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CALSPAN/CHRYSLER
RESEARCH SAFETY VEHICLE
PHASE III
FINAL TECHNICAL REPORT

VOLUME II – TECHNICAL DISCUSSION

April 1980

Contract No DOT HS-7 01551

Edited by

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Calspan Corporation
Advanced Technology Center

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16 Abstract

In Phase III of the RSV program, the Phase II design of subsystems and components was refined and adapted to exemplify mass production techniques. This report summarizes the integration of the various elements into a coordinated design from which ten vehicles were fabricated for test and evaluation by others in Phase IV. The five-passenger family car is designed to be fabricated by mass production techniques from materials chosen to minimize energy content, rare mineral requirements, and facilitate recycling for recovery and reuse. Using a combination of mathematical modeling on the computer with static and dynamic testing, design issues that remained at the completion of Phase II were resolved; validation tests were conducted to demonstrate performance resulting from these design improvements; and the results were incorporated in the final design. Additional investigations defined emissions and fuel economy, documented the degree of RSV compliance with current Federal Motor Vehicle Standards, and studied the effect of the RSV design on collision repair, producibility, and cost. All RSVs built for evaluation in Phase IV were delivered to NHTSA by 8 May 1979. Tests confirmed the successful achievement of the program goals.

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Automobile Handling, Economy Safety, Crashworthiness Occupant Restraints, Pedestrian Safety, Bumpers, Structure, Chassis, Body, Design Styling

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FOREWORD

The first phase of the Research Safety Vehicle (RSV) program was initiated at Calspan in January 1974, Phase II began in July 1975. The third phase of the Calspan RSV program was started on 26 January 1977 and is the subject of this report. With two exceptions, the Phase III effort is complete. Although the testing for the collision repairability study (Task 9) is done, the results will be presented in a report in March, installation of the anti-skid brake system will be effected in Phase III, but its evaluation will be part of the Phase IV report

As in the earlier work, Chrysler Corporation has been the major subcontractor and has been responsible for most of the vehicle body and chassis design as well as the high degree of mass production technology that has been incorporated in the methods for fabricating and assembling the components. This final technical report has been prepared by the combined efforts of program staff members at both Calspan and Chrysler Most of the information included has previously appeared in correspondence, internal memos, progress reports, and various other documents cited in the references It is the intention of the editor to combine that information into a comprehensive summary referencing other documents that more completely recount the work accomplished during the third phase of the RSV program which culminated in the ten final vehicles built for testing during Phase IV.

The Phase I reports (Reference 1) document the original definition of the program A preliminary design review data package (Reference 2a) 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. Additional information on the Phase II vehicle is presented in the final reports on the Phase II program (References 2b, c and d) as well as in the papers presented at the Sixth Experimental Safety Conference, References 2e through 2j and test reports, References 2k, l, m and n

All reports prepared during Phase III are referenced. The detailed Program Plan is Reference 3. The status reports prepared at intervals during Phase III are included as References 4 through 17. Reports on individual tests and tasks undertaken during the third phase of the program are listed as separate documents. The report of the static crush tests (Task 6.1) is Reference 18. References 19 and 20 are the final reports in the development of the air belt and the driver air bag (Tasks 4.2 and 6.2). The test plan for integrated systems validation (Task 6.7) is Reference 21. The reports on the Phase III crash tests (Task 6.7) are included in References 22 through 31. Research Safety Vehicle handling (Tasks 6.5 and 6.6) is discussed in References 33 and 34, while the compliance with Federal Motor Vehicle Safety Standards (Task 8) is assessed in Reference 35. References 36 through 39 document portions of the overall program, and Reference 40 is the final design report which discusses, in detail, the development of the design of the overall vehicle as well as the various components utilized in the Calspan/Chrysler RSV (Task 4). Available reports of Phase IV test results are included as References 32 and 41 through 43.

Volume II of this Final Technical Report is organized by the various tasks which, for easy reference, are numbered in accordance with the work statement of the contract. Each task of the contract is briefly summarized with a description of the work accomplished during the Phase III program. Volume I comprises an Executive Summary. The two volume report is submitted in partial fulfillment of the requirements of Paragraph 3.1 of the Statement of Work of Contract No. DOT-HS-7-01551 under which Phase III of the RSV contract has been accomplished. *The Contract Technical Manager for the sponsor*, DOT/NHTSA, is Frank G. Richardson. The contents of this publication reflect the views of the Calspan and Chrysler RSV staffs and are not necessarily those of the National Highway Traffic Safety Administration.

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 editor wishes 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
Atwood Vacuum Machine - Seat Tracks
Bendix Corporation, Auto. Control Systems Group - Anti-Skid Brakes
Chrysler/France - Simca Components
CIBIE Corporation - Headlamps and High Level Tail Lamps
Conwed Corporation - Headliners
Cranz Co., J.M - Insolite Material
Creative Industries of Detroit - Engineering Services and Fabrication of Vehicles
Custom Trim Products - Molding
Davidson Rubber Company - Soft Bumper Systems
Dynamic Science, Inc - Use of Test Facilities and Measurements of Parameters on the RSV

Essex Chemical Corporation - Windshield Adhesives

Essex Group, Inc. - Wiring Harnesses

General Electric Company - Plastics

Goodyear Tire and Rubber Company - Flatproof Tires

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

Lake Center Industries - Secondary Hood Latches

Lone Star Manufacturing - Air Conditioning Condensers

Marui Industrial Company, Ltd - Soft Emblems and Headlamp Bezels

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

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1.0 SCOPE

Under the Phase III RSV Contract No. DOT-HS-7-01551, Calspan Corporation Advanced Technology Center has provided, either directly or through subcontract, the necessary qualified personnel, facilities, suppliers, and services to complete the design, development, and fabrication of the Calspan/Chrysler Research Safety Vehicle (RSV) as summarized in this document and reported more completely in the cited references. The development and fabrication is the responsibility of the Calspan Corporation This work constitutes Phase III of a four-phase DOT/NHTSA program for the research, development, fabrication, and testing of the RSV and its completion signifies the end of the Calspan effort under the contract on Phase III. Phase IV tests of the RSVs are being conducted by other organizations mainly in foreign countries.

2.0 BACKGROUND

The RSV program was initiated in January 1974 with the award of five contracts for a 15-month, Phase I, RSV Program Definition and Performance Specification Development. The major products of these five identical contracts were safety performance specifications and preliminary designs which conceptually defined vehicles optimized for the mid-1980s time frame. Phase I was completed 18 April 1975[1][*]

In July 1975 two of the Phase I contractors (Calspan Corporation and Minicars, Inc.) were selected to proceed in Phase II to develop vehicle designs based on their Phase I work Scheduled for completion by 16 November 1975, the design development work resulted in designs in accord with the Phase I performance specifications and conceptual designs The designs were developed to the extent that subsystems were defined and specified, and necessary development testing had been performed to verify the design approach These development tests included subsystems integration tests as required to ensure the performance of related subsystems (e g , structures and occupant restraints). Materials and manufacturing processes were also identified, and their feasibility was verified.[2]

In Phase III Calspan Corporation, with Chrysler and other subcontractors, refined the Phase II design where necessary, resolved design issues not completed in Phase II due to time and/or scope limitations, refined analyses and simulations of performance, and produced ten vehicles for the fourth and final phase of the RSV program - test and evaluation. The car is shown in Figures 1 through 4, its performance specifications are contained in the appendix

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[*] Superscripts denote references listed at the end of the report

Figure 1 FRONT VIEW

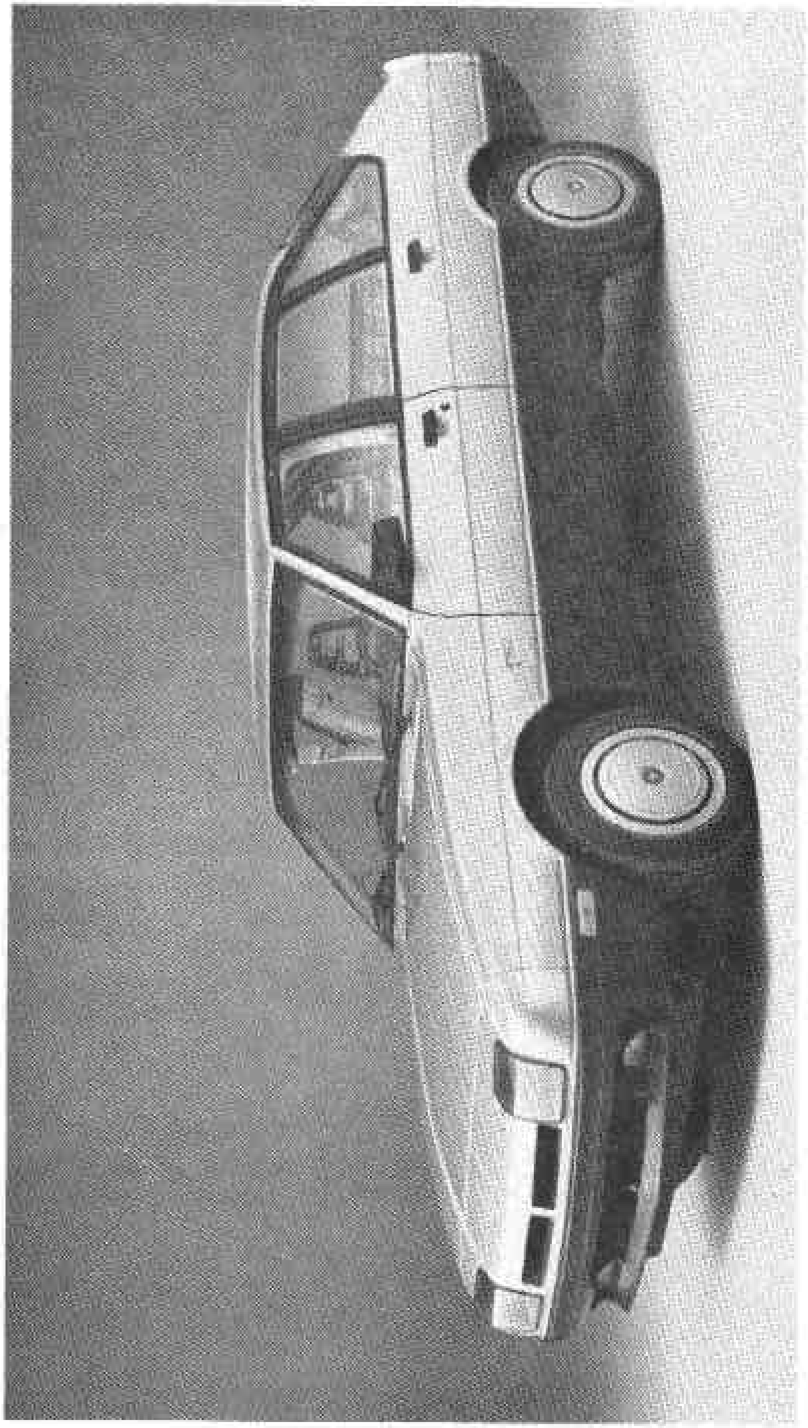


Figure 2 FRONT QUARTER VIEW

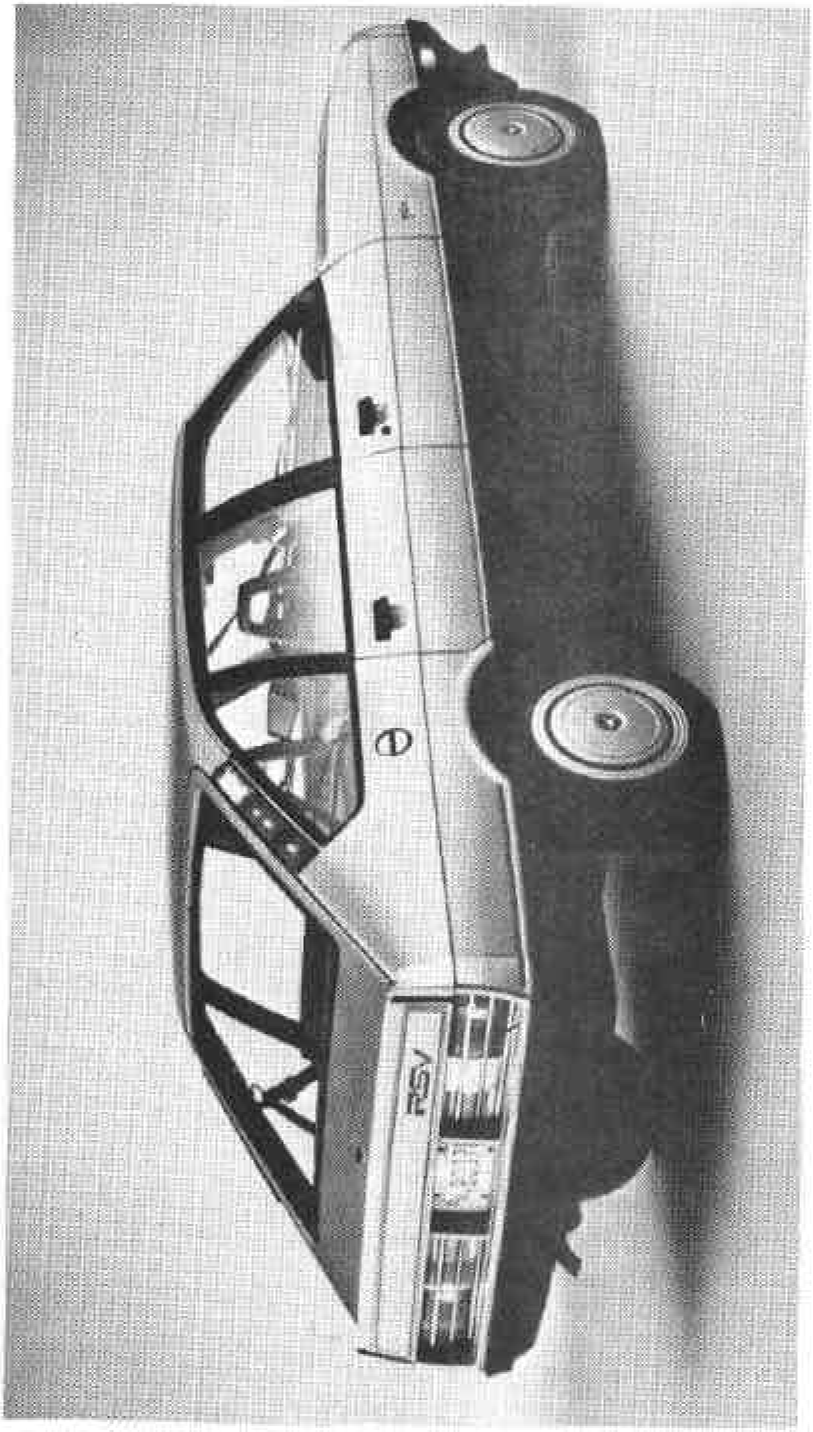


Figure 3 RSV REAR QUARTER VIEW

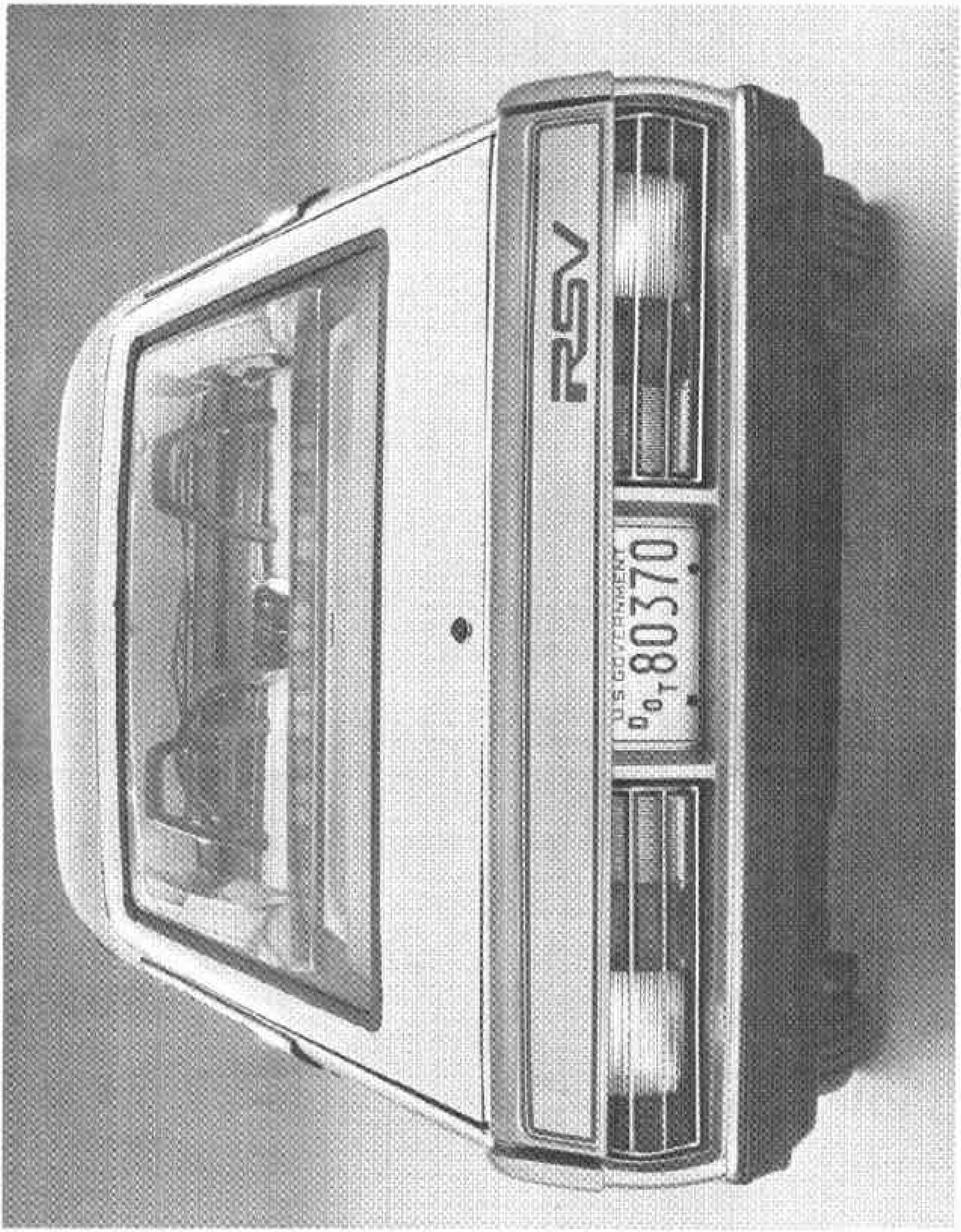


Figure 4 RSV REAR VIEW

The fourth and final phase, Test and Evaluation, is a separate NHTSA program being undertaken by different organizations, largely in foreign countries. Although Calspan has provided some support to help implement those tests, Phase IV will be separately reported later.

