This improvement, however, would be achieved at the expense of a 4 to 10% reduction in acceleration capability which would no longer enable the RSV to meet established performance goals.

4.11.3 Inertia Weight Effects

Probably the most obvious way of improving the fuel economy/emissions/performance trade-off is through reduced vehicle weight. Initially, it was desired to quantify the fuel economy and performance improvements that might be expected by lowering the RSV to the 2750 lbs. IWC. Based on an assumed 6.5 hp dynamometer setting, the projections were as follows:

	Fuel Economy - mpg			Performance - mph		
	EPA Estimate			30-65	50-70	Max Speed
Configuration	City	Highway	Composite	Thru Gear	Direct	5% Grade
3000 IWC, 3.70 Axle	24.1	37.1	28.6	13.0	13.8	75.4
2750 IWC, 3.70 Axle	24.6	38.4	29.4	11.9	12.4	78.3
2750 IWC, 2.48 Axle	25.3	39.7	30.2	12.3	13.6	76.6

As expected, both fuel economy and performance would be improved significantly by the lower inertia weight. In addition to the 3% improvement in composite fuel economy, another 3% improvement could be gained by using a 3.48 axle and sacrificing the potential 4 to 10% improvement in performance. Unfortunately, a weight reduction task of this magnitude was beyond the scope of the RSV program during Phase III.

Midway into Phase III of the RSV program, the EPA decided that, starting in 1980, the inertia weight classes would be redefined by switching to 125 lbs. test weight increments. The net result is that the RSV, when equipped with all accessories, will no longer fall in the 3000 lb. IWC. When air conditioning in conjunction with an automatic transmission is specified, the RSV will be considered a 3125 lb. test weight vehicle. Computer projections indicate that the penalty associated with the change from the 3000 IWC to 3125 IWC is .3 mpg city, .4 mpg highway, and .3 mpg combined.

4.11.4 Vehicle Options

The options specified on the RSV can also have a significant effect on fuel economy and performance. Computer simulations were used to identify the penalties associated with each of the power steering, air conditioning and automatic transmission options. The results, given below, were based on an assumed 6.5 hp dynamometer setting:

	Fuel Economy - mpg			Performance - mph		
	EPA Estimate			30-65	50-70	Max Speed
Configuration	City	Highway	Composite	Thru Gear	Direct	5% Grade
Base Car	24.1	37.1	28.6	13.0	13.8	75.4
With P/S	23.0	35.4	27.3	13.8	14.6	73.3
With A/C	23.8	36.2	28.1	13.4	14.2	74.6
With Automatic	23.1	33.5	26.9	17.0	15.0	72.7
P/S, A/C, Auto	22.1	31.3	25.5	18.4	16.4	68.9

When power steering, air conditioning and automatic transmission are all added to the base RSV, a loss of 3 mpg in EPA composite fuel economy and significant deterioration in vehicle performance results. Thus, a fully optioned RSV will not meet the 30 mpg goal. Furthermore, the automatic transmission option reduced the 50-70 mph direct gear passing performance so that it is no longer within Chrysler's acceptance range. Finally, when all options are specified, such a vehicle could not maintain 70 mph on a 5% grade.

4.11.5 Final Fuel Economy

As a result of the trade-offs identified in the preceding analyses, the final RSV driveline was specified as follows:

- 1716 cc engine w/California Emission Package
- four speed manual transmission
- 3.70 axle ratio

In order to justify some of the fuel economy projections, a 1978 Omni with manual transmission was ballasted to RSV weight and EPA cycle tested. Tests were conducted at odometer readings of both 400 and 900 miles, with the following results:

Odometer Miles	EPA Fuel Economy		
	City	Highway	Composite
400	23.48	36.66	28.01
900	22.46	38.34	27.61

While the goal of 30 mpg was not achieved, it was apparent that the RSV fuel economy should exceed the Federally mandated 1985 standard of 27.5 miles per gallon.

5.0 SPECIFICATIONS, DIMENSIONS AND WEIGHT

These data were reported as they developed in References 1, 2, 3 and finally in 22 and 23.

5.1 RSV Specifications

Body Style

- Five passenger, four door, hatchback sedan with fold-down rear seat and luggage compartment (58% F, 42% R weight distribution)
- EPA interior space - 2.69 m^3 (95 cu. ft.)
- EPA cargo space - .54 m^3 (19 cu. ft.) with rear seat up
- Curb weight - 1213 kg (2675 lbs.)

Engine

- Transverse mounted Chrysler Omni/Horizon 1716 cc overhead camshaft adapted for 1978 California emissions
- Clutch - 190 mm (7.48 inches) in diameter cable actuated
- Transmission - Manual - A412 transxle

  Ratios - 3.45, 1.94, 1.29, 0.97 Fwd; 3.17:1 Reverse

  Final Drive Ratio - 3.70:1

  Automatic -

  Ratios - 2.47, 1.47, 1.0 Fwd. 2.1:1 Reverse

  Final Drive Ratio - 3.74:1

Front Wheel Drive

- Rack and pinion steering
- Inner CV joint - Chrysler Omni/Horizon
- Outer CV joint - from Simca 1308

Brakes

- Vacuum assisted hydraulic disc/drum with diagonal split

Suspension

- Front: unequal length upper and lower control arms with torsion bar spring and swaybar