2.1 Program Objectives

The overall objective of the RSV program is to develop technological data applicable to automotive safety requirements for the mid 1980s for the National Highway Traffic Safety Administration (NHTSA) 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 in January 1974 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 other than strict safety considerations 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 easily recycled and require minimal energy in its manufacture. The purchase, 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/pedestrians that might be involved in collisions with the RSV.

Phase I studies furnished (1) definitions of vehicle characteristics suitable for automobiles operating in the mid 1980 and later time frame, (2) comprehensive sets of vehicle performance specifications, and (3) preliminary design concepts[1] Major safety emphasis in the Calspan effort was placed on crashworthiness (occupant protection) and pedestrian protection, economic and environmental constraints identified limits on vehicle weight and power. Calspan defined its goal as a 2700 lb. sedan having a capacity suitable for normal family use and a fuel economy approaching 30 mpg. Recovery (recycling) of most vital mineral contents, using conventional scrap metal processing, was a design consideration. The preliminary Phase I design was derived from an existing Chrysler/France production car and featured a transverse front engine/front drive system, flatproof tires, pedestrian bumpers, and a number of high strength low alloy steel body components.

The objective of the Phase II RSV program was to develop an RSV design in accord with the performance specifications and conceptual designs formulated under the Phase I contract. Efficient realization of program objectives was achieved by using a base vehicle modification approach - the base vehicle selected is the Chrysler/France (Simca) 1308 introduced in Europe in model year 1976. This base vehicle provided dimensional, weight and handling characteristics that approximate Phase I RSV specifications. Additionally, the Simca 1308 manufacturing facilities furnished a realistic basis for estimating the effects on cost and producibility of design/process changes attendant to achievement of RSV safety, emissions, and efficiency goals. Environmental (emissions) aims and fuel efficiency performance goals were consistent with the 1985 time period, i.e., approaching 30 mpg in the EPA combined driving cycle test. Economic considerations (consumer costs) were based on an assumed annual production run of 300,000/year. Production tooling, processes, facilities and materials necessary for such an output were investigated. Further, the design implications of resource conservation through recycling were addressed. Subsystems were defined and developmental tests performed to demonstrate conformance with specifications and compatibility of subsystems. A mock-up was prepared to demonstrate subsystems integration, interior arrangement, occupant restraints, plus driver and passenger entrance and egress accommodations.[2]

2.2 Phase III Objectives

In Phase III, the Phase II design of subsystems and components was refined and adapted to exemplify mass production techniques.[3] The various elements were integrated into a coordinated vehicle design which was used in fabricating ten vehicles for test in Phase IV.[39,40] This report summarizes the work in Phase III that culminated in the vehicles fabricated for testing in Phase IV. Using a combination of mathematical modeling on the computer with static and dynamic testing, design issues that remained at the completion of Phase II were resolved, validation tests were conducted to demonstrate performance resulting from these design improvements, and the results incorporated in the final design. Additional investigations defined emissions and fuel economy, documented the degree of RSV compliance with current Federal Motor Vehicle Standards, and studied the effect of the RSV design on collision repair, producibility, and cost.

Ten vehicles were built to this final design in Phase III. Tests conducted on prototypes in Phase III and tests by others on the ten Phase IV vehicles indicate successful achievement of the RSV goals. The results of developmental testing during Phase III are completely reported in references and are summarized in the appropriate sections of this report to document that achievement. Information from tests so far completed in Phase IV is summarized in Section 15. Specific significant results include demonstration of survival of RSV occupants (1) in head-on collisions with both cars traveling at 40 mph (80 mph relative car-to-car speed), (2) when struck on the side at 40 mph, and (3) when hit from the rear at 45 mph. In addition, 50th percentile dummy pedestrians exhibited reduced injury levels from primary impacts at speeds up to 25 mph. Handling and braking exceeded the design specifications (e.g., the RSV stopped in a distance of 151 feet from 60 mph). Fuel economy was shown to be in the range of the 1985 requirements and emissions were shown to meet the 1978 California standard. Design of the vehicle is consistent with mass production techniques. Also, materials used in fabrication were chosen to minimize energy content, rare mineral requirements, and facilitate recycling for reuse. The goals identified and performance achieved are shown in the specifications in the appendix. The results of the RSV tests in the U.S. and abroad prove the practicability of the design and substantiate its applicability to current production vehicles.

3.0 PROGRAM MANAGEMENT

The concept for management of Phase III of the RSV program included the development of a comprehensive program plan (Task 3.1) for accomplishing the required tasks including manpower, schedules, milestones, and fund expenditures, as well as the utilization of that plan in evaluating progress achieved so that any shortcomings could be rapidly identified and remedied. That plan identified the various design issues still unresolved at the completion of Phase II as well as numerous developmental and validation tests necessary to demonstrate satisfactory performance of the proposed RSV design. In addition, other tasks were defined that needed to be undertaken to insure demonstration of achievement of the RSV goals by the vehicles to be built at the end of Phase III. The schedule of the tasks undertaken during Phase III of the Calspan RSV program is shown in Figure 5. Incomplete tasks are indicated by open symbols or blocks (e g , this final technical report is shown as an open triangle during the month of February 1980) Where the activities have been completed, the graphical representation has been filled in. As can be seen, the remaining unfinished Phase III tasks include installation of the anti-skid ABS brake system in RSV No 6 (Task 6.6), the completion of the report on the collision repairability study (Task 9), and the continuation of Calspan's support for the tests being accomplished by other organizations in the Phase IV program (Task 15) Task 6.4, the durability/vibration testing and Task 10, the maintenance/service study have been omitted from the schedule since no vehicle has been available for their accomplishment All other Phase III activities are complete.

3 1 Program Plan

The Program Plan was initially submitted on 1 March 1977 and later, on 18 April, it was reviewed with NHTSA at a briefing in Washington, D.C. After that review, the Program Plan was revised and in May 1977, initial negotiations were completed for the conduct of the program. The work statement of the contract was modified to incorporate the changes to the Program Plan, but there was no subsequent formal revision of that document.

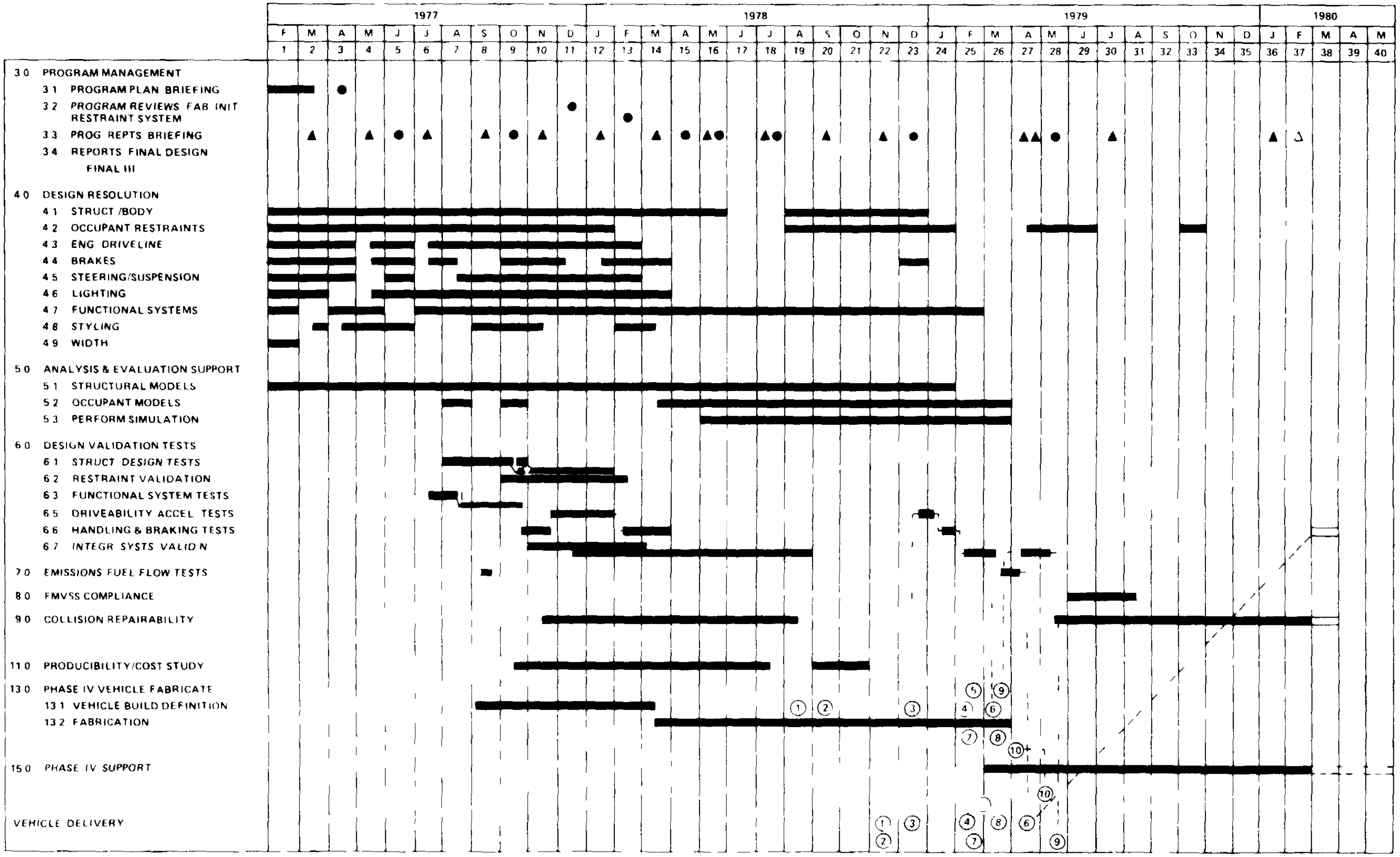


Figure 5 RSV PHASE III SCHEDULE

3.2 Program Reviews

Two major program reviews were conducted. The first one was a review to authorize fabrication of the RSVs to be built for evaluation by others in Phase IV. That review was held in conjunction with the Bidder's Briefing on 15 December 1977 at the Chrysler Engineering Center in Highland Park, Michigan and is discussed in Reference 9 The second major review was the restraint system review accomplished on 2 February 1978 and discussed in Reference 10 The restraints review considered the results of the driver air bag and passenger air bag programs being conducted under different contracts as well as the development of the air belt carried out under Phase III of this contract The air belt program development is more thoroughly reported in Reference 19 and that of the driver air bag in Reference 20

3.3 Progress Reports and Status Briefings

As indicated in the Schedule, Figure 5, 14 status reports (References 3 through 17) have been submitted to document progress throughout the program. Four status briefings were conducted at NHTSA facilities during the course of the contract and one briefing was held to review the cost analysis. The status briefings occurred on 29 June 1977, 25 October 1977, 17 May 1978, and 7 December 1978 At the last one, the RSV final design was discussed. The cost briefing occurred on 11 May 1979. In addition, a Bidder's Briefing was conducted in Detroit on 15 December 1977 to acquaint prospective fabricators with the RSV design (Reference 9).

3.4 Reports

Sixteen technical reports have been prepared and submitted under the Phase III contract. Twelve of these reports document the results of static and dynamic tests (References 18 and 21 through 31). Four of them (References 19, 33, 34 and 35) recount the results of various task investigations. A highly specialized report on the collision repairability study of the RSV, being prepared by the Motor Insurance Research Repair Centre at Thatcham, England, is scheduled for completion in March and distribution in April 1980 Two comprehensive major reports have been prepared the Final Design Report (Reference 40, submitted in January 1980) and this final Phase III report

In addition to the formal reports identified above, References 36 through 39 are typical examples of technical papers prepared for presentation at technical meetings during Phase III of the program.

Finally, design documentation, including microfiche records of drawings and specifications, was submitted to the sponsor on 3 August 1975 t revise, bring up to date, and replace the information submitted during Phas

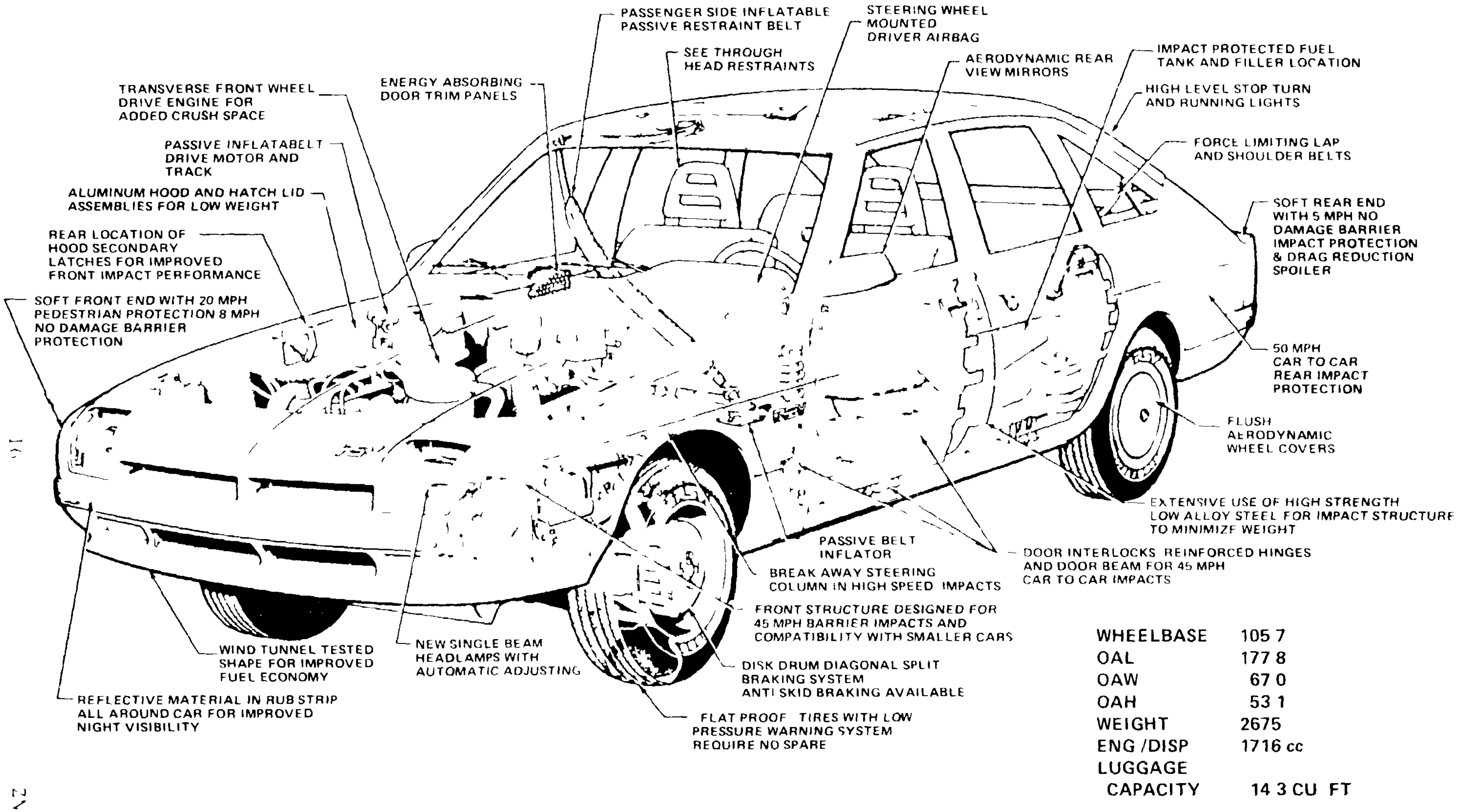
4.0 DESIGN RESOLUTION AND COMPLETION

At the beginning of Phase III[3] about 50 issues that required resolution for the completion of the RSV design were identified. These included items uncovered in development tests or not addressed in detail in Phase II as well as new or improved subsystems or components, changes requested by the sponsor, and refinements to improve the RSV goals. Their solutions are addressed categorically under Tasks 4.1 through 4.9 below.

The design features of the Calspan/Chrysler RSV, which were developed during Phase III, are identified in Figure 6. Further discussion of those features is provided in Reference 40, the Final Design Report. As noted above, design documentation was submitted in August 1978. The performance specification achieved with the vehicles developed during Phase III forms the Appendix of this report.

4.1 Structural/Body Design

The re-design of the Phase II front structure to accommodate the Chrysler Omni/Horizon 1716 cc engine with its emissions package included (1) revisions of the upper and lower load paths to reduce the undesirable vehicle pitch, (2) modifications of the firewall region to reduce pitch, steering column, and engine intrusion, and (3) an increase in length of 2-1/2 inches. These changes are discussed in References 4 through 10, as well as in References 37, 39 and 40. In addition to further development of the soft front bumper, whose Phase II development is reported in Reference 21, a rear bumper was developed to provide 5 mph no-damage rear end protection. In conjunction with its soft front bumper, RSV front-to-rear impacts were expected without serious damage below 13 mph. Most importantly, however, the front bumper was designed to reduce injuries to pedestrians to the maximum extent possible. As indicated in References 22, 39 and 40, as well as by results of subsequent tests during Phase IV,[41] the RSV bumper goals have been met. Those achievements are documented in the Appendix. Other design activity including new engine mounts, torsion bars, door latches, hood latches, seats, roll bar,



WHEELBASE	105 7
OAL	177 8
OAW	67 0
OAH	53 1
WEIGHT	2675
ENG /DISP	1716 cc
LUGGAGE CAPACITY	14 3 CU FT

Figure 6 RSV DESIGN FEATURES

and the attachments and welding at the extremities of the A, B and C pillars was undertaken to improve both the occupant environment and the producibility of the vehicle. A specific example of re-design for mass production feasibility is provided by the revisions to the tunnel reinforcement in which the number of parts was reduced from seven to two.[40] The final Phase III structure is illustrated in Figure 7

Changes in the vehicle structure during Phase III were planned so as to minimize rework of the Phase II tooling However, installation of a different engine involved appreciable revision to the front end structure as well as the outer sheet metal surrounding it. In addition, as discussed in other sections below, the Phase III development and validation tests later identified a requirement for a rework of the rear bumper support, the front structure, the fuel filler, and the door hinges, as well as further development of restraint components to successfully absorb the higher g levels demonstrated in the crash pulses in the Phase III barrier tests

The Calspan/Chrysler RSV design followed a base vehicle approach That is, advanced state-of-the-art technology was judiciously applied to an existing production car (the Simca 1308 base vehicle) in order to bring its performance up to stipulated RSV standards Thus, the Simca structure was modified to meet the RSV's stringent high-speed crashworthiness and low-speed pedestrian protection/vehicle damageability goals

Structural changes, for the most part, were embodied in particular structural elements. In some instances, the basic element design was retained but the material and/or gauge were altered. In other cases, the original part was reinforced or completely redesigned. Liberal use was made of high strength low alloy (HSLA) steel for weight efficiency and structural strength. Beside replacing the Simca front and rear bumpers with soft urethane units to provide pedestrian and low-speed vehicle exterior protection, an aluminum hood was substituted for the original steel counterpart primarily to help mitigate the severity of injury to struck pedestrians but also to reduce vehicle weight.