- Rear: trailing link, coil spring with swaybar

- Tread: 1.415 m (55.71 inches) front; 1.390 m (54.72 inches) rear

Tires

- 185/70-13 Goodyear Flatproof

Wheelbase - 2.685 m (105.7 inches)

- Overall length - 4.516 m (177.8 inches)
  height - 1.35 m (53.1 inches)
  width - 1.7 m (67 inches)

- Turning circle - 11.58 m (38 feet)

5.2 Dimensions

The dimensions and capacities of the RSV were largely determined by the characteristics of the base vehicle. As indicated in the discussion of styling, a major effort was made to carry over a maximum number of base vehicle body components to the RSV. Thus, the RSV has the same general dimensional properties as the base car. Certain changes were made to attain the RSV objectives. These include wheelbase extension and a change in vehicle attitude to bring the RSV more in line with typical domestic practice. As previously noted in Sections 2 and 3, the base vehicle was stretched 80 mm (3.15 inches) between the front wheels and the dash to provide additional space for installation of the Omni engine and frontal impact protection.[3,20,22] The wheelbase increase combined with the newly designed soft front and rear bumpers and the protective rub strip gave the RSV a total length increase of 282 mm (11.1 inches) over the base car.

The improved occupant protection system had an important influence on the interior dimensions of the RSV. Most notably, as indicated in Section 3.7.3, the addition of the energy absorbing door trim panels without widening the car reduced the interior width of the RSV by about five inches. On the other hand, adoption of the flatproof tire concept allowed the RSV luggage capacity to be increased over that of the base vehicle.

The RSV dimensional properties are summarized in Table 2 which shows design values and actual measurements of Car No. 4.

5.3 Weight

Through Phases II and III of the RSV program, a detailed and complete weight analysis of every component of the vehicle has beem maintained. Each time a component was designed, added, modified, or eliminated, the effect of the weight change was incorporated into the weight of the vehicle. Additionally, each part of the Phase IV vehicles was weighed and directly compared to the estimated weights as the cars were being built. The following pages illustrate the weight trends thoughout Phase II and III and indicate precisely which components represent added weight and which represent reduced weight.

Table 2
RSV DIMENSIONS

	RSV PHASE III DESIGN		CAR NO. 4 MEASURED	
	MM	INCH	MM	INCH
EXTERIOR				
OVERALL LENGTH	4517	(177.83)	4521	178
OVERALL HEIGHT (3-PASS.)	1349	(53.11)	1346	53
OVERALL WIDTH	1702	(67.01)	1702	67
WHEELBASE	2684	(105.67)	2692	106
FRONT OVERHANG	895	(35.24)	895	35-1/4
REAR OVERHANG	938	(36.93)	940	37
TRACK - FRONT	1415	(55.71)	1416	55-3/4
TRACK - REAR	1390	(54.72)	1391	54-3/4
ENGINE DISPLACEMENT	1716 cc	(105)	1716cc	105 cu in
LUGGAGE CAPACITY	14.92 ft^3	.42	.54	19 cu ft
CURB WEIGHT	1200 Kg	(2646 #)	1213 Kg	2675 #
FUEL TANK CAPACITY	41.6 ℓ	11 gal	39.7 ℓ	10.5 gal
INTERIOR				
HIP ROOM - FRONT	1249	(49.17)	1245	49
HIP ROOM - REAR	1355	(53.35)	1295	51
SHOULDER ROOM - FRONT	1268	(49.92)	1237	48.7
SHOULDER ROOM - REAR	1352	(53.23)	1290	50.8
LEG ROOM - FRONT	1023	(40.20)	1038	40.85
LEG ROOM - REAR	915	(36.02)	860	33.85
EFFECTIVE HEAD ROOM - FRONT	947	(37.28)	953	37.5
EFFECTIVE HEAD ROOM - REAR	935	(36.81)	917	36.1
SEAT BACK ANGLE - FRONT	26^o			26^o
SEAT BACK ANGLE - REAR	29^o			27^o
WINDSHIELD ANGLE	55^o			55^o
SIDE GLASS RADIUS	1270	(50.00)	1270	50
ROOF RAIL TO GROUND (3-PASS.)	1231	(48.46)	1265	49.8
FRONT HEEL POINT TO GRD (3-PASS.)	250	(9.84)	295	11.6
FRONT H-PT. TO HEEL-VERT (3-PASS.)	239	(9.41)	213	8.4
FRONT H-PT. TO GROUND (3-PASS.)	489	(19.25)	508	20
FRONT WHEEL TO HEEL-HORIZ.	666	(26.22)	566	22.3
FRONT H-PT. TO HEEL-HORIZ.	801	(31.54)	839	33.05
COUPLE	772	(30.39)	781	30.75
REAR HEEL TO GROUND (3-PASS.)	209	(8.23)	249	9.8
REAR H-PT. TO HEEL-VERT. (3-PASS.)	277	(10.91)	271	10.65
REAR H-PT. TO GROUND (3-PASS.)	486	(19.13)	519	20.45
REAR H-PT. TO RR. WHEEL-HORIZ.	492	(19.37)	508	20.
FRONT H-PT. TO ROOF RAIL	747	(29.41)	749	29-1/2
FRONT H-PT. TO BELT	378	(14.88)	411	16.2