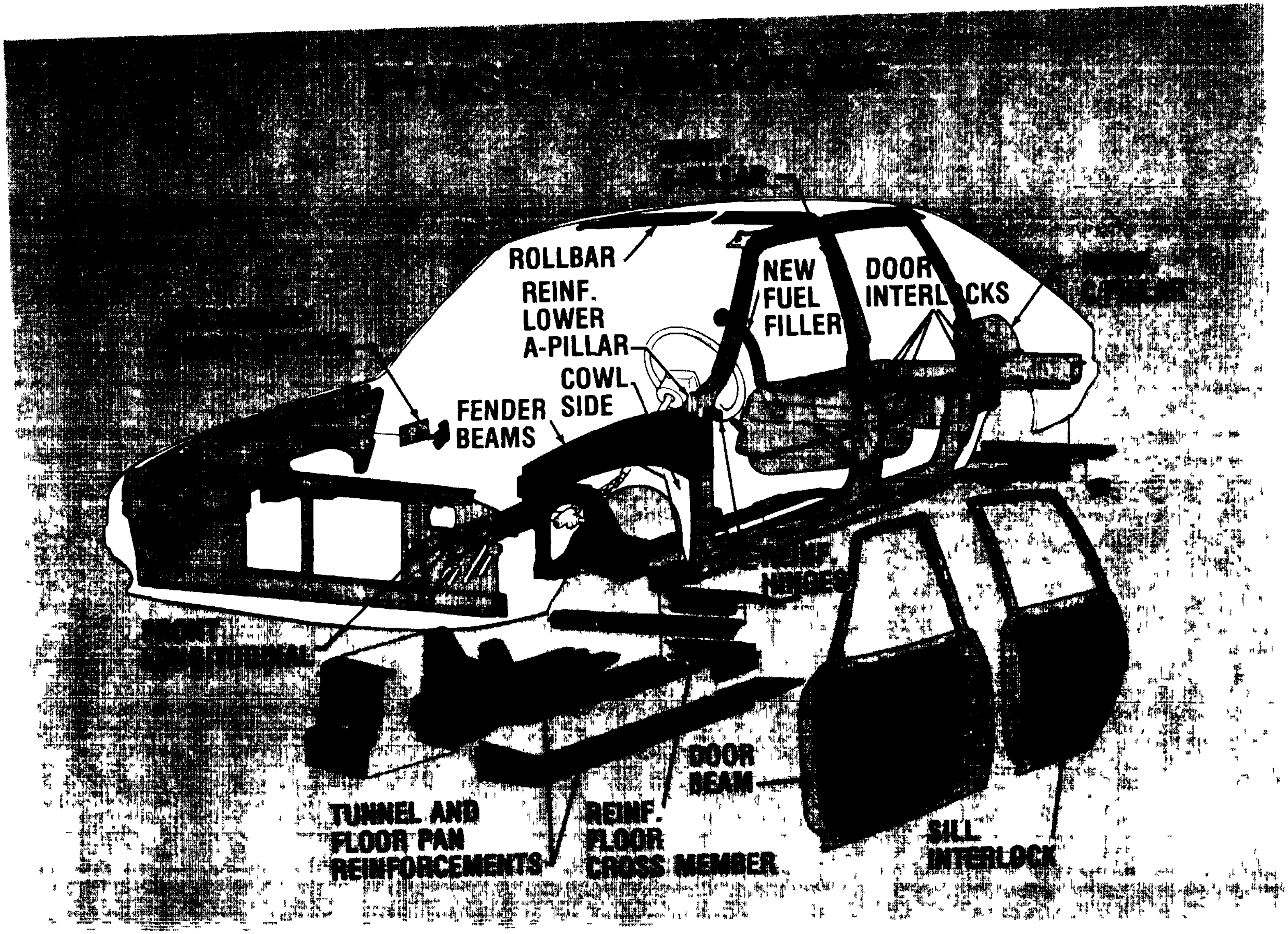


Figure 7 PHASE III STRUCTURE

Similarly, the steel liftgate was replaced by an aluminum unit to gain additional weight savings. Table 1 has been prepared to show the principal changes made to the base vehicle and indicate their effectiveness in satisfying objectives specified for the RSV[*] as revealed by actual demonstrated performance in full-scale crash tests. Results are presented for desired impact protection objectives in three principal collision modes: front, side and rear. Listed design modifications reflect those in the RSV Phase III final design; they are fully described in Reference 40. References 22 through 30 constitute test reports which completely document the RSV performance noted in the table.

Satisfactory vehicle structural performance (i.e., structural integrity, controlled collapse, and adequate crash energy dissipation potential) alone does not insure a survivable environment for occupants of vehicles involved in high-speed impacts. Other considerations such as restraint system effectiveness, interior surface compliance, material flammability and occupant escape potential also constitute part of a vehicle's total crashworthiness rating. In this regard, the reader is referred to Section 6.7 for an overall assessment of both RSV and base vehicle crashworthiness performance.

Examination of Table 1 indicates that the effected structural modifications did indeed satisfy almost all of the desired performance objectives. One notable exception, however, is occupant survivability in a high-speed (41 mph) flat barrier impact. Despite adequate structural performance manifested in two similar tests, failures of restraint system components precluded demonstration of full compliance with all occupant injury criteria [31,32]

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[*] These requirements stem from the RSV specifications and subsequent knowledge acquired from crash tests conducted during the Phase II and III RSV programs.

Table 1

EVALUATION OF BASE VEHICLE STRUCTURAL MODIFICATIONS INCORPORATED IN THE RSV

DESIRED PERFORMANCE OBJECTIVE	DESIGN MODIFICATIONS TO BASE VEHICLE	DEMONSTRATED PERFORMANCE WITH MODIFIED STRUCTURE	REMARKS	REFERENCE(S)
FRONT IMPACT PROTECTION				
• Provide pedestrian impact protection and simultaneously minimize the extent of exterior damage to the RSV front end and other conventional vehicles in low speed fixed-object/vehicle collisions	Conventional front bumper replaced by soft urethane plastic, energy absorbing bumper Material properties and shape selected on the basis of pedestrian contact pressures/post impact Kinematics and vehicle damageability considerations Aluminum hood substituted for steel hood to help mitigate severity of struck pedestrian injuries	No damage to exterior sheet metal or bumper shell in flat barrier impacts up to 8 1 mph (Test 1) Only visually apparent damage in a series of front to rear impacts with another RSV (Test 2M) was one minor crack in bumper fascia at 11 4 mph Low speed 90 degree side impacts into a Plymouth Fury at speeds up to 6 1 mph (Test 11A) produced no damage to the RSV and only minor struck car door skin wrinkling (max dent approx 3/16 inch deep) Front end design demonstrated potential for reducing pedestrian injury (both adults and children) at impact speeds up to 20 mph)	12 9 mph impact in Test 2M caused minor (approx 1/16 inch) yoke panel rearward set but no other visually apparent front end damage The aluminum hood can be more readily damaged in non impact situations than its original steel counterpart but provides a weight savings of about 21 lbs	5 6 11 22 26 40 2)
• Transmit frontal impact loads into vehicle front rails and sheet metal	Original radiator support replaced by flat yoke panel which also serves as a mounting surface for the front bumper and headlamp assemblies	Yoke panel structural integrity maintained and desired force transfer manifested in a variety of impact configurations		4 5 23 25 26, 28 32 40
• Effective Kinetic energy management Develop relatively low frontal crash force levels to reduce vehicle aggressivity in frontal impacts with lighter cars as well as in side and rear impacts in general Con currently develop high crush forces to protect RSV occupants in high speed frontal impacts with equally weighted or heavier vehicles	Simca longitudinal front rails were lengthened and redesigned using HSLA steel to obtain the desired force levels/collapse characteristics Strategically located slots cut into the first 12 inches of the rail provide the low crush forces required for inter vehicular collision compatibility high force levels developed in aft portion of the rail Side engine mounts designed to yield consistent with front rail collapse	RSV exhibited excellent front to side compatibility in a 90 degree side impact with another RSV at 39 mph (Test 6) striking and struck cars sustained max exterior crush of 14 4 and 7 3 inches respectively RSV collapsed in an orderly manner and effectively utilized all available frontal crush space (less possible additional firewall crush) in second and third flat barrier impacts	In Test 6 striking vehicle passenger compartment decelerations were generally less than 20 g's while corresponding struck car accelerations ranged between 22 30 g s Injury levels for all dummy occupants in both cars were well below allowable FMVSS 208 limits Relatively high passenger compartment deceleration levels (peak values ranged from 51 to 72 g's) were generated in the barrier crash tests Restraint system component failures prevented compliance with occupant injury criteria	4, 5 6 10 25, 28 29 40
• Minimize pitch of passenger compartment	Upper fender beam added to balance impact forces imparted to the A pillar HSLA cowl panel assembly added between aft end of fender beam and sill to stabilize beam in vertical bending	Maximum 4 degree pitch measured via high speed film analysis of flat barrier Tests 9 and 10	Upper fender beams sustained vertical plane bending near A pillar anchorage points collapse mode of front structure essentially axial in nature	3 4 5, 6 25 28, 29, 40
• Limit firewall intrusion into the passenger compartment	Reinforced A pillar reacts impact forces transmitted by upper fender beam and directs these forces into the heavily reinforced sill HSLA steel substituted for mild steel in front floorpan area joint between firewall and floor pan toeboard strengthened with HSLA strap Tunnel area reinforcement installed forward of the firewall to help resist engine/steering rack penetration Additional reinforcement incorporated between the aft portion of the front rail and the sill to help resist shear failure of the floorpan and rail from the sill Capped sill extension (tire blocker) added to facilitate direct load transfer from tire/wheel system to sill	Structural integrity of passenger compartment maintained and relatively minor firewall intrusion (4 6 inches max) sustained in two 43 + mph flat barrier impacts Floor pan buckling confined primarily to the toeboard and tunnel area aft of the front seat riser		3, 4, 5, 6, 11, 28, 29, 38, 40
• Prevent windshield zone intrusion	Secondary hood latches located on the fender side shields installed to help arrest rearward motion of the hood	Windshield cracked but remained intact during the most severe impact test exposure (barrier Tests 9 and 10) Cracking stemmed from steering wheel rim/instrument panel top contact with inner glass surface Minor intrusion in cowl area under windshield	Secondary latches help compensate for the reduced crush resistance of the aluminum hood	5 11, 28 29, 39 40
• Facilitate post crash occupant egress	See enhanced aperature panel and B pillar integrity under SIDE IMPACT PROTECTION heading	One or more doors either manually operable or easily opened with conventional hand tools (e g crowbar) following high-speed frontal barrier, perpendicular and oblique front to-side, and moving barrier rear impact tests	In Tests 8M and 12 selected RSV doors were removed/jammed shut prior to impact as a result of previous test exposure	4 5, 7, 25, 27 30, 28, 29, 39 40

Table 1

EVALUATION OF BASE VEHICLE STRUCTURAL MODIFICATIONS INCORPORATED IN THE RSV (C nt.)

DESIRED PERFORMANCE OBJECTIVE	DESIGN MODIFICATIONS TO BASE VEHICLE	DEMONSTRATED PERFORMANCE WITH MODIFIED STRUCTURE	REMARKS	REFERENCE(S)
SIDE IMPACT PROTECTION				
• Enhanced aperture panel/B-pillar integrity and controlled sidewall collapse	Single-stamped, continuous aperture panel utilized to reduce the number of required weld joints. B-pillar attachment to sill and roof rail improved Band C pillars reinforced with HSLA steel, B-pillar substantially larger in cross section than base vehicle counterpart to facilitate early sidewall loading	Integrity of sidewall structure maintained in 39 mph perpendicular and 32 mph oblique side impacts by an RSV (Test 6) and a Plymouth Fury (Test 8M), respectively Max exterior deformation following the above tests was limited to 7 3 and 9.2 inches (front door region) respectively, with corresponding interior intrusions of only 4.5 and 5.3 inches	Strengthened sidewall construction also provides a longitudinal load path along the sides of the vehicle to help reduce passenger compartment intrusion and permit easy door opening/removal for emergency egress of vehicle occupants following high-speed frontal impacts.	4, 5, 6, 7, 9, 25, 27, 39, 40
• Impact load transfer/distribution	Full height HSLA door beams and associated end support structure added to direct impact forces to the aperture panel/B pillar HSLA rollbar installed between upper ends of B pillars to help minimize excessive roof crush and transfer loading to the side opposite impact Transverse HSLA reinforcement added to floor pan in seat riser area to provide a similar, lower across the car load path	Passenger compartment acceleration time histories obtained from both impact and non impact side floor pan mounted sensors exhibit early onset and comparable magnitudes in Test 6 Deformed RSV sidewall experienced fairly uniform crush, e.g., 7.3 and 6 2 inches of max exterior deformation near the center of the front and rear doors, respectively	Sill to rail reinforcement added primarily to reduce compartment deformation in frontal impacts also aids in maintaining transverse load path continuity in side impacts	3, 4, 5, 6, 7, 9, 25, 27, 39, 40
• Door retention	Door inward motion restrained by added door interlocks dual pin type interlocks installed on door latch faces L-shaped bracket installed on bottom faces engages a slot in the sill Base vehicle door hinges strengthened	Adequate door retention maintained under severe concentrated loading condition imparted to front door during 32 mph oblique side impact by a Plymouth Fury (Test 8M) Similar satisfactory performance demonstrated in 39 mph perpendicular side impact (Test 6)	Interlocks force the door beams into a tension mode to help transfer impact loading into the surrounding aperature panel and B pillar	4, 5, 7, 9, 25, 27, 39, 40
• Occupant survivability	See side modifications above Also, aluminum honeycomb inserts added to space between exterior door skin and interior trim panel to help cushion occupant torso against intruding sidewall structure	All applicable FMVSS 208 occupant injury criteria satisfied for struck RSV's in Tests 6 and 8M	RSV occupants experienced reasonable (approx. 50 g's) pelvic accelerations	4, 5, 9, 25, 27, 39, 40
REAR IMPACT PROTECTION				
• Reduce extent of rear end exterior damage resulting from low-speed impacts by another vehicle or fixed-object collisions	Original fiberglass rear bumper replaced by redesigned bumper featuring soft urethane plastic, energy-absorbing inserts. Base vehicle rear crossmember redesigned to increase bending stiffness capacity and help promote impact load transfer into strengthened rear rails/luggage well floor in order to prevent local bumper/rear liftgate panel collapse	Rear end of struck RSV sustained only minor permanent set (1/8 inch) in lower liftgate panel when struck by the front end of another RSV at speeds up to 11.4 mph (Test 2M) Resulting deformation barely noticeable without comparison of pre and post test measurements.	9.8 mph impact by RSV caused tail lamp lens cracking, 12 9 mph impact increased lower liftgate panel set to 1/4 inch.	6, 12, 22, 39, 40
• Limit rear passenger compartment intrusion and provide improved fuel tank protection	Rear longitudinal rail reinforced to accept loads directed into it by strengthened rear crossmember Fuel tank moved ahead Spare tire replaced by luggage well	A 40 mph colinear rear impact of the RSV by a rigid SAE contoured surface moving barrier (Test 12) resulted in an acceptable 5 inches of passenger compartment intrusion and no damage to the fuel tank. Moderate compartment acceleration environment (24 g's max) resulted in generally favorable dummy responses.	Test 12 conditions equivalent to a front to-rear collision between two RSV's at 47 5 mph Fuel filler tube motion relative to fuel tank led to minor but acceptable fuel leakage (1/2 oz./min.) following impact	4, 5, 6, 7, 9, 10, 22, 30, 39, 40
• Provide additional rear impact protection for fuel tank	Fuel filler tube rerouted to prevent tube rupture and/or pullout from the fuel tank during rear structure collapse. Quarter panel filler tube attachment redesigned breakaway plastic retaining collar added to insure tube separation during quarter panel buckling	Fuel filler pipe integrity maintained in Test 12 Breakaway pipe support demonstrated satisfactory performance		6, 7, 8, 9, 10, 22, 31, 39, 40
• Occupant survivability	See rear modifications above	With the exception of one femur loading, occupant injury exposure levels for all three dummy occupants were well below, acceptable FMVSS 208 values.	Contact between the knees of the right rear dummy and the back of the right front seat produced a 2600 lbs axial force in the dummy's left femur.	16, 17, 30, 39, 40

4.2 Occupant Restraints

The development of the air belt and driver air bag from the initial concepts identified during Phase II to the final components installed in the vehicles built to be tested during Phase IV is fully described in References 4 through 9, 19, 20, 39 and 40. Further amplification of the development during the last year of the program carried out in an effort to accommodate the severe 72 g peak deceleration pulse observed in the barrier crash tests of the Phase IV vehicle is included in References 14 through 17. References 29, 31 and 32 report the results of these systems in barrier tests

Early in Phase III,[5] the front axle was moved forward 2-1/2 inches to make feasible the adjustment of force levels in the rear section of the front structure (Zone 3) so as to approach more closely the goal of 50 mph barrier capability. However, as reported in Reference 16 and in the Phase III frontal barrier crash tests,[28,29] the resultant dynamic crush occurring in the barrier crashes was only of the order of 30 inches, in part explaining the higher g loading developed during those crashes. Other Phase III tests[26,27] indicated a desirable reduction of force transmitted to the struck car (aggressivity) had been achieved.