RESEARCH SAFETY VEHICLE
CRASHWORTHINESS WEIGHT STATUS
PHASE III

	KG		LBS	
Base Car (C-6) Changes		1051		2317
Increase Coolant	+ 1.261		+ 2.78	
C-6 Door Trim Panels	- 8.500		-18.74	
Jack	- 3.991		- 8.80	
Spare Tire	-14.921		-32.90	
Lift Gate (aluminum)	- 5.215		-11.50	
Reduce Fuel Capacity	- 9.206	(-7.846)	-20.30	(-17.30)
Flatproof Tires	+15.601		+34.40	
Console	+ 1.360		+ 3.00	
New Fuel Lines	+ 0.766		+ 1.69	
Add 64 mm to Front Structure	+ 2.916		+ 6.43	
VW Transmission	+ 5.442		+12.00	
Larger Radiator	+ 1.388		+ 3.06	
New Clutch Linkage	- 0.650		- 1.43	
Hood (aluminum)	- 9.614		-21.20	
Upper Level Lighting	- 0.231		- 0.51	
Headlamp Covers	+ 0.531		+ 1.17	
Wheel Covers	+ 0.735		+ 1.62	
Dual Outside Mirrors	+ 0.943		+ 2.08	
Quarter Windows (plastic)	- 2.340		- 5.16	
	1027.071		2264.69	

Front Structure		
Add 80 mm to wheelbase	+ 3.628	+ 8.00
Loading member sill to tire (longitudinal)	+ 0.322	+ 0.71
Fender reinforcement (upper load path)	+ 2.672	+ 5.89
Soft nose	+14.059	+31.00

Front Structure (Cont'd)

Fender skirts for soft nose	+ 1.026		+ 2.26	
Upper and lower yoke crossmembers	+ 4.493		+10.90	
Hood restraint system	+ 2.993		+ 6.60	
Front floor pan reinforcement	+ 3.719		+ 8.20	
Front rail gage increase	+ 8.719		+19.21	
Front floor pan reinforcement	+ 3.351		+ 7.39	
Front floor pan (1 mm)	+ 2.454		+ 5.41	
Grille	- 0.800		- 1.75	
Torsion bars	+ 0.971		+ 2.14	
Upper control arm crossmember	- 2.776		- 6.10	
Front suspension crossmember	+ 1.551		+ 3.42	
Add front floor pan reinforcement-sill to rail	+ 7.256		+16.00	
Front bumper	- 9.342		-20.60	
Sill reinforcement	+ 3.039		+ 6.70	
Side sill inner		(2.721)		(+6.00)
Windshield side frame inner	+ 1.360		+ 3.00	
Beam - yoke vertical	+ 1.143		+ 2.52	
Yoke gussets	+ 0.617		+ 1.36	
Extension - fender flange front	+ 1.180		+ 2.60	
Support - bumper front	+ 0.467		+ 1.05	
Radiator - Upper mounting bracket	+ 0.045		+ 0.10	
Add gusset - floor pan to sill inner	+ 1.905		+ 4.20	
Add closure panel front rail	+ 0.544		+ 1.20	
Add headlamp mounting brakets	+ 0.639		+ 1.41	
Increase size of cowl side inner	+ 0.204		+ 0.45	
Redesign engine mounts	+ 2.811		+ 6.20	
Add cap-longitudinal ext front	+ 0.612		+ 1.35	
Add reinf-ext longitudinal	+ 5.197		+11.46	
Add panel-front floor pan catch		(+0.653)		(+1.44)
Add slot to front floor and rail	- 0.272		- 0.60	
Add reinf-dash pnl to front floor pan	+ 0.535		+ 1.18	
TOTAL	64.784		142.85	

Side Structure

Side Exclusively

	KG	LBS
Gussets - sill to floor	+ 1.995	+ 4.40
Exterior rub strip	+ 2.721	+ 6.00
Center pillar outer reinforcement	+ 6.122	+13.50
Center pillar inner reinforcement	+ 5.555	+12.25
Add front seat crossmember reinforcement	+ 2.182	+ 4.81
C Pillar reinforcement	+ 1.995	+ 4.40
Add front seat crossmember reinforcement upper	+ 1.088	+ 2.40
Remove center portion of center floor pan crossmember	- 0.816	- 1.80
TOTAL	20.843	45.96

Front/Side

	KG	LBS
A Pillar lower doubler	+ 3.002	+ 6.62
Reinforcement - body lock pillar to wheelhouse	+ 1.633	+ 3.60
Front door beam	+13.283	+29.29
Front door interlock	+ 1.873	+ 4.13
Front door impact beam support front	+ 3.202	+ 7.05
Front door impact beam support rear	+ 0.873	+ 1.92
Front door impact beam reinforcement rear	+ 1.814	+ 4.00
Front door outer panel reinforcement	- 1.211	- 2.57
Rear door lock pillar reinforcement	+ 2.279	+ 5.02
Rear door impact beam support front	+ 2.943	+ 6.49
Rear door impact beam	+12.508	+27.68
Rear door hinge pillar reinforcement	+ 2.118	+ 4.67
Rear door interlock	+ 1.674	+ 3.69
Rear door outer panel reinforcement	- 1.211	- 2.57
Increase gage of front door hinge pillar 1.2 to 1.8	+ 1.696	+ 3.74
Larger front door hinges	+ 1.166	+ 2.57

Front/Side (Cont'd)

Larger rear door hinges		+ 1.165	+ 2.57
Shorten front door frame		- 0.068	- 0.15
Shorten rear door frame		- 0.068	- 0.15
	TOTAL	48.803	107.61

Side/Rollover

Roll bar and roll bar impact panel		+ 4.209	+ 9.28
Roof bow		- 0.635	- 1.40
	TOTAL	3.574	7.88

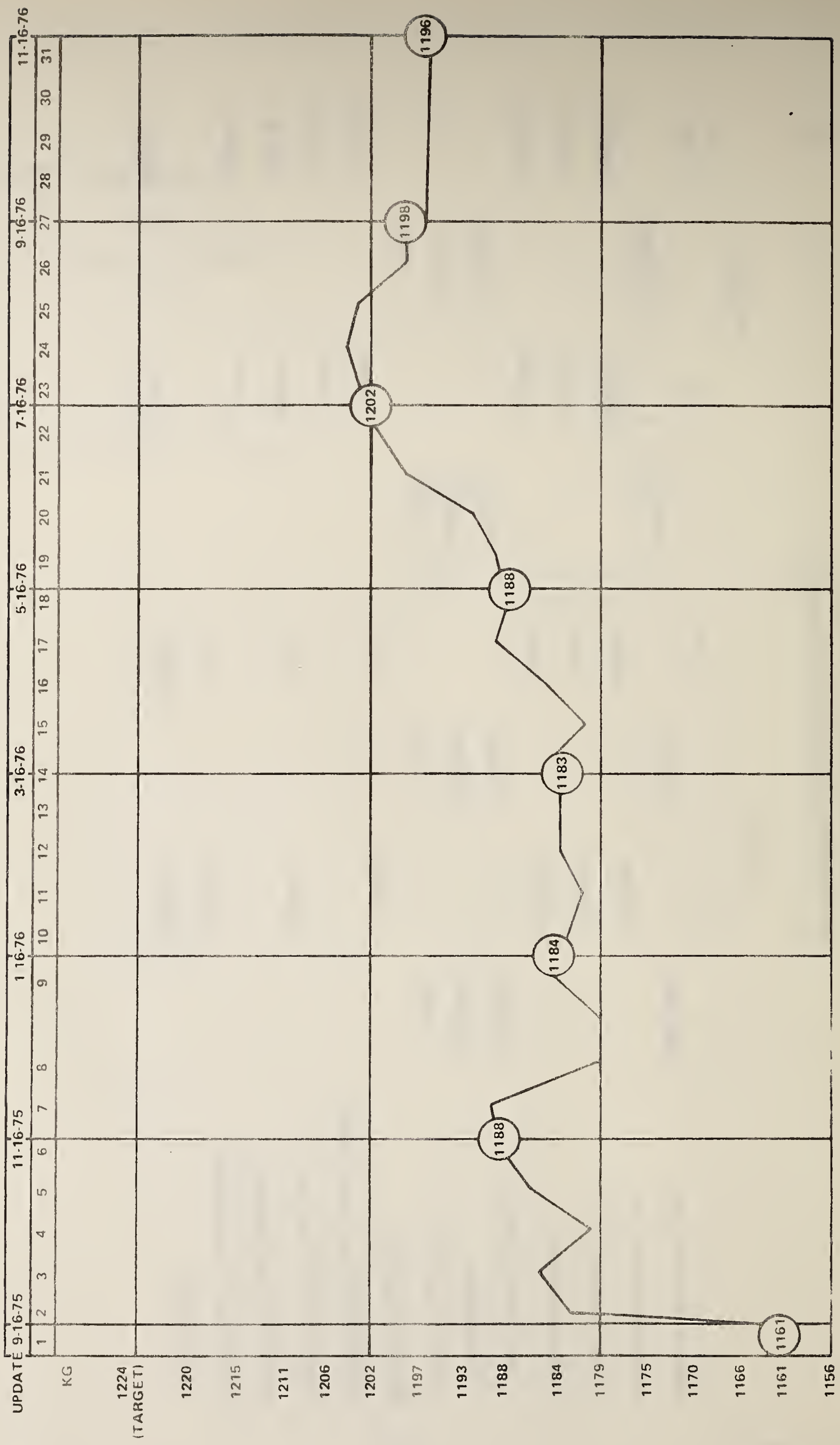
	KG	LBS
Rear Structure		
Soft rear panel	+ 6.989	+15.41
Add gusset - lower deck panel to rear floor pan	+ 5.80	+ 1.28
Remove rear bumper	- 9.535	-21.02
Add RR rail reinforcement	+ 0.317	+ 0.70
Add reinforcement - rear crossmember	+ 3.959	+ 8.73
Add bulkhead - rear crossmember	+ 0.871	+ 1.92
Add gusset - rear side rail to rear crossmember	+ 0.417	+ 0.92
TOTAL	3.598	7.94
Occupant Protection		
Folding rear seat hardware reinforcement	+ 2.268	+ 5.00
Energy absorbing honeycomb door panels	+ 1.043	+ 2.30
Front door trim panels	+ 2.931	+ 6.44
Rear door trim panels	+ 1.950	+ 4.30
Front seat reinforcements	+ 9.017	+19.88
Rear seat reinforcements	+ 3.265	+ 7.20
Larger seat adjusters	+ 1.388	+ 3.05
Occupant restraint system	+14.594	+31.18
Add knee blocker to trim panel	+ 1.909	+ 4.21
Add belt retractor mounting bracket	+ 1.266	+ 2.77
TOTAL	39.610	87.30
Environmental Protection		
Emissions equipment	+ 9.614	+21.20
TOTAL	9.614	21.20