At a meeting held on 19 July 1978 at Calspan, attended by representatives of NHTSA, Chrysler, and Calspan, a decision was made to proceed with only the minor modifications that could be readily accommodated in the front structure which had already been fabricated for the Phase IV cars and to try to ameliorate the effects of the 72 g crash pulse by improvements in the occupant restraints and a decrease of the crash velocity to 40 mph. As noted in References 14 through 17, that achievement seemed feasible if all worked well. However, malfunction of one or another of the restraint system components precluded its realization during the Phase III tests. On the other hand, in a Phase IV head-on staged collision in Japan between an RSV going at 41 mph and a similar weight Japanese car approaching at 40 mph (relative car-to-car velocity - 81 mph), HIC numbers, chest g's and femur loads developed by the front seat occupants of the RSV were well below the maximum acceptable values identified in FMVSS 208. The automatic load limiting air belt and D ring motor control used in the RSV is shown schematically in Figure 8, the air bag, Figure 9.

4.3 Engine/Driveline

At the Phase II design review, NHTSA directed that the 1442 cc Simca 1308 engine be replaced by the 1716 cc engine used in Chrysler's Omni and Horizon (References 3, 5, 9, 39 and 40). The engine change was made to provide the desired power capability to meet the acceleration goals for the RSV and comply with at least the 1978 California emissions standards. In addition, the Chrysler engine was available with an automatic transmission and a compressor for an air conditioning system as well as a hydraulic pump for power steering and both manual and automatic transmissions. Finally, although it was appreciated that the 30 mpg goal would probably not be achieved, 1985 fuel economy requirements of 27.5 mpg seemed within reach. As identified in the references, as well as in the specification in the Appendix, the RSV emission and fuel economy goals of 0.41 HC, 9.0 CO, and 1.5 NOx at the combined EPA fuel economy of 27.5 mpg have been achieved.

The driveline components on the engine end of the drive shafts are standard Chrysler Omni/Horizon parts, those on the outboard end come from the Simca. These parts are described in detail in Reference 40.

Figures 10 and 11 show the standard Chrysler engine and manual transmission utilized in the RSV. Details of the other components are shown in the final design report.[40] In the development of the installation of the engine and driveline, design criteria were carefully reviewed to insure that the required volume was kept to a minimum without compromising maintenance, service, repair, or low speed no-damage provisions.

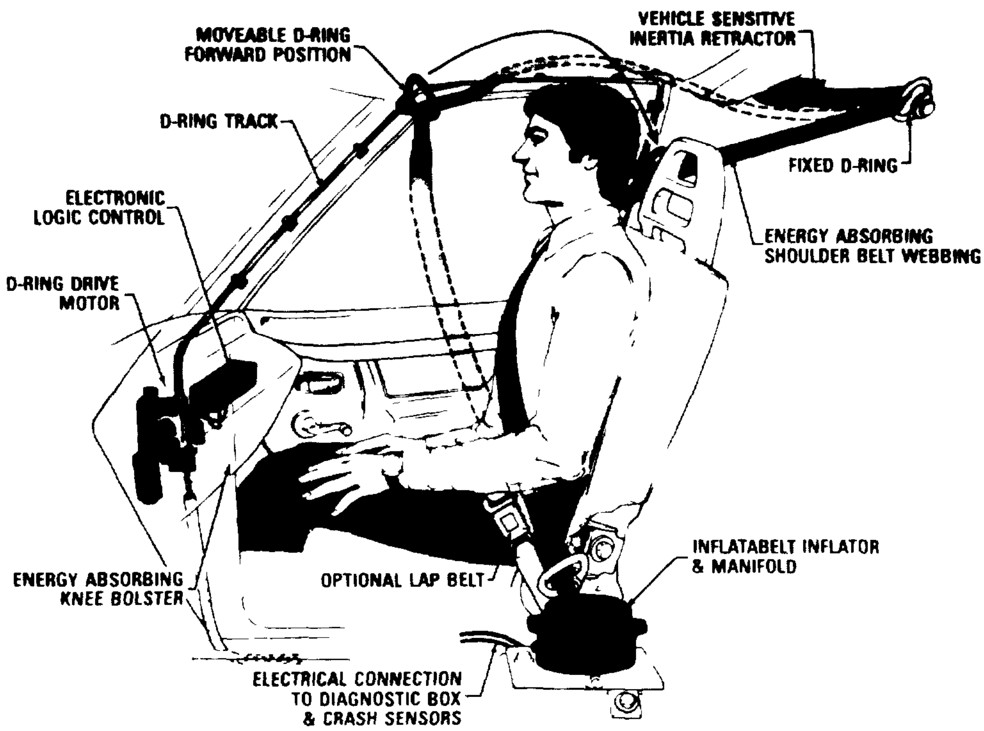

Figure 8 RSV INFLATABLE SHOULDER BELT – PHASE III

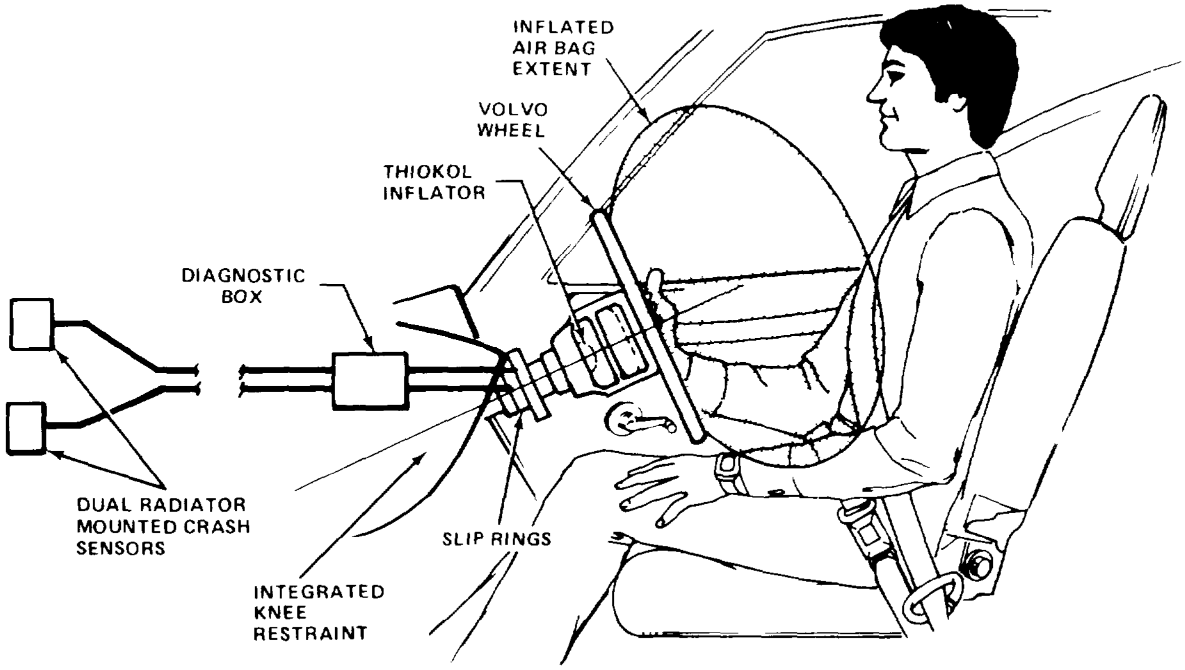

Figure 9 DRIVER RSV AIR BAG SYSTEM

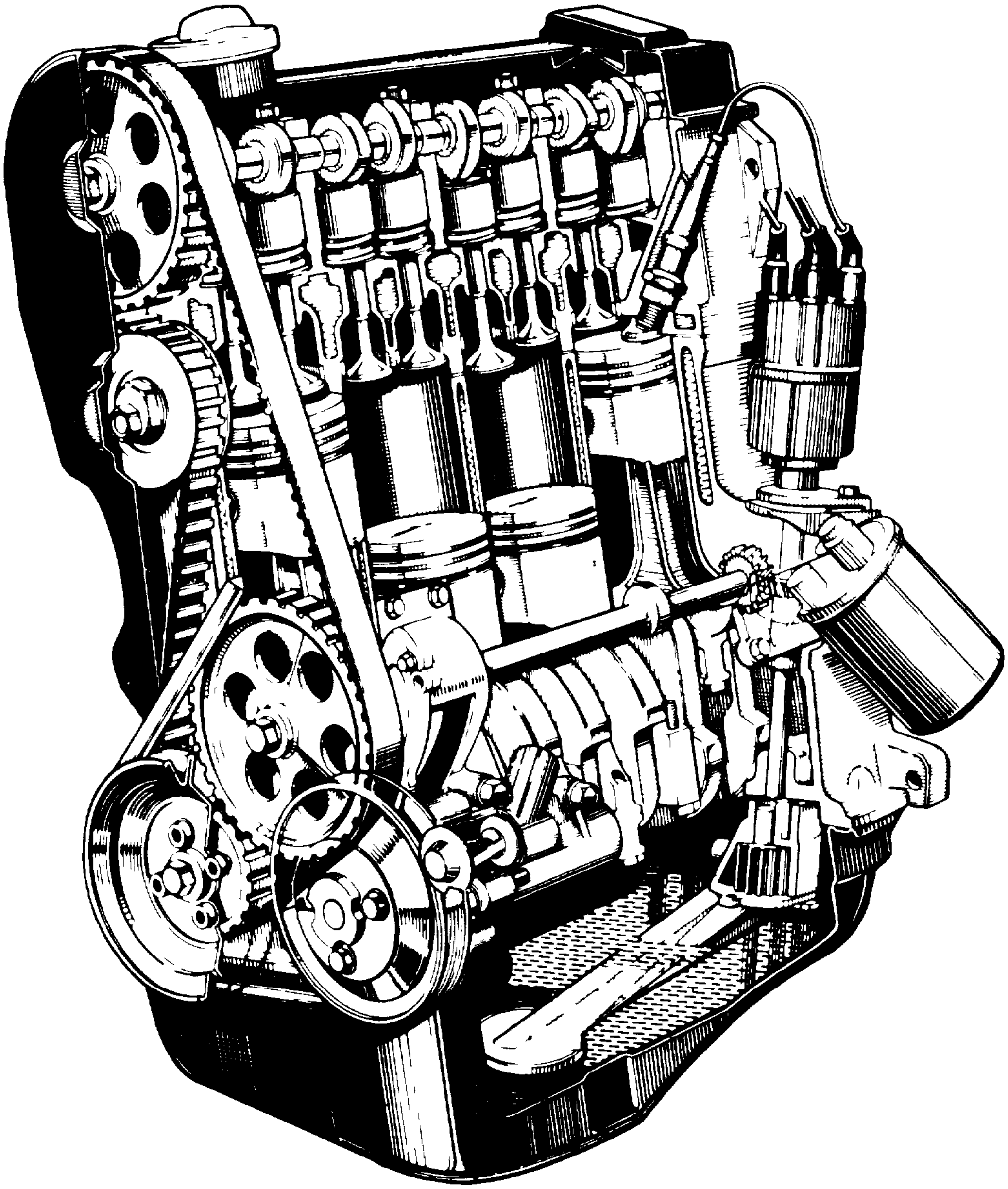

Figure 10 OMNI/HORIZON 1716 cc ENGINE

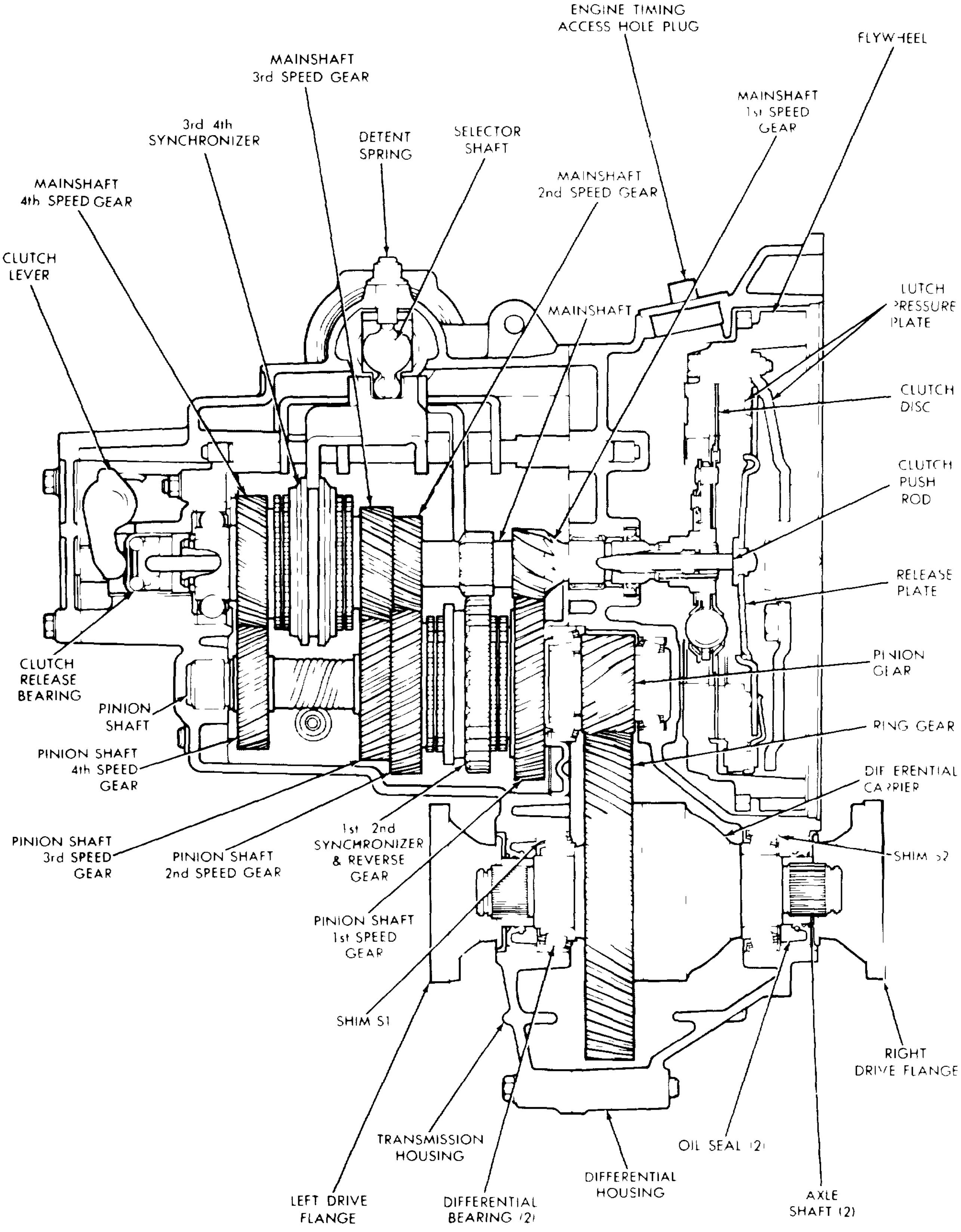

Figure 11 MANUAL TRANSAXLE SCHEMATIC

4.4 Brakes

The brakes in the RSV are essentially those from the Simca 1308, modified to provide a diagonal split to retain maximum braking in case of failure. It is a vacuum-assisted system with disc brakes at the front and self-adjusting drum brakes at the rear To reduce the possibility of locking the rear wheels with the split system lightly loaded, two proportioning valves control the hydraulic pressure to the two rear brakes. The parking brake operates on the rear brake through a cable linkage. Compliance with FMVSS 105 was demonstrated by tests performed at the Chrysler Proving Ground as reported in Reference 8. Performance data are included in the specification in the Appendix.

An anti-skid (or adaptive) brake system (ABS) was developed by Bendix for the RSV During development, the system was initially installed on a Simca 1308, results of tests of that system are included in Reference 13. Unfortunately, delays in developing a satisfactory ABS system and, subsequently, the unavailability of a Phase IV RSV on which to install it have precluded completion of that effort. The ABS system is currently planned to be installed by Bendix on Vehicle No. 6 and checked by Calspan, its evaluation will be carried out in Phase IV. The brake systems are completely described in References 39 and 40.

4.5 Steering/Suspension

During Phase III, the basic modification to the steering system involved changes to achieve the desired reduction in the turning circle from 13.7 to 11.6 meters (45 to 38 feet) without experiencing over-center conditions in the linkage or exceeding the limited acceptable angles for operation of the constant velocity universal joints. These requirements involved a redesign of the steering knuckle. In addition, a new fabricated lower control arm was designed to accommodate the increased RSV loads and take advantage of standard U.S. high-production manufacturing practices. The front swaybar and torsion bars and their anchors were also redesigned. The tires were also changed during Phase III. The 14-inch Goodyear runflat tires with internal stabilizers that had been picked in the Phase II design were supplanted by new 13-inch Goodyear flatproof tires capable of supporting the vehicle on their specially designed sidewalls. These new tires were developed to provide a capability for running 40 miles at a maximum of 40 mph after the internal pressure had been depleted. Since there is so little change in vehicle response, a low pressure indicator was added to warn the driver of pressure sufficiently low that it could lead to tire destruction. These various changes are documented in References 4 through 11, 39 and 40. Figure 12 shows the 13-inch flatproof tire supporting the front of the RSV despite removal of a section to show its construction.

4.6 Lighting

For the Phase III design, CIBII developed a new plastic single-beam headlight, shown in Figure 13. It does not comply with FMVSS 108. The performance objective of this lamp is to provide sufficient light for the driver to see the road ahead as well as he does with American high beam and at the same time, improve his vision along both sides of the road without subjecting on-coming driver to objectionable glare. The beam cut-off is less sharp than is common practice in Europe, but more distinct than that exhibited by current U.S. lamps. Figures 14 and 15 show the beam patterns for the standard sealed beam low beam and the RSV. A CIBII-developed hydraulic headlamp aim compensator is available for dynamic adjustments which could eliminate some of the objections associated with the bounding of the upper cut-off of the beam. Lexan covers have been applied over the headlamps to provide a smooth unbroken surface to pedestrians, to reduce aerodynamic drag and to eliminate the possibility of collecting snow in winter. In addition to the normal parking and turn signals, side marking lights and conventional stop and taillights, rear high level taillights with combined side markers that provide all the normal taillight functions have been added on the D pillar at a position between the beltline and the roofline (as shown in Figures 3 and 4). The lights are discussed in References 5, 7, 11, 39 and 40.