Steering and Suspension	KG	LBS
Redesign lower control arm	- 2.127	- 4.69
Increase torsion bar diameter	+ 0.871	+ 1.92
Redesign exhaust system	- 2.298	- 5.07
Addition of brake line and proportioning valve	+ 2.055	+ 4.62
Redesign front swaybar	- 1.719	- 3.79
Redesign intermediate shaft	+ 0.154	+ 0.34
Steering Gear mounting brackets	- 1.714	- 3.78
TOTAL	- 4.739	-10.45
TOTAL CAR	1213.161 (1213.973)	2675.02 (2676.59)

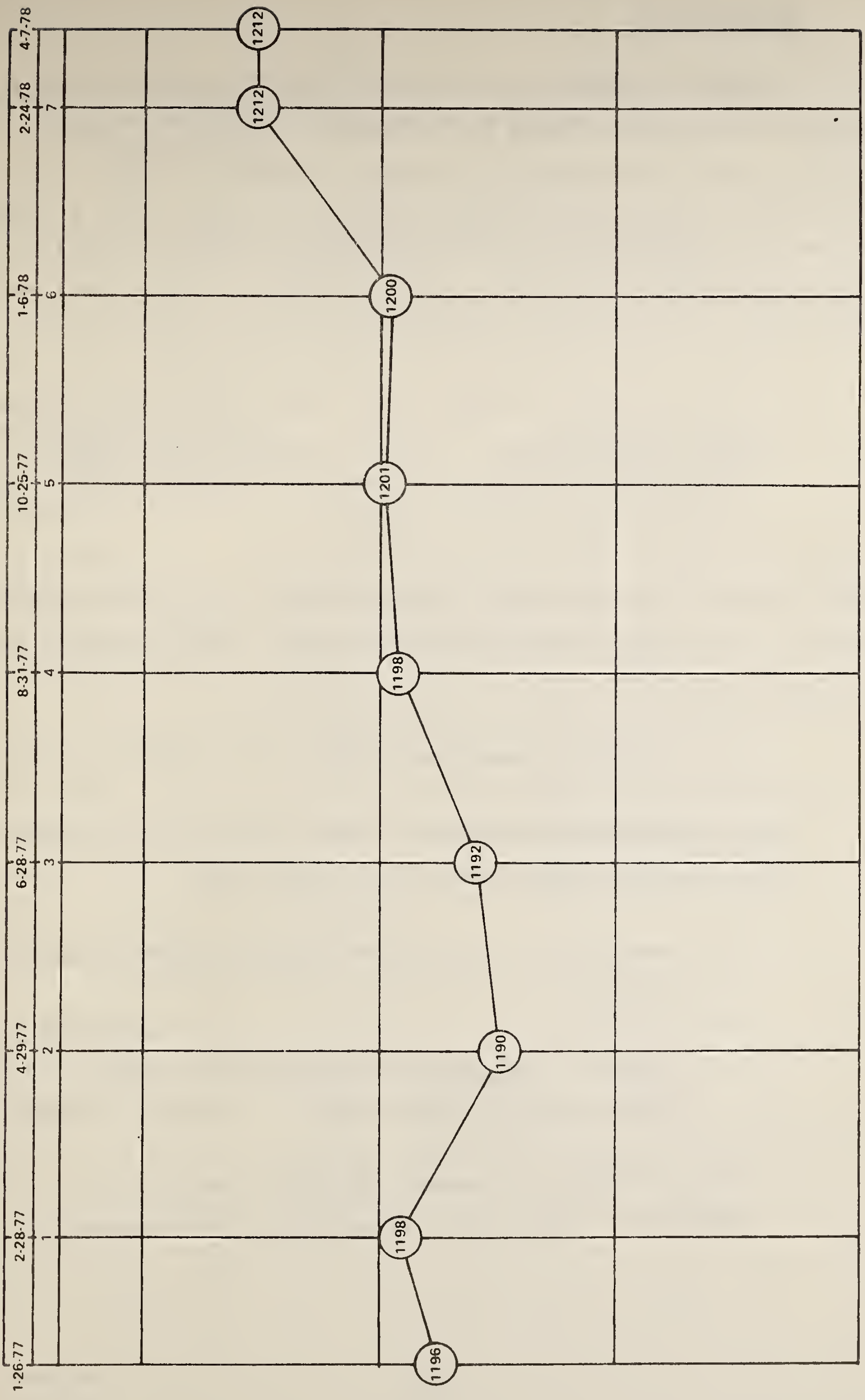
RESEARCH SAFETY VEHICLE
CRASHWORTHINESS WEIGHT STATUS

	PHASE II				PHASE III			
		KG		LBS		KG		LBS
BASE CAR (SIMCA C-6)	(1050.794)		(2317.00)		(1050.794)		(2317.00)	
ADJUSTED BASE CAR		1027.659		2265.53		1026.844		2264.19
FRONT STRUCTURE		59.502		132.62		64.784		142.85
SIDE STRUCTURE		75.953		168.67		73.220		161.45
SIDE EXCLUSIVELY	(23.876)		(53.65)		(20.843)		(45.96)	
FRONT/SIDE	(48.585)		(107.32)		(48.803)		(107.61)	
SIDE ROLLOVER	(3.492)		(7.70)		(3.574)		(7.88)	
REAR STRUCTURE		3.350		7.07		3.598		7.94
ENVIRONMENTAL PROTECTION						9.614		21.20
OCCUPANT PROTECTION		33.991		74.95		39.610		87.34
STEERING & SUSPENSION						−4.739		−10.45
PRODUCIBILITY & SHIPPING		1.969		4.34				
TOTAL CAR		1202.424		2653.18		1210.739		2675.02

RSV PHASE II
WEIGHT TREND



RSV PHASE III
WEIGHT TREND



6.0 COST ANALYSIS

A complete consumer cost analysis has been prepared for the Research Safety Vehicle to provide a basis for evaluating the financial effects on society of a vehicle possessing the innovative features of an RSV. The Chrysler Cost Analysis Department was provided with copies of all pertinent RSV engineering drawings which were then utilized to perform a detailed cost analysis on each revised component. The ground rules for this study were as follows:

(1) The base car is assumed to be a Simca 1308 vehicle adjusted in design to meet all currently applicable U.S. Federal regulations. Federalized examples of assumed product changes in this context are as follows:

- The Simca rigid fiberglass bumper system was revised to plated, high strength steel with hydraulic energy absorber units.
- Side impact beams were added to the doors.
- A laminated windshield bonded into the body replaced the Simca tempered glass with rubber seal.
- Simca exterior lighting was adjusted to meet existing U.S. standards.
- Powerplant and chassis were adjusted to meet all emissions, braking, and other applicable U.S. Federal standards.

(2) Tools, facilities, research and development, pre-production and program launch costs are updated to 1979 economics.

(3) The vehicle would be produced in a single U.S. assembly plant, using conventional sourcing of components, at an annual volume of 300,000 units.