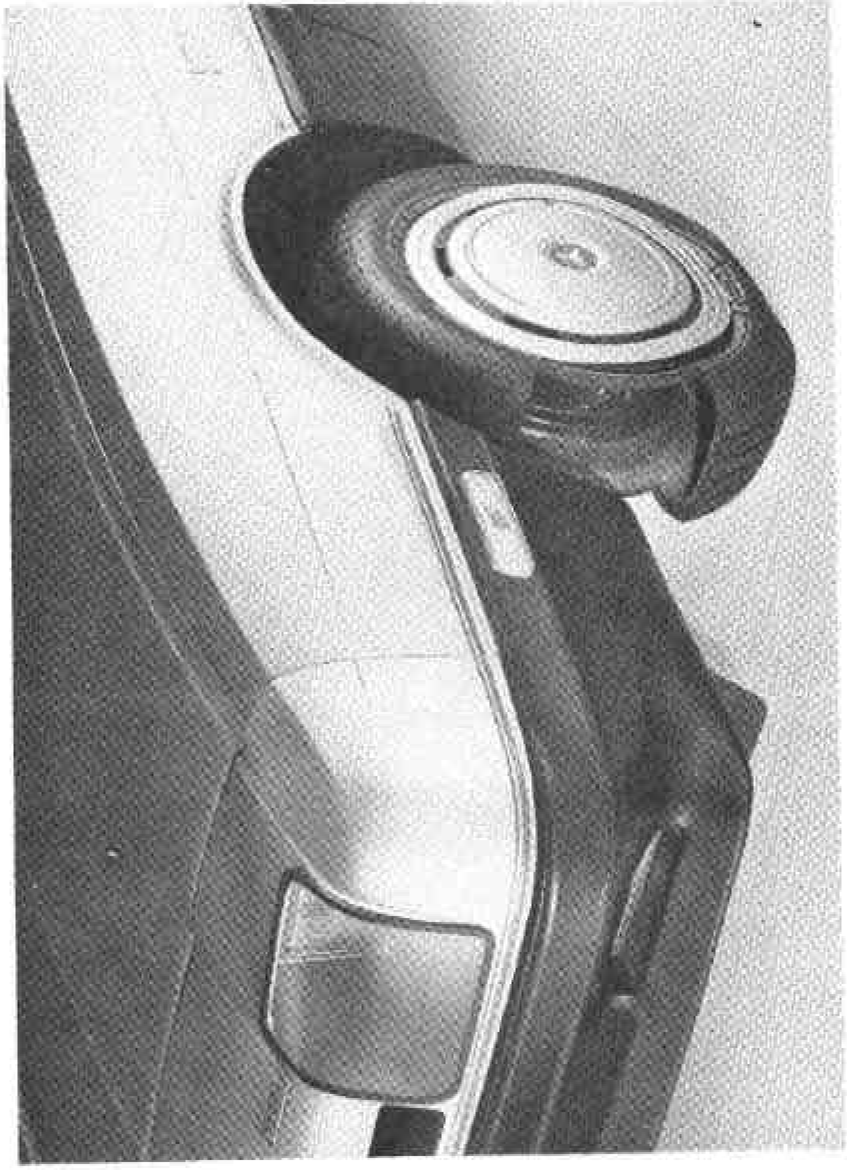

Figure 12 FLATPROOF TIRE

Figure 13 RSV PLASTIC HEADLAMP

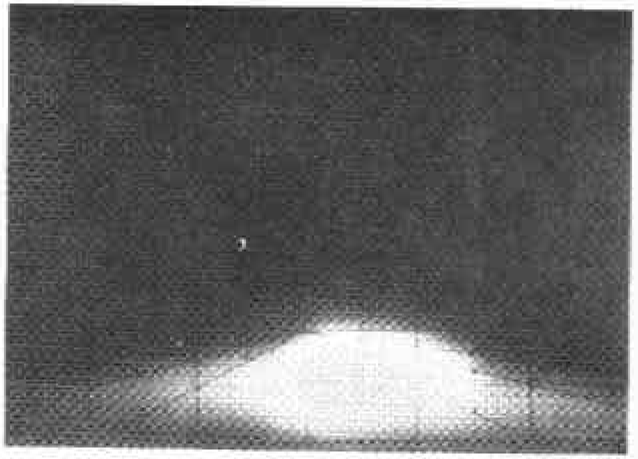

Figure 14 STANDARD TUNGSTEN SEALED BEAM LOW BEAM

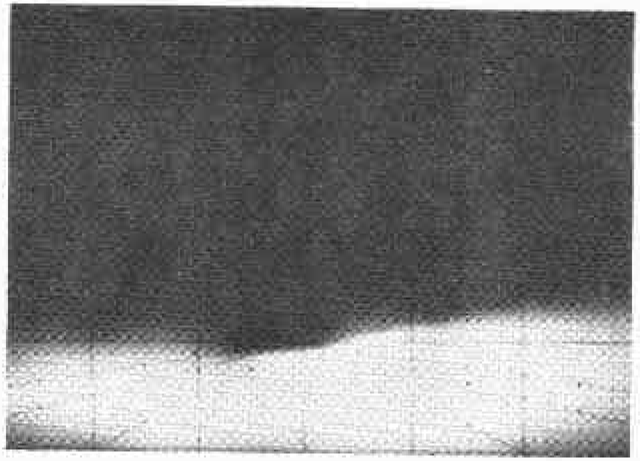

Figure 15 RSV HEADLIGHT BEAM

4.7 Functional Systems

During Phase III, the design of the functional systems such as engine cooling, heating/defrosting, electrical, instrumentation, and fuel systems were completed as discussed in References 5, 6, 7, 8, 10, 16, 39 and 40. The radiator appropriate for the Chrysler 1716 cc engine is mounted in the RSV for Phase III along with the proper thermostatically-controlled fan and, if required, a condenser for the air conditioning system. The heater/defroster system has been carried over directly from Simca 1308 as have the instruments and electrical system insofar as possible.

The fuel system includes modifications to the Simca fuel tank to move it forward, slightly reduce its volume and change its mounting to a strap type system which is less prone to damage in rear end impacts. In addition, the filler pipe has been changed to further remove it from the rear damage area and an evaporative control system with charcoal canister for vapor storage and rollover vapor separator have been added from the Chrysler Omni/Horizon The frame mounted trailer hitch developed for the baseline Simca is available for use with the RSV. Also, a storage well was added to the rear luggage compartment area in the space previously occupied by the spare tire and fuel tank

Since weight has been regarded as a very critical element in the development of the RSV, a program for monitoring weight changes and keeping track of the final vehicle weight was maintained throughout the Phase III program. The success of that activity is substantiated by the fact that the final cars built for evaluation in Phase IV tests were within five pounds of the estimated weight A summary of the vehicle weight changes as a result of modifications in Phase II and Phase III is shown in Figure 16. The value on the first line is for the French car that does not meet U.S requirements More detailed information on the final vehicle weight is included in the Final Design Report [40]

	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		1029 411		2264.69
FLIGHT STRUCTURE		59 502		132 62		64 784		142.85
SIDE STRUCTURE		75 953		168 67		73 22		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
OCCUPANT PROTECTION		33 991		74 95		39 610		87 34
ENVIRONMENTAL PROTECTION						9 614		21 20
STEERING & SUSPENSION						–4 739		–10 45
PRODUCIBILITY & SHIPPING		1 969		4 34				
TOTAL CAR		1202 424		2653 18		1210 755		2669.62

Figure 16 SUMMARY OF WEIGHT CHANGES EFFECTED IN RSV PHASE II AND PHASE III MODIFICATIONS TO THE BASE CAR

4.8 Styling

The final styling of the RSV was developed at Chrysler to accommodate the Phase III changes. Although aesthetic appeal is important, the aerodynamic evaluation conducted by Chrysler at the NRC wind tunnel in Ottawa, Canada dictated the majority of the exterior shape revisions. The success of the aerodynamic development is indicated by the drag coefficient reduction from 0.49 for the Simca to 0.42 for the RSV. The conformation of the interior trim parts was primarily determined by occupant safety considerations, and includes such components as instrument panel, knee blocker, door trim panels, energy absorbing elements, pillar padding, and restraint systems. Both fuel economy and occupant safety were primary design objectives and a very attractive appearance that possesses a high degree of consumer appeal was achieved. Figures 1 through 4 show the exterior of the vehicle. The interior is shown in Figures 17 and 18. The styling activity during Phase III is discussed in References 5, 6, 7, 11, 39 and 40

4.9 Width

At the start of the Phase III, an investigation was undertaken to assess weight and cost penalties associated with adding width to the vehicle to compensate for space taken up by the energy absorbing door panels. This modification would restore the capability for accommodating three full-size occupants in the rear seat. It was estimated that the indicated four-inch increase in width would add 50 pounds to the weight of the RSV, if applied to all vehicles built in Phase III, the additional cost including design, tooling and parts would be $1,500,000. The investigation is reported in References 3 and 4. Widening the car is a straightforward engineering task that involves the development of no new technology, its realization would contribute neither research nor test data applicable to automotive safety requirements for the mid 1980s or their evaluation Consequently, it was deemed not cost-effective, and hence inappropriate at that time to increase the width of the RSV.

Figure 17 RSV FRONT INTERIOR

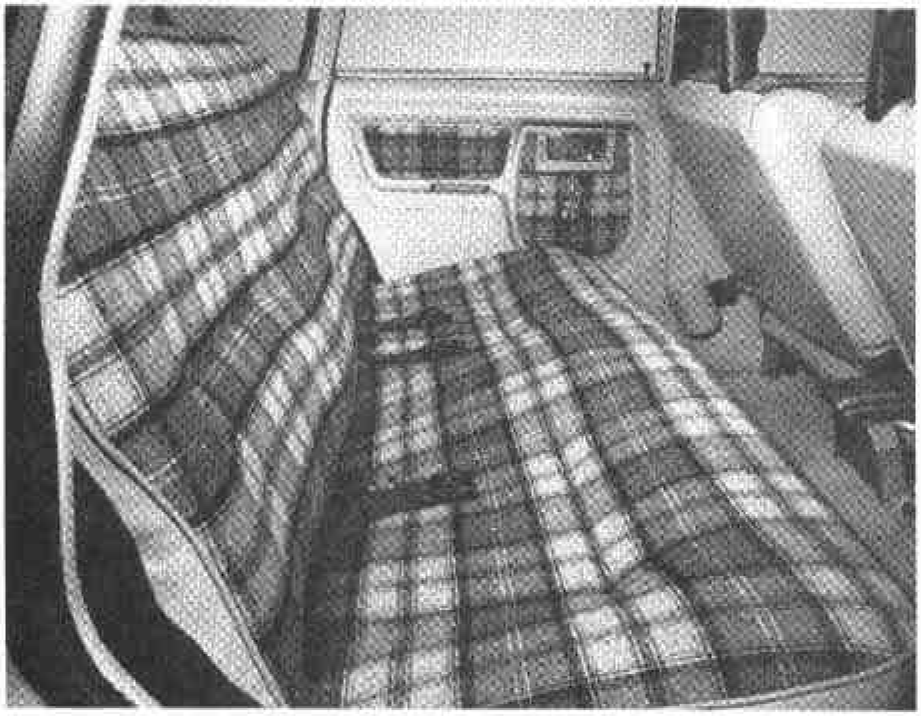

Figure 18 RSV REAR INTERIOR

5.0 ANALYSES AND EVALUATION SUPPORT

Important advances relative to computer modeling were made during the Phase II study. There the modeling was used primarily as a design tool to provide a means of establishing design parameters. In Phase III both structural collision models and the Calspan Crash Victim Simulation computer program (CVS) were employed to support the structural and restraint system design and development. Since a computer simulation model is a mathematical representation of analog of a physical system in which the equations describing the properties and behavior of the system are programmed for solution by computer, it is clear that the calculated result can be no more accurate than the simplifying assumptions and lumped parametric variations used in defining the model. In fact, the complexity of the physical system itself usually precludes accurate mathematical definition. Consequently, differences can be expected between the responses of actual systems and those predicted by the mathematical models. However, even though predicted responses must be viewed with caution, their utilization for comparative purposes to assess the results of changes of a single parameter, particularly within a matrix of experimental data, can considerably broaden the scope of an experimental investigation.

In Phase III, both the structural and restraint systems design and development were guided by computer simulations. To extend the applicability of the previous work, a survey was undertaken at the start of Phase III in an attempt to identify and obtain a more generalized collision model. The results of that investigation indicated that no improvement on the previously employed Calspan Three-Dimensional Crash Victim Simulation computer program (CVS III) was available. It retained a multi-dimensional capability allowing application to a broad range of dynamic systems and at the same time was easy to use in a predictive capacity. As a result, it was useful both for the vehicle structure and the restraints to be employed within that structure. The program was used to support the planning and conduct of dynamic tests of the vehicles as well as the analysis of the data obtained in those tests. The results of the frontal barrier impact tests (e.g., Reference 29) demonstrated that vehicle pitch and frontal compartment intrusion had been minimized, albeit at the expense of reduced crush distance and consequently higher passenger compartment accelerations. Simulations of the vehicle test which reproduced the vehicle deceleration and crush to a reasonable degree were successfully extended to investigate the effect of modifications in the restraint system in an effort to find a mechanism to alleviate the results of the high maximum acceleration. A comparison of the changes of the dummy responses resulting from modifications of the system components was readily, and relatively inexpensively, available from the computer, even though the absolute values of the results might be questioned, the predicted trends were borne out by subsequent tests. Examples of results of utilizing mathematical modeling in the analysis and evaluation of the RSV Phase III program are included in the paragraphs below.

5.1 Structural Model

The structural model was modified to approximate the vehicle response shown in frontal barrier Test No 10. A comparison of the computer simulation to the test deceleration pulse, which is in fact the average between the sill, tunnel and header, is shown in Figure 19 (from Reference 13). The excellent correlation shown was the result of changes in the static crush force/deflection characteristics of the various front-end components. Further extensions of the component modifications were investigated in an attempt to reduce the peak deceleration levels. In addition, simulations were made at various speeds to determine if a speed reduction would reduce the peak g's. As indicated in Reference 13, speed reduction to 35 mph did not materially reduce the maximum accelerations. A simulation of sheet metal modified to represent a load beam that had been lengthened and slots added to the upper load beam indicated possible achievement of a less harsh deceleration environment. However, these changes would have required considerable modification of tooling as well as a scrapping of parts that had already been made.

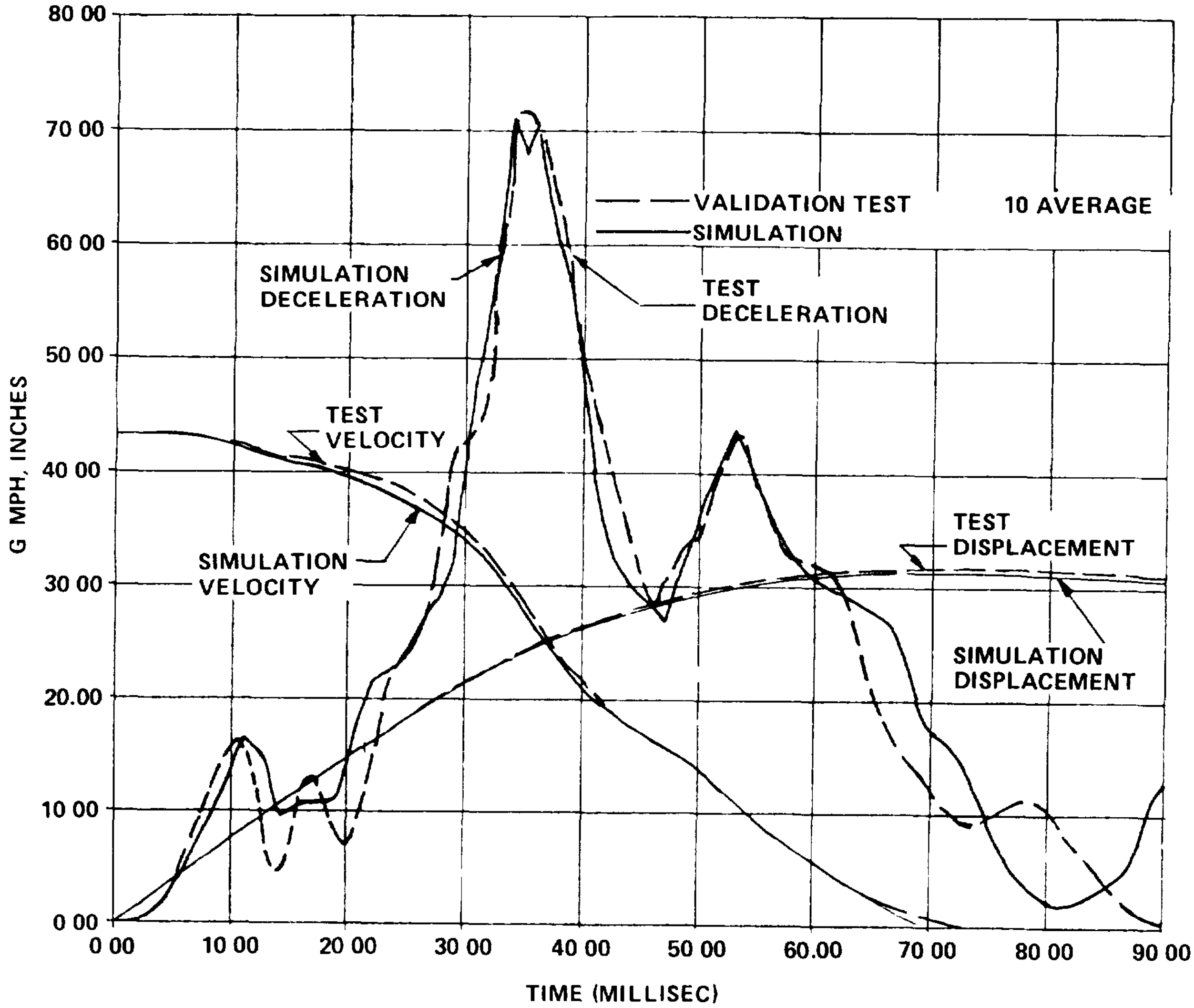

Figure 19 MODEL SIMULATION OF TEST PARAMETERS

The side impact model was used in conjunction with CVS III simulation to assess the aggressiveness of the Phase IV front end design. The one-dimensional side impact model simulated the results of Test No. 6 reasonably well.[14] Based on average passenger compartment acceleration traces, a maximum total dynamic crush of both vehicles was shown to be 26.2 inches at 67 msec after impact. Of that amount, roughly 5.7 inches occurs in the struck car, while 20.5 inches takes place in the front of the striking vehicle. The computer model and the test showed very similar results, although, of course, there were differences because of disparities between the average test and computer-generated acceleration waveforms