(4) Retail prices have been adjusted to 1979 levels.

The following is a detailed breakdown of the estimated suggested retail price with a brief description of the reason for each change in cost:

		Suggested Retail Price Vs. Federalized C-6	Description of Changes
Ia	Body-in-White		
	Front Underbody	$+ 38.00	Gage increased; reinforcement added
	Rear Underbody	+ 17.00	Gage increased; reinforcement added
	Front Structure & Dash	+ 16.00	Upper load path added; gage increased
	Body Side Structure	+ 50.00	Reinforcements at pillars and sills
	Roof	+ 10.00	Roll bar added; restraint reinforcement added
	Windshield Opening	0.00	No change
	Quarter Panel	+ 10.00	Reinforcements & panel extensions added
	Front Door	+ 28.00	Larger beams; interlocks added
	Rear Door	+ 25.00	Larger beams; interlocks added
	Liftgate	+ 9.00	
	TOTAL	$+203.00	
Ib	Front Sheet Metal		
	Hood	$+ 7.00	Aluminum
	Hood Latch	+ 15.00	Cable-actuated dual side latches added
	Fender	+ 1.00	Two inches longer
	TOTAL	$+ 23.00	

	Suggested Retail Price Vs. Federalized C-6	Description of Change
Ic Glass		
Windshield	$+ 28.00	Four layer laminated glass
Backlight	0.00	No change
Front Door Glass	0.00	No change
Rear Door Glass	0.00	No change
TOTAL	$+ 28.00	
Id Paints, Sealers, Deadeners		
	$ 0.00	No change
TOTAL	$ 0.00	
II Bumpers		
Soft Bumper System		
- Front	$+ 66.62	Approximate cost vs. Federalized C-6
- Rear Upper	+ 10.10	Added to liftgate
- Rear Lower	+ 30.28	Approximate cost vs. Federalized C-6
TOTAL	$+107.00	
III Grille and Lights		
Grille Assembly	$- 3.00	Deleted
Headlamps		
- Bulb	+ 8.50	Single beam replaces conventional
- Bezel & Cover	+ 5.00	Cover added
High Level Rear Lights and Wiring	+ 20.50	Added; includes side marker
TOTAL	$+ 31.00	
IV Exterior Ornamentation		
Rub Strip Molding	$+ 23.72	Added
Wheel Covers	+ 30.28	Aerodynamic design - replaces hub caps
TOTAL	$+ 54.00	

	Suggested Retail Price Vs. Federalized C-6	Description of Change
V Instrument Panel		
Panel & Instrumentation	$ 0.00	No change
Knee Blocker	+ 37.00	Added
Low Tire Pressure Warning	+ 9.00	Added (see also Group VII)
Steering Wheel	+ 14.00	Change to modified Volvo wheel
TOTAL	$+ 60.00	
VI Interior Trim		
Front Seat	$+ 16.64	Structural reinforcements added - recliner eliminated
Rear Seat	+ 11.59	Cushion and back reinforcements added
Door Trim Panels	+ 38.82	Vacuum molded with foam vs. conventional
Side E.A. Panels	+ 32.26	Aluminum honeycomb added
Head Rests	+ 2.02	See thru - added structure
Seat Belts	+473.87	Includes inflatabelt and passive motor drive mechanism
Pillar Pads and Retractor Covers	+ 36.80	Padded, vacuum formed ABS
TOTAL	$+612.00	