5.2 Occupant Models

The CVS III program was used to develop the restraint system to satisfactorily accommodate the 72 g acceleration pulse demonstrated in Test No. 10. Computer simulation of the occupant response, when exposed to the 55 g maximum available sled acceleration, was compared to that calculated from the actual Test No 10 pulse. Figure 20 shows two sled pulses as well as the Test No. 10 pulse for comparison The pulse of Run 2062 seems to be a reasonable simulation of Test No. 10 except that the peak acceleration at 35 msec is only 55 g's instead of the 72 g's registered in the vehicle test However, 55 g's was the maximum acceleration pulse that could be developed with the RSV sled buck with its weight reduced to a minimum and carrying only one occupant. Simulation results of the occupant responses for the Test No 10 pulse compared to those of Run 2062 and 2067 are shown in Figures 21 and 22 along with the actual dummy head and chest resultants experienced in the sled Run 2062. It is recognized that the modeling of the physical components is inexact, further, since the head is a very light mass at the end of a lever arm, small differences in force applied to it could have a significant effect on the resultant head acceleration. However, with these limitations in mind, the simulations used in a comparative manner rather than as a predictive tool were useful in assessing response changes due to variations in the occupant environment. In the belief that the model could predict a trend, two

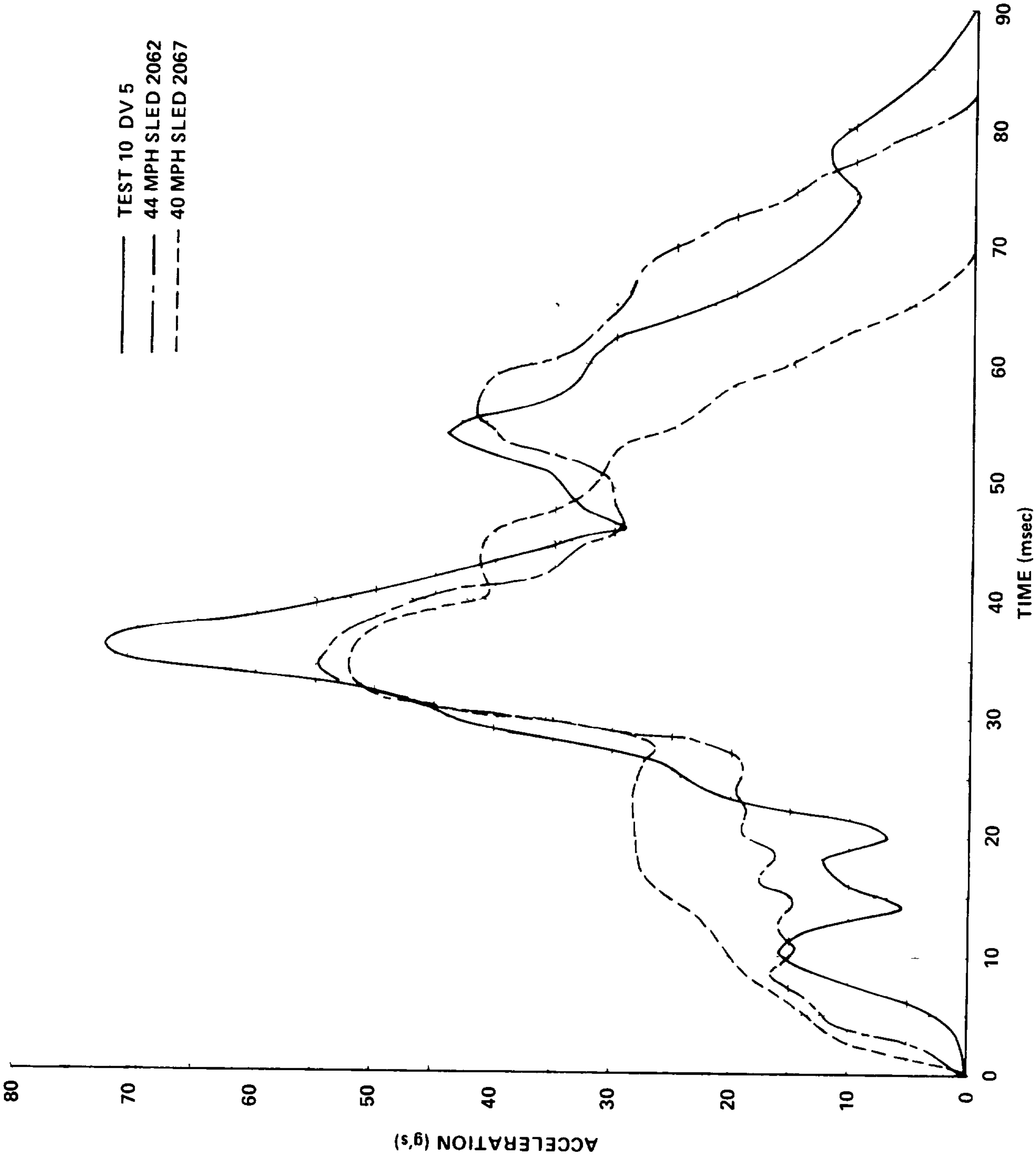

Figure 20 RSV ACCELERATION VS. TIME CURVES

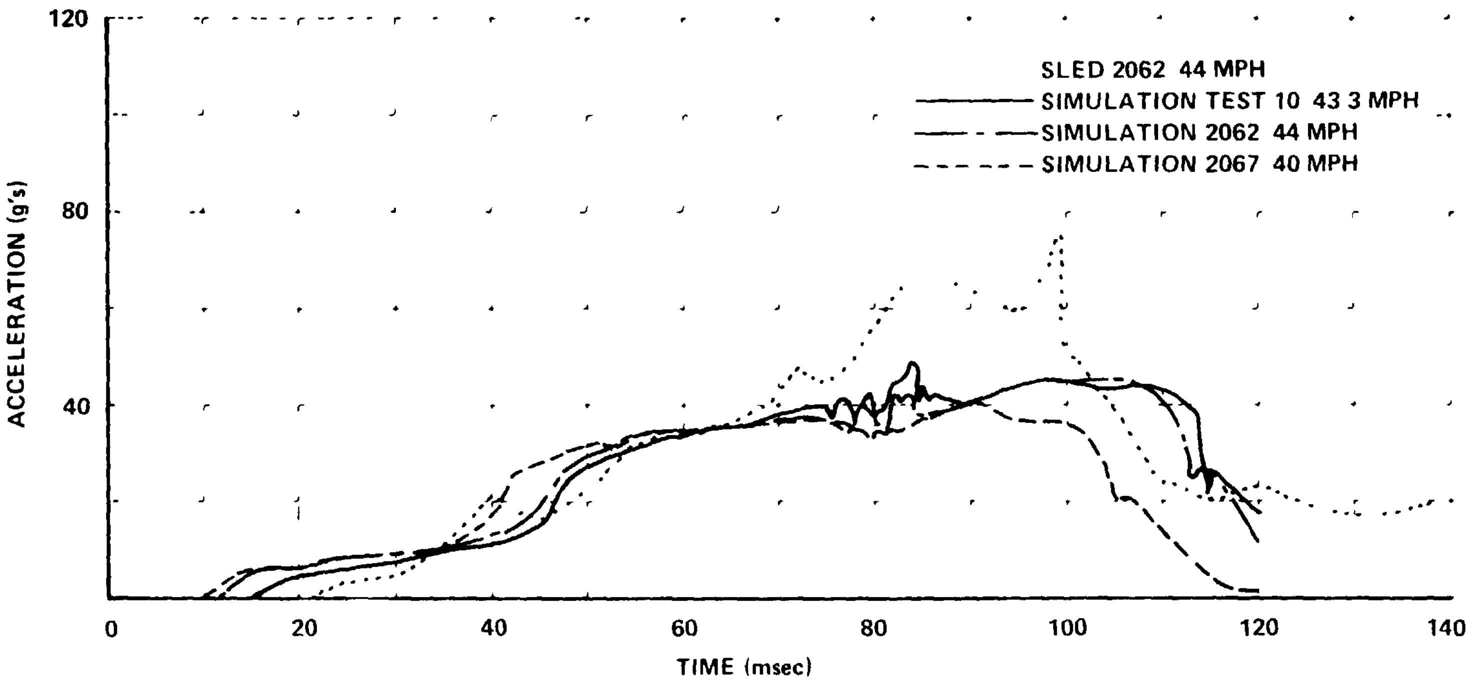

Figure 21 HEAD RESULTANT ACCELERATIONS VS TIME

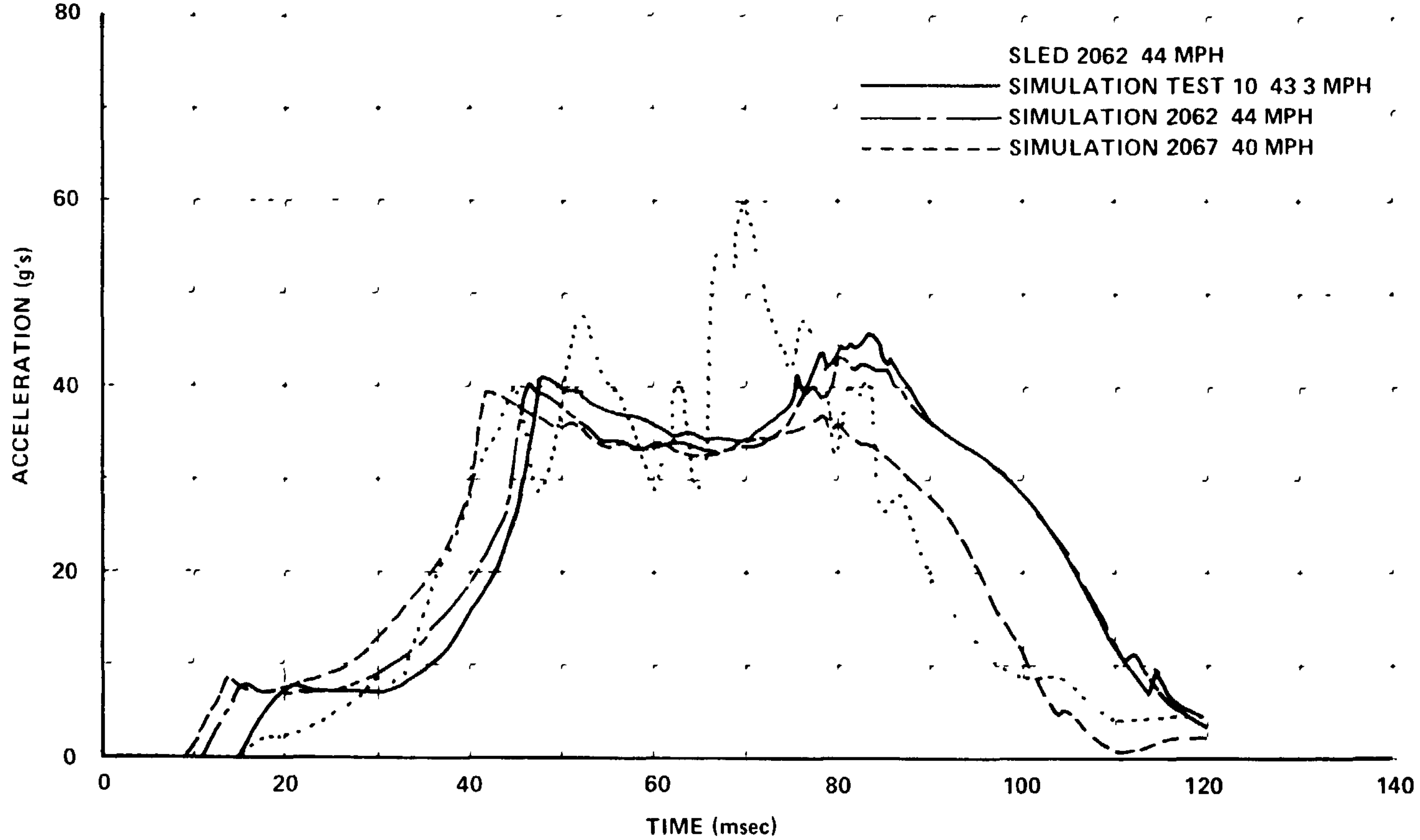

Figure 22 CHEST RESULTANT ACCELERATION VS. TIME

conclusions were drawn. First, the increased peak acceleration of the Test No. 10 pulse has relatively little effect on the head acceleration since the three simulations do not vary widely. Second, the decreased speed associated with the pulse for Run 2067 has a small effect on the maximum values observed although the duration is less.

The simulations were utilized in this manner to investigate variations in the characteristics of different components such as modifications in the knee blocker force displacement characteristics. Those desired characteristics were utilized in the revision of the knee blocker design in order to optimize it for the observed acceleration pulse.

5.3 Performance Simulations Studies

The task was added to the RSV Phase III contract in the spring of 1978 to support NHTSA personnel operating basic models of the Calspan RSV for their independent simulations and parametric studies in anticipation of crash test evaluations.

6.0 DESIGN VALIDATION TESTS

The objective of this task was two-fold (1) the principal goal was to obtain fundamental data with which to assess the performance of RSV design revisions implemented during Phase III, (2) a secondary goal was to obtain detailed experimental data to be used to validate the occupant and structural simulations performed during the Phase III design resolution process Within the scope of that effort, tests were performed on selected crash avoidance, functional, and crashworthiness subsystems to provide an evaluation of the RSV design[40] Duplication of Phase II tests that were not relevant to the evaluation and validation processes was avoided. In general, Calspan performed the crashworthiness tests and Chrysler tested the functional systems, crash avoidance tests were conducted by both organizations. An outline of these tests is shown below

	Subtask	Performing Organization	Type of Test
6.1	Structural Design	Calspan	Static Vehicle Crush
6.2	Restraints Validation	Calspan	Accelerator Sled
6.3	Functional Systems	Chrysler	Proving Ground
6.5	Driveability/ Acceleration	Calspan/Chrysler (Grade Starts)	Proving Ground
6.6	Handling and Braking	Calspan (Handling) Chrysler (Braking)	Proving Ground
6.7	Integrated Systems	Calspan	Barrier & Car-to-Car Impacts

For the conduct of these tests, two static crush articles, four integrated systems cars, one chassis development car for functional systems tests, and a prototype which embodies the Phase IV RSV front structure and sheet metal were fabricated by Modern Engineering Services in Detroit Each subtask is discussed below.

6.1 Structural Design Validation

Static crush tests of the RSV front and side structure were conducted to demonstrate the performance capability of the design. These tests were performed on the Calspan crusher to obtain load/deflection data of the various structural assemblies and components. The static crush report[18] gives the detailed results of these tests. The first crush test article was used to obtain data for the crush of the front and rear structure. The second was used for side tests Its right side was made completely of mild steel, while its left side incorporated HSLA components. An SAE barrier was used in the test to crush the restrained vehicle. The total force levels generated in the right side were very similar to those on the left, both reached a maximum slightly over 40,000 pounds. The small difference in overall force levels that appeared could be attributed to the softer support system on the left hand side or possibly an effect from previous tests In any case, the differences were very minor.

Crush tests of various components were also performed to obtain force deflection data for use in structural simulations. The front bumper, the front rail, the upper load beam, and the floor pan were investigated. The procedures for the static crush tests of the Phase III RSV are included as the appendices to References 8 and 9.

Following the unsatisfactory performance of the front structure in the first Phase III frontal barrier test, static crush tests of a modified longitudinal were performed prior to another barrier test in an effort to assess the performance changes resulting from redesign. This information is reported in Reference 11. It rapidly became apparent on initial loading of the rail that the crush load in the forward zone was too high, hence, an additional relief slot was put into the bottom flange. This caused the initial collapse to occur at 10.2 kips (approximately the desired load). The undercut motor mounts behaved as intended, deforming to allow forward rail crush The reinforcement under the floor did not exceed the static limit, however, crippling occurred in the sidewall of the "D" section and collapse finally occurred forward of the reinforcement. To combat the bending, an additional reinforcement of the seam between the floor board and dash panel was added at the level of the top of the rail offset to counteract the rotation of the "D" section and the bending stress in the rail.

Figures 23 and 24 show the front end of the RSV before the frontal crush and after the test was completed. Figure 25 shows the configuration of the modified rail as it was initially placed in the crusher as well as in its final bent condition

After the frontal barrier crash of the prototype front structure, another series of static crush tests was performed to develop an appropriate support structure for the knee blocker. Its purpose was to provide the desired kinematic responses of the occupants despite the severe acceleration experienced in the barrier tests. This effort is discussed in Reference 15. Figure 26 shows the manner in which the dummy knees were forced into the knee blocker in the sled buck. The support structure, shown in Figure 27, was developed to provide a resistance to knee motion consistent with the results of the modeling effort discussed previously in Section 5.2. Results of sled tests utilizing this revised knee blocker support are discussed in the next section.

6.2 Restraint Validation Testing

As proposed in the Phase III plan,[3] following its development using a 35 g maximum deceleration pulse postulated in Phase II, a series of sled tests of the final design of the automatic air belt system was performed to evaluate the capability of the design. The objective was to validate on the sled the design developed under Task 4.2. Twenty-five validation sled tests were conducted on the driver and passenger air belt to determine system performance sensitivity. Variables examined included occupant size, sled speed, lap belt use, seat position and sled angle. Emphasis during both the developmental and validation tests was directed toward demonstrating performance

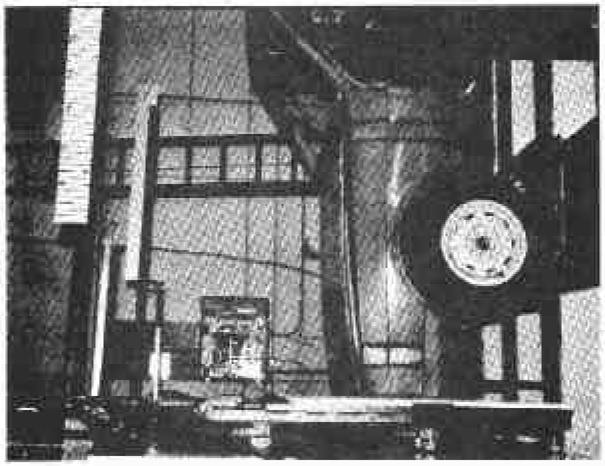

Figure 23 RSV PRIOR TO FRONTAL CRUSH

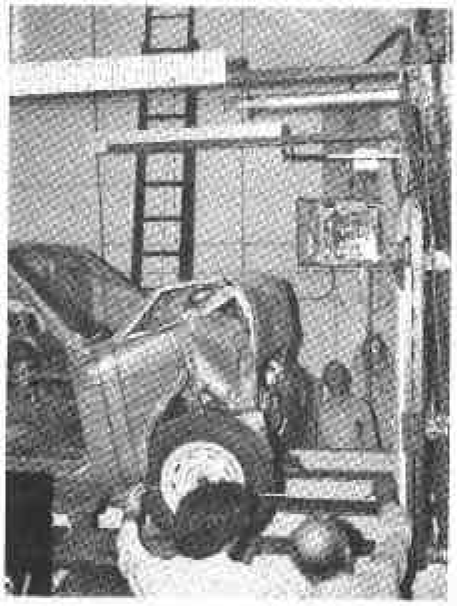

Figure 24 RSV AFTER COMPLETION OF FRONTAL CRUSH

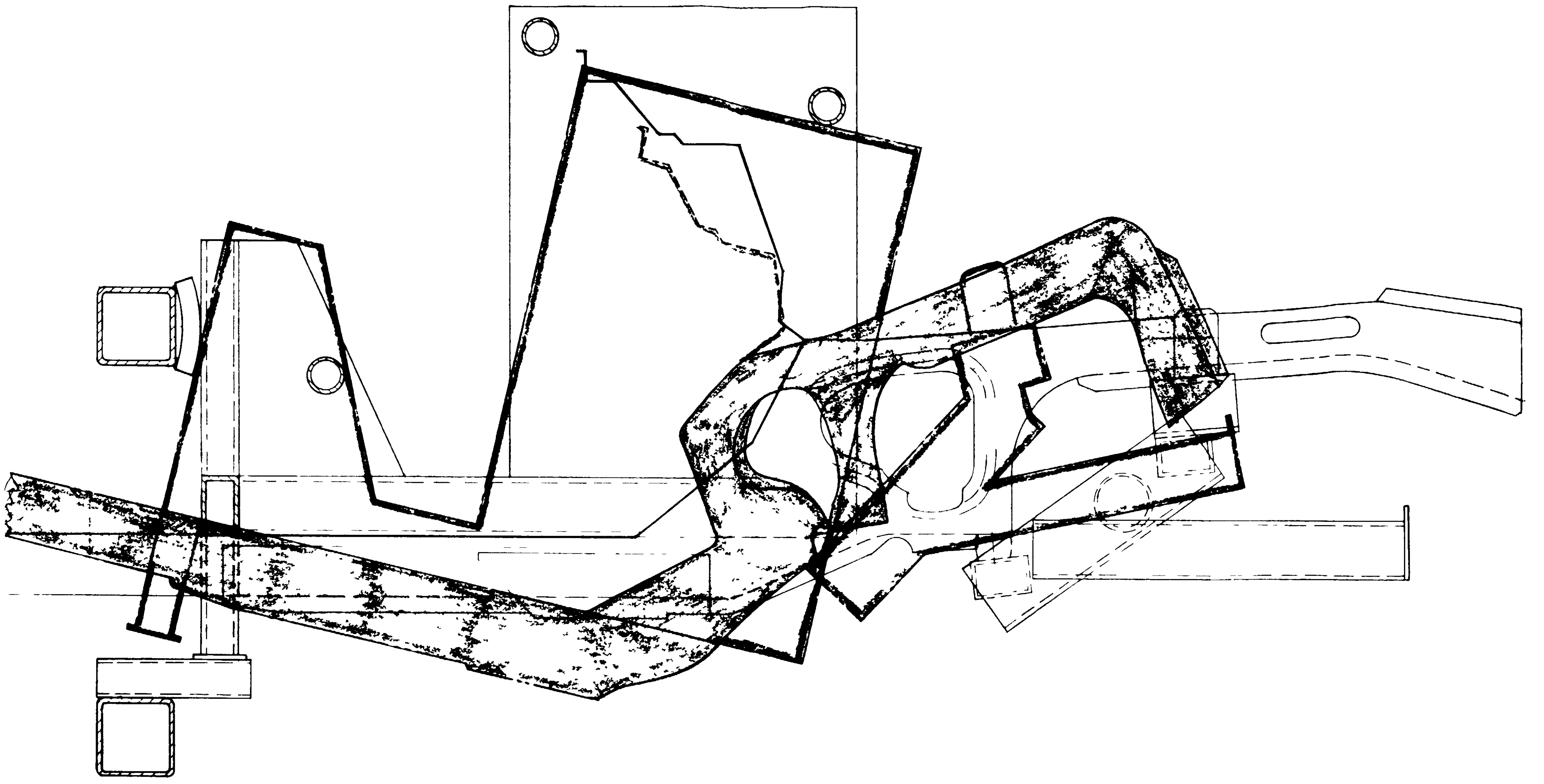

Figure 25 MODIFIED RAIL CRUSH CONFIGURATION

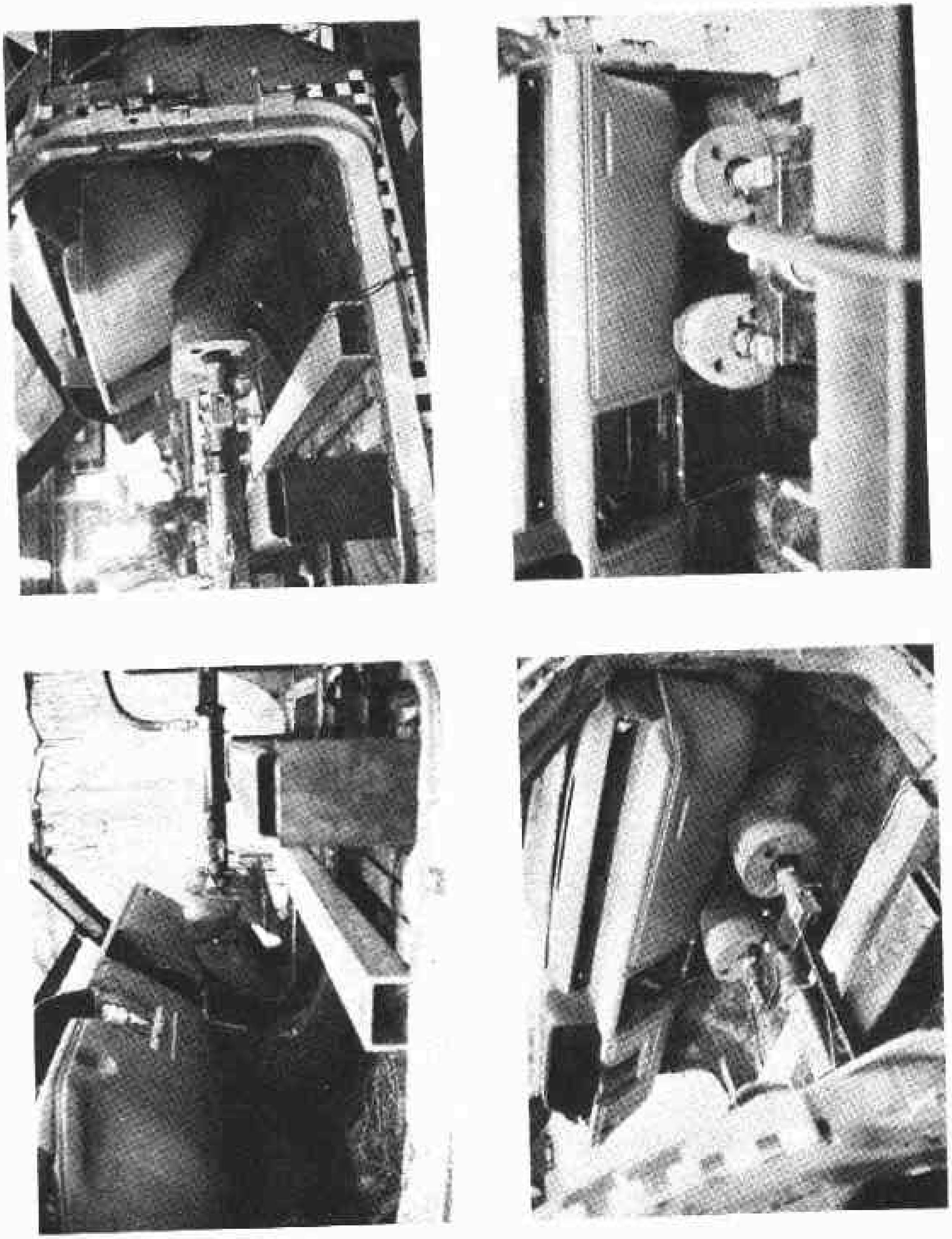

Figure 26 RSV KNEE BLOCKER CRUSH TEST

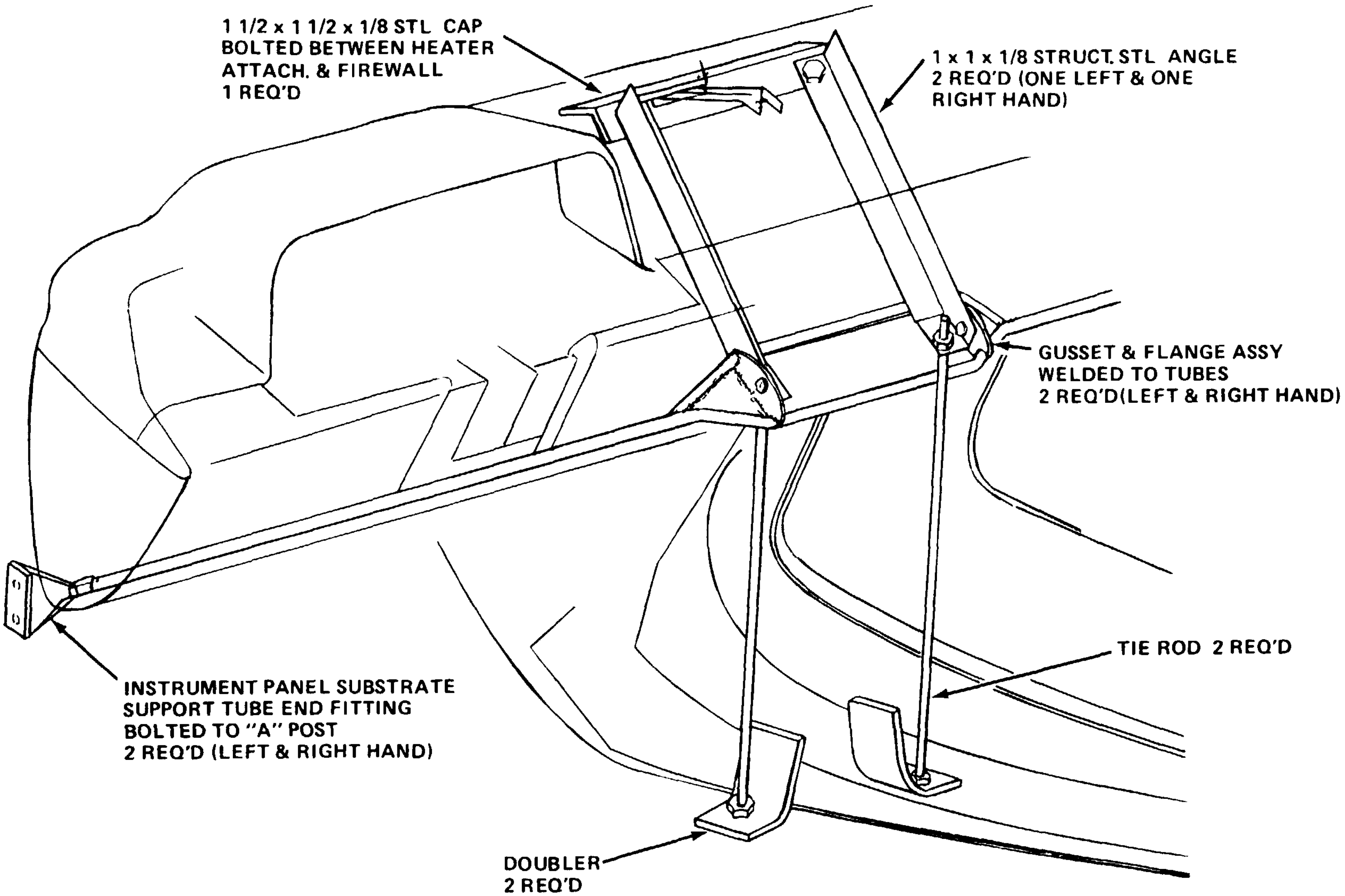

Figure 27 RSV KNEE BLOCKER SUPPORT STRUCTURE MODIFICATIONS

with the 50th percentile male size dummy occupant in both the driver and passenger seating positions. Figure 28 shows the air belt on the passenger side. (In Section 4.2 Figure 8 schematically shows the installation and the action of the D ring driving motor to provide an automatic belt capability.) As indicated in the development report,[19] satisfactory performance was achieved on the sled using the 35 g pulse.

The driver air bag system development (under the Phase II contract) is described in detail in Reference 20. The installation in the center of the steering wheel is shown in Figure 29 (also shown schematically in Figure 9 in Section 4.2). The air bag was developed and validated using the same 35 g test pulse that was initially used with the air belt. An additional series of 15 sled runs was later undertaken with the same sled pulse to improve the driver air bag and to investigate further the Minicars-developed passenger air bag system. These tests are reported in Reference 12.

The subsequent emergence of a 72 g crash pulse (Figures 19 and 20) for the barrier test of Phase IV RSVs[16,29] confounded the satisfactory test results obtained with both systems as well as the utilization of steering column bending for energy absorption in the driver air bag system.

To further develop the restraint system in an attempt to accommodate that high deceleration, a series of sled runs using a maximum available sled g approximation of the barrier Test No. 10 deceleration pulse was initiated. This pulse is shown in Figure 30. The results of these investigations are reported in References 16 and 17. Suffice it to say here that results of restraint system modifications developed during these sled tests in conjunction with the mathematical modeling (Section 4.2) indicated that the occupants had a good chance of surviving a 40 mph collision. Although not demonstrated in Phase IV barrier tests, Japanese Phase IV car-to-car collisions (Section 15) substantiated this conclusion.