	Suggested Retail Price Vs. Federalized C-6	Description of Change
VII Chassis and Electrical		
Engine Mounts	$+ 7.09	Forth engine mount and bracket added
Flatproof Tires	+ 81.06	Spare tire eliminated
Low Pressure Warning	+ 34.45	Added special sensors (see Group V)
Spare Tire Hanger	- 12.67	Eliminated
Jack Assembly	- 10.64	Eliminated - includes jack mounting structure
Front Suspension Revisions	+ 3.55	Longer torsion bars - increased gage of lower control arm
Steering System Revisions	+ 5.07	Revise column angle - relocate rack - modify knuckle
Fuel Tank	- 1.01	Smaller - 10 gallons vs. 13 gallons
Miscellaneous Chassis and Electrical	+ 8.10	Includes exhaust, tailpipe, etc.
TOTAL	$+115.00	
Provision for unidentified items and product changes	$+ 41.00	
TOTAL VEHICLE	$+1274.00	

This amount represents the total increased cost to the consumer of a vehicle exhibiting the features of a Research Safety Vehicle based on 1979 economics.

Engineering program, tooling, facilities, pre-production and launch cost estimates are listed below. Since these elements involve significant short term corporate expenditures, they are of particular importance:

- Engineering, research and development - $11.4 million
- Pre-production and launch - $ 4.8 million
- Tooling - $26.6 million
- Facilities - $10.7 million

7.0 REFERENCES

1. P.M. Miller, S.M. Pugliese, M.O. Ryder, Jr., F.A. DuWaldt and S.W. Chesley, "Research Safety Vehicle Program (Phase I) - Volume I - RSV Introduction and Executive Summary," Calspan Report No. ZN-5450-V-11, April 1975. HS-801607, PB 246765.

   P.M. Miller, S.M. Pugliese, M.O. Ryder, Jr., F.A. DuWaldt and S.W. Chesley, "Research Safety Vehicle Program (Phase I) - Volume II - RSV Program Definition and Foundation; Accident Data, Automobile Usage, Natural Resources, Related Safety Costs," Calspan Report No. ZN-5450-V-12, April 1975. HS -801608, PB 246766.

   P.M. Miller, S.M. Pugliese, M.O. Ryder, Jr., F.A. DuWaldt and S.W. Chesley, "Research Safety Vehicle Program (Phase I) - Volume III - RSV Characterization and Performance Specification," Calspan Report No. ZN-5450-V-13, April 1975. HS-801609, PB 246767.

   P.M. Miller, S.M. Pugliese, M.O. Ryder, Jr., F.A. DuWaldt and S.W. Chesely, "Research Safety Vehicle Program (Phase I) - Volume IV - RSV Conceptual Definition; Final Phase I Bi-Monthly Report," Calspan Report No. ZN-5450-V-14, April 1975. HS-801610, PB 246768.

2. Research Safety Vehicle (RSV), Preliminary Design Review, Data Package, Contract No. DOT-HS-5-01214, March 1976.

3. P.M. Miller and J.E. Greene, Editors, "Design, Development and Testing of Calspan/Chrysler RSV - Phase II," Calspan Report No. ZM-5793-V-1, November 1976. HS-802250, PB 265247/7WT.

   Saverio M. Pugliese, "Research Safety Vehicle - Phase II - Specifications Review," Calspan Report No. ZM-5793-V-2, November 1976. HS-802251.

   Roy F. Macuga (Chrysler Corporation) and Frank A. DuWaldt (Calspan Corporation), "Research Safety Vehicle - Phase II - Producibility Studies," Calspan Report No. ZM-5793-V-3, November 1976. HS-802252, PB 265248/5WT.

4. B.R. Donnelly, D.E. Massing, "Research Safety Vehicle (RSV) Phase III. Static Crush Test Report," Calspan Report No. ZN-6069-V-8, February 1978.

5. S.M. Pugliese, D.J. Romeo and A.R. Johnson, "Phase III Development of the Calspan RSV Air Belt Restraint System," Calspan Report No. ZN-6069-V-18, May 1978.

6. S.M. Pugliese, "Development and Evaluation of a Driver Air Bag System for the Calspan Research Safety Vehicle," Calspan Report No. ZM-5793-V-4, April 1979.

7. R.A. Galganski, "Research Safety Vehicle (RSV) Phase III. Crash Test Report. Test No. 1 - 5-8 mph Frontal Flat Barrier Impacts; Test No. 2 - 6-8 mph Front-to-Rear Colinear Impacts; Test No. 2M - 6-13 mph Front-to-Rear Colinear Impact; Test No. 4 - Modified FMVSS 215 Pendulum Impacts," Calspan Report No. ZN-6069-V-9, June 1978.

8. R.A. Galganski, D.E. Massing, "Research Safety Vehicle (RSV) Phase III. Crash Test Report. Test No. 3 - 46 mph Barrier Frontal Impact," Calspan Report No. ZN-6069-V-10, March 1978.

9. R.A. Galganski and D.E. Massing, "Research Safety Vehicle (RSV) Phase III. Crash Test Report. Test No. 5 - 40 mph Moving Barrier Rear Impact," Calspan Report No. ZN-6069-V-11, March 1978.

10. R.A. Galganski, "Research Safety Vehicle (RSV) Phase III. Crash Test Report. Test No. 6 - 90° Front-to-Side Impact of Stationary RSV by RSV at 39 mph," Calspan Report No. ZN-6069-V-12, July 1978.

11. R.A. Galganski, "Research Safety Vehicle (RSV) Phase III. Crash Test Report. Test No. 11 - Low Speed RSV Impacts into Stationary Plymouth Fury," Calspan Report No. ZN-6069-V-13, June 1978.

12. R.A. Galganski, "Research Safety Vehicle (RSV) Phase III. Crash Test Report. Test No. 8M - 60° Front-to-Side Impact of Stationary RSV by Plymouth Fury at 32 mph," Calspan Report No. ZN-6069-V-14, July 1978.

13. R.A. Galganski, B.R. Donnelly, S.M. Pugliese, "Research Safety Vehicle (RSV) Phase III. Crash Test No. 9 - 44 mph Flat Barrier Frontal Impact," Calspan Report No. ZN-6069-V-15, May 1978.

14. R.A. Galganski, "Research Safety Vehicle (RSV) Phase III. Crash Test Report. Test No. 10 - 43 mph Front Flat Barrier Impact," Calspan Report No. ZN-6069-V-16, August 1978.

15. R.A. Galganski, "Research Safety Vehicle (RSV) Phase III. Crash Test Report. Test No. 12 - Colinear Rear Impact by Moving Barrier at 40 mph," Calspan Report No. ZN-6069-V-21, August 1978.

16. R.A. Galganski, "Research Safety Vehicle (RSV) Phase III. Crash Test Report. Test No. 13," Calspan Report No. ZN-6069-V-28, May 1979.

17. Roy S. Rice, Calspan/Chrysler Research Safety Vehicle Phase III - Chassis Development Car Handling Tests," Calspan Report No. ZN-6069-V-19, April 1978.

18 Roy S. Rice, "Research Safety Vehicle (RSV) Phase IV - Handling Tests," Calspan Report No. ZN-6069-V-29, May 1979.

19. R.A. Galganski, "Research Safety Vehicle (RSV) Phase III FMVSS Compliance Evaluation," Calspan Report No. ZN-6069-V-31, July 1979.

20. G.J. Fabian, S.M. Pugliese and A.J. Szilagyi (Chrysler Corporation), "Development of the Calspan/Chrysler Research Safety Vehicle (RSV)," presented at the Society of Automotive Engineers, Inc. Passenger Car Meeting in Troy, Michigan, June 5-9, 1978 (Paper No. 780602).

21 G.J. Fabian, "Occupant Protection in a Research Safety Vehicle," Paper No. 790325 presented at the Society of Automotive Engineers, Inc. Congress and Exposition in Detroit, Michigan, February 26 - March 2, 1979.

22. G.J. Fabian and G.E. Frig (Chrysler Corporation), "The Calspan/Chrysler Research Safety Vehicle (RSV)," paper presented at the Seventh International Technical Conference on Experimental Safety Vehicles in Paris, France, June 1979.

23. G.J. Fabian, "Research Safety Vehicle (RSV) Phase III Final Technical Report," Calspan Report No. ZN-6069-V-32, to be published.

24. P.M. Miller, "A Status Report on the Calspan/Chrysler RSV," presented at the Sixth International Technical Conference on Experimental Safety Vehicles in Washington, D.C., October 12-15, 1976.

25. Patrick M. Miller and Frank A. DuWaldt, "Influence of Material Resources on the RSV," presented at the Sixth International Technical Conference on Experimental Safety Vehicles in Washington, D.C. October 12-15, 1976.

26. Frank J. Glasgow (Chrysler Corporation) and Thomas L. Treece (Chrysler Corporation), "Calspan/Chrysler Research Safety Vehicle Front Impact Structure Development," presented at the Sixth International Technical Conference on Experimental Safety Vehicles in Washington, D.C., October 12-15, 1976.

27. Wayne L. Kruse (Chrysler Corporation), "Calspan/Chrysler Research Safety Vehicle Front End Design for Property and Pedestrian Protection," presented at the Sixth International Technical Conference on Experimental Safety Vehicles in Washington, D.C. October 12-15, 1976.

28. H.B. Pritz (Columbus Laboratories), "A Preliminary Assessment of the Pedestrian Injury Reduction Performance of the Calspan RSV," presented at the Sixth International Technical Conference on Experimental Safety Vehicles in Washington, D.C., October 12-15, 1976.

29. Daniel E. Massing, Gregory W. Kostyniuk and Saverio M. Pugliese, "Crash Victim Simulattion - A Tool to Aid Vehicle Restraint System Design and Development," presented at the Sixth International Technical Conference on Experimental Safety Vehicles in Washington, D.C., October 12-15, 1976.

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