Figure 28 RSV AIR BELT

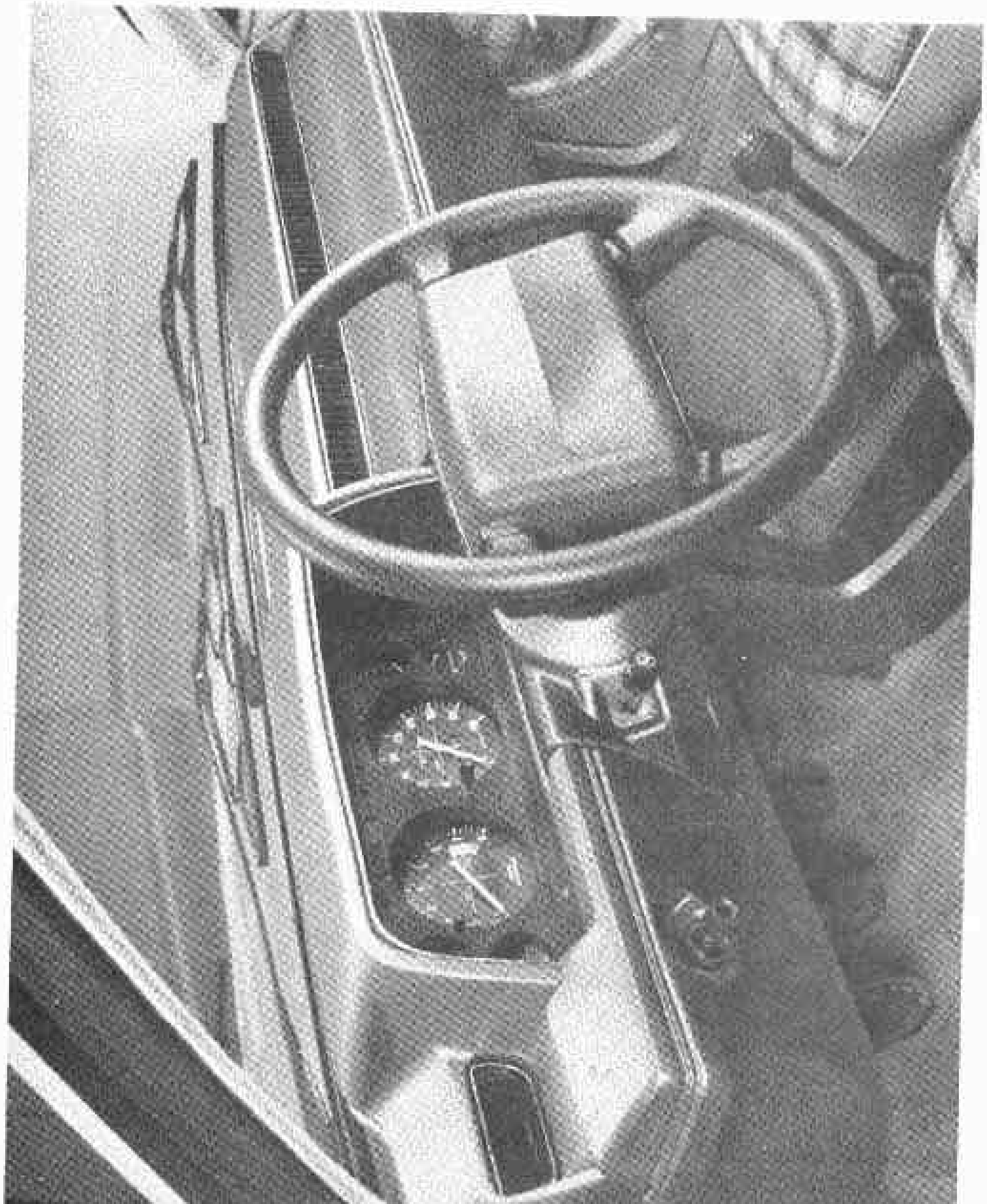

Figure 29 RSV DRIVER AIR BAG AND INSTRUMENT PANEL

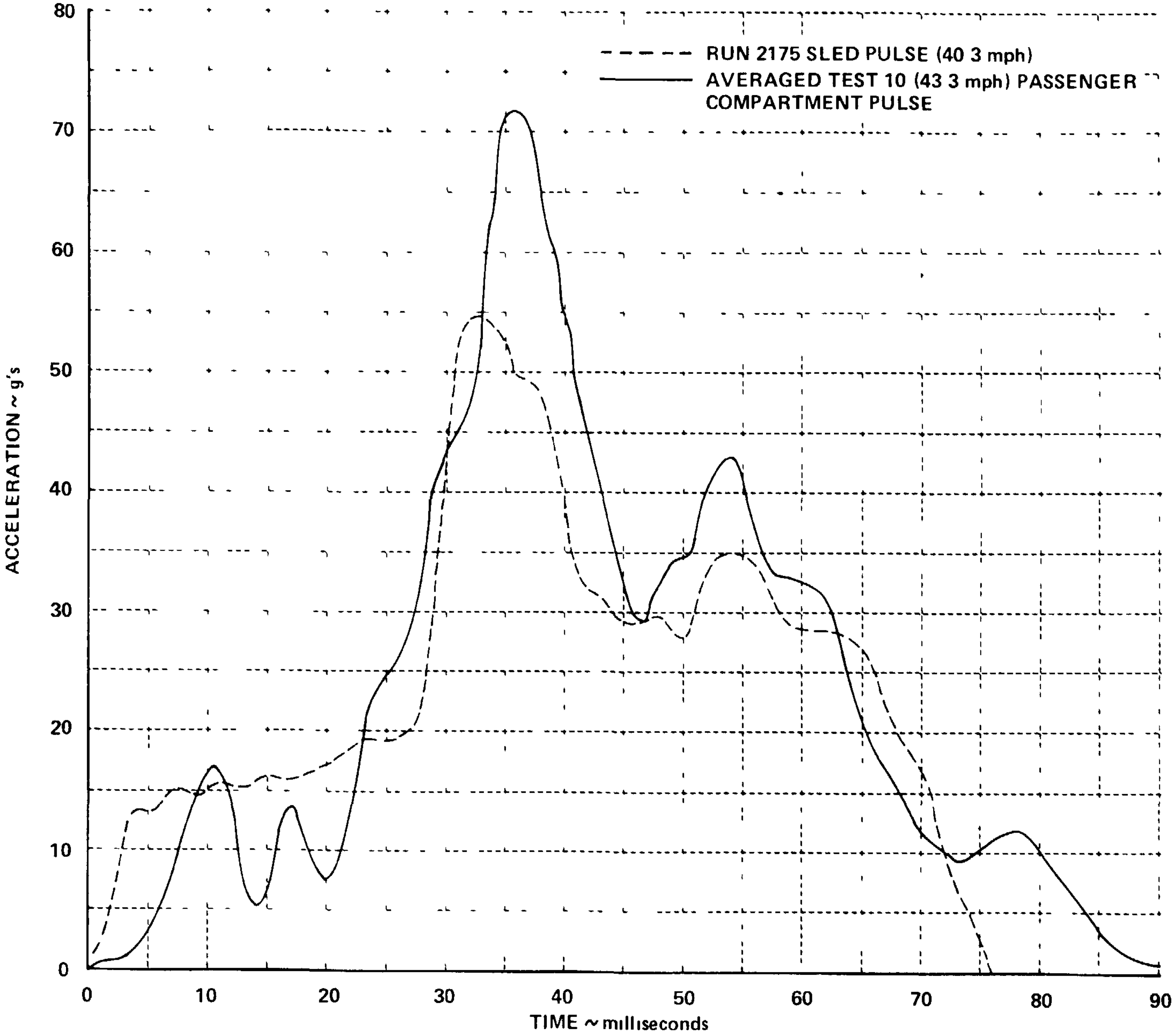

Figure 30 COMPARISON OF SLED AND TEST 10 ACCELERATION-TIME HISTORIES

6.3 Functional Systems Tests

A chassis development car was fabricated and utilized for testing the RSV functional systems at the Chrysler Proving Grounds to validate the design of RSV non-safety performance. The systems included engine, cooling, fuel, electrical, instruments, and controls. The tests are discussed in References 6, 7, 8 and 14. The RSV engine cooling performance was evaluated in the Chelsea Chrysler Wind Tunnel. As indicated in References 8 and 40, the manual transmission RSV was well within the desired cooling performance goals, even with the upper cooling slots closed. However, it was projected that the upper cooling slots would provide the increased performance needed to accommodate the heat load added by an air conditioner and an automatic transmission. The test also indicated that the underhood and underbody temperatures were satisfactory and, with a double walled heat shield installed between the tail pipe and the fuel tank, the underbody temperatures would be satisfactory even with one spark plug malfunctioning (aggravating temperature effects in the catalysts).[40]

6.4 Durability/Vibration Tests

To be meaningful, these investigations must be conducted on the final design. Therefore, they were scheduled to be accomplished on Phase IV vehicles at the Chrysler facilities. Unfortunately, other higher priority tests and rescheduling of the Phase IV vehicles has precluded accomplishment of either the 25,000 mile durability or the vibration tests. At present, it is not anticipated that these tests will be run.

6.5 Driveability/Acceleration Tests

Driveability characteristics of the final RSV were examined on Phase IV Vehicle No. 8 in three principal areas acceleration, range, and insensitivity to lateral force effects. Results of full scale tests of these characteristics are reported in References 8, 9, 16, 17 and 40. The RSV met all acceleration goals. A summary of these results is given in Table 2. Gas mileage indicated a range of over 250 miles, and, in driveability tests,[16] the RSV exhibited good handling characteristics as well as commercially acceptable ride qualities.

6.6 Handling and Braking

By the time of completion of the Phase II studies, a reasonably firm foundation of information on the handling and braking characteristics of the Simca 1308 base car* had been established by simulation and full-scale test results. As reported in Reference 2c, performance generally satisfied ESV/RSV specifications, and it was expected that the proposed modifications to the design in Phase III would not adversely affect RSV characteristics. This indeed was the case. Full-scale testing of a chassis development vehicle (mule car) midway through Phase III (as described in Reference 33) and of the final design late in the phase (results of which are reported in Reference 34) showed the RSV to satisfy all requirements. Minimum performance limits were comfortably exceeded for several criteria.

Of the many changes made to base car design to improve its safety quality, those having substantial influences on handling and braking characteristics are

- increase in engine displacement to 1716 cc (with consequent weight increase and change in weight distribution)

- application of flatproof tires (having different performance characteristics and increasing the unsprung mass)

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*The production automobile on which the Calspan/Chrysler RSV is based is the Simca 1308 sedan. It is referred to as such in this discussion of handling and braking, but it should be understood that modifications in Phase II (e.g., the addition of ballast to provide an improved approximation to expected RSV weight) could have altered its basic performance characteristics.

Table 2
RSV NO. 8 ACCELERATION TEST RESULTS

	ACTUAL MEASURED VALUE	"MINIMUM ACCEPTABLE" LEVELS FOR RSV
W O T ACCELERATION THROUGH THE GEARS		
SPEED-RANGE (mph)	TIME (sec)	
0-30	6.2	
0-60	19.2	
30-65	16.3	24
40-60	9.9	11
50-70	13.5	14
DISTANCE TRAVERSED	DISTANCE (ft)	
FIRST		
5 sec	98	90
20 sec	1121	
W O T ACCELERATION IN DIRECT GEAR		
SPEED ENCOMPASSED	TIME (sec)	
50-60 mph	7.8	
50-70 mph	17.4	22
MAX GRADE IN		
TOP GEAR @ 55 mph	6.1%	5.5%

- redesign of the steering system linkage (producing a small change in steering ratio)
- increase in the moment of inertia of the steering wheel assembly (with the addition of driver restraint system components)
- increase in total vehicle curb weight (of approximately 350 pounds)
- incorporation of shock absorbers with reduced damping characteristics (primarily for ride improvement)
- incorporation of a split-diagonal braking system

The handling test vehicle is briefly described by the following physical characteristics and equipment complement.

Weights

Curb - 2627 pounds (58%/42%, front/rear weight distribution)

Reference test condition - 2976 pounds (nominal two passenger load; 54.5%/45.5% distribution)

Maximum test condition - 3652 pounds (1025 pounds payload; total distribution of 47.5%/52.5%)

Tires Goodyear P185/70R13, flatproof design; inflation pressure for reference test configuration - 35 psi (cold)

Steering Manual, 15-inch steering wheel diameter, overall ration of 22 4

Transmission four-speed manual, floor-mounted shifter; front drive

Engine 1716 cc, four cylinder, transverse front mounting

Brakes: manual disc/drum, diagonal split

RSV handling and braking performance is summarized in Tables 3 through 5 and in Figures 31 through 34. In all cases, actual performance values are compared with ESV/RSV specifications; where practical (i.e., for those characteristics for which equivalent data exist), comparisons with the Simca 1308 are also shown. These data have been drawn from References 39, 40 and 43, as well as from References 26, 33 and 34 cited previously. Additional information on handling and braking performance of the RSV (obtained in tests on one of the other eight driveable vehicles) is given in Reference 43.

These results would seem to require little detailed discussion. Satisfaction of performance specification is demonstrated for each criterion For the important safety-related stopping distance parameter, minimum requirements are surpassed by a substantial margin Also noteworthy is the performance of the vehicle when operated with an almost completely deflated tire (on either axle) and the relative insensitivity of the response characteristics to high loading.

6.7 Integrated Systems Validation Tests

A series of full-scale integrated systems validation tests was conducted with the RSV during the Phase III program. The testing scheme (see Figure 35) is reported in Reference 21, the detailed test plans. Two distinct types of dynamic tests were performed (1) low-speed impacts to evaluate the vehicle damageability aspects of the RSV design, and (2) high-speed impacts to assess RSV crashworthiness performance (i.e., occupant protection capability). The thirteen tests were performed with five Phase III development cars designated as DV-1 through DV-5.*

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*Car DV-5 was equipped with a front structure designed for Phase IV.

Table 3
RSV HANDLING PERFORMANCE

CATEGORY	PERFORMANCE			REMARKS	REF
	SPEC IFICATION	SIMCA 1308	RSV		
STEERING				FOR STEADY STATE LATERAL ACCELERATION OF 4 g	
• STEADY STATE YAW RESPONSE GAIN	SHOWN IN FIGURE 31 VOL II			UNDERSTEER GRADIENT ≐ 3 deg/g	2c, 33, 34
• TRANSIENT YAW RESPONSE	SHOWN IN FIGURE 32 VOL II			SPECIFIED AT 25 & 70 mph	2c, 33, 34
• RETURNABILITY	SHOWN IN FIGURE 33 VOL II			SPECIFIED AT 25 & 50 mph	2c, 33, 34
HANDLING					
• LATERAL ACCELERATION	SHOWN IN TABLE 5 VOL II			SPECIFIED IN TERMS OF COMBINATIONS OF ± 20% OF RECOMMENDED TIRE INFLATION PRESSURE	2c, 33, 34
• CONTROL AT BREAKAWAY	PATH RECOVERY WITHIN 4 secs	–	PATH RECOVERED IN 3.5 - 4 5 secs	MANUAL CONTROL, CLOSED-THROTTLE OPERATION TO RECOVER 100 ft RADIUS PATH FROM 110 ft RADIUS AT HIGH LATERAL ACCELERATION	33, 34
• DIRECTIONAL STABILITY	<1 ft	–	NEAR ZERO	SPECIFIED AT LATERAL DEVIATION 2 secs AFTER DISTURBANCE CONTACT	33, 34
• STEERING SENSITIVITY	>5 in-lb	–	>5 in-lb	SPECIFIED FOR YAW RATE OF 2 deg/sec AT SPEED OF 30 mph OR GREATER	33
OVERTURNING IMMUNITY					
• SLALOM	45 mph	–	50 mph	100 ft PYLON SPACING	33, 34
• BRAKE/STEER	–	–	–	LITTLE AMPLIFICATION OF STEADY STATE ROLL ANGLE	

Table 4
RSV BRAKING PERFORMANCE

CATEGORY	PERFORMANCE			REMARKS	REF
	SPEC IFICATION	SIMCA 1308	RSV		
SERVICE BRAKE EFFECTIVENESS					
• STOPPING DISTANCE FROM 60 mph	190 ft	153 ft	151 ft	RSV PEDAL FORCE ∿100 lbs	2c, 40
• STOPPING DISTANCE FROM 60 mph WITH BOOSTER FAILURE	350 ft	199 ft	192 ft	RSV PEDAL FORCE = 150 lbs	2c, 40
• STOPPING DISTANCE FROM 60 mph WITH PROPORTIONING SYSTEM FAILURE	250 ft	194 ft	157 ft	RSV PEDAL FORCE ∿ 75 lbs	2c, 40
• STOPPING DISTANCE FROM 60 mph WITH 1/2 SYSTEM FAILURE	400 ft	300 ft	329 ft	RSV DATA FOR BOTH LIGHT AND MAXIMUM LOAD, PEDAL FORCE <150 lbs	2c, 40
• FADE & WATER RECOVERY	FMVSS 105	–	SATISFIES FMVSS 105	RSV FADE PEDAL FORCE 26 lbs FOR 10 fps^2, RSV RECOVERY 29 lbs FOR 10 fps^2	2c, 40
• BRAKING IN TURN, STOPPING DISTANCE FROM 40 mph ON 357 ft RADIUS ARC	90 ft	–	85 ft		34
PARKING BRAKE					
• (30% GRADE)	< 90 lbs	–	<86 lbs	FOR BOTH UPHILL AND DOWNHILL ORIENTATIONS	2c, 40

Table 5
LATERAL ACCELERATION CHARACTERISTICS

CONFIGURATION TEST WEIGHT (lbs)	TIRE INFLATION PRESSURE (psi)	UNDERSTEER GRADIENT (deg/g)	PEAK LATERAL (g)	ROLL SENSITIVITY (deg/g)	TERMINAL RESPONSE
REFERENCE – 2980	ALL – 38	3.0	0.70	8	U/S
	FRONT – 38 REAR – 33	3.0	0.67	8	U/S
	ALL – 33	3.0	0.66	8	U/S
	FRONT – 28 REAR – 33	3.0	0.65	8	U/S
	ALL – 28	4.0	0.68	8	U/S
	OUTSIDE FRONT – 5 REMAINDER – 33	6.5	0.61	8	U/S
	OUTSIDE REAR – 5 REMAINDER – 35	2.0	0.59	8	O/S
	FRONT – 35 REAR – 5	1.0	0.60	8	O/S
FULL LOAD 3650	ALL – 35	2.0	0.68	8	U/S

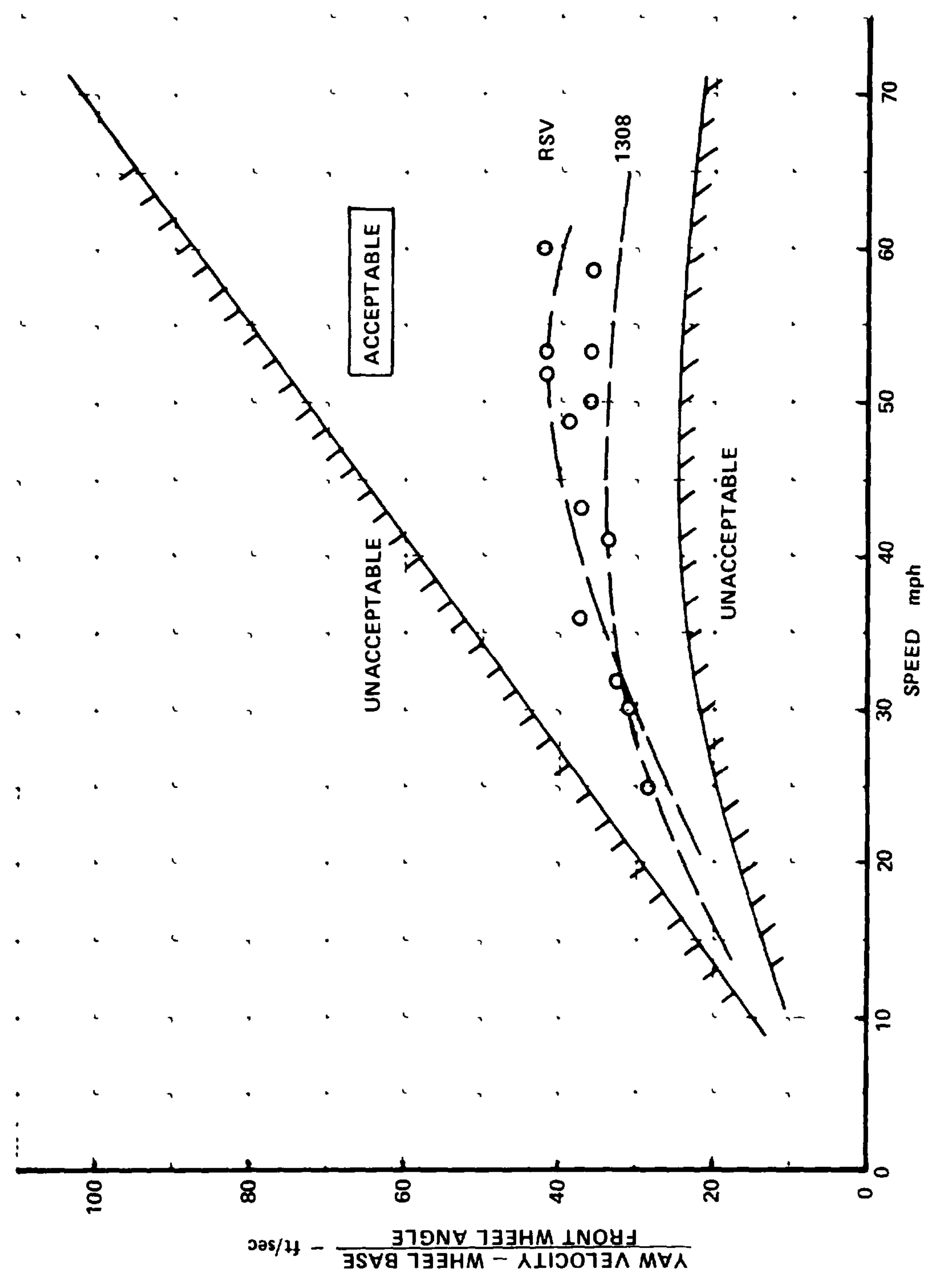

Figure 31 STEADY STATE YAW RATE CONTROLLABILITY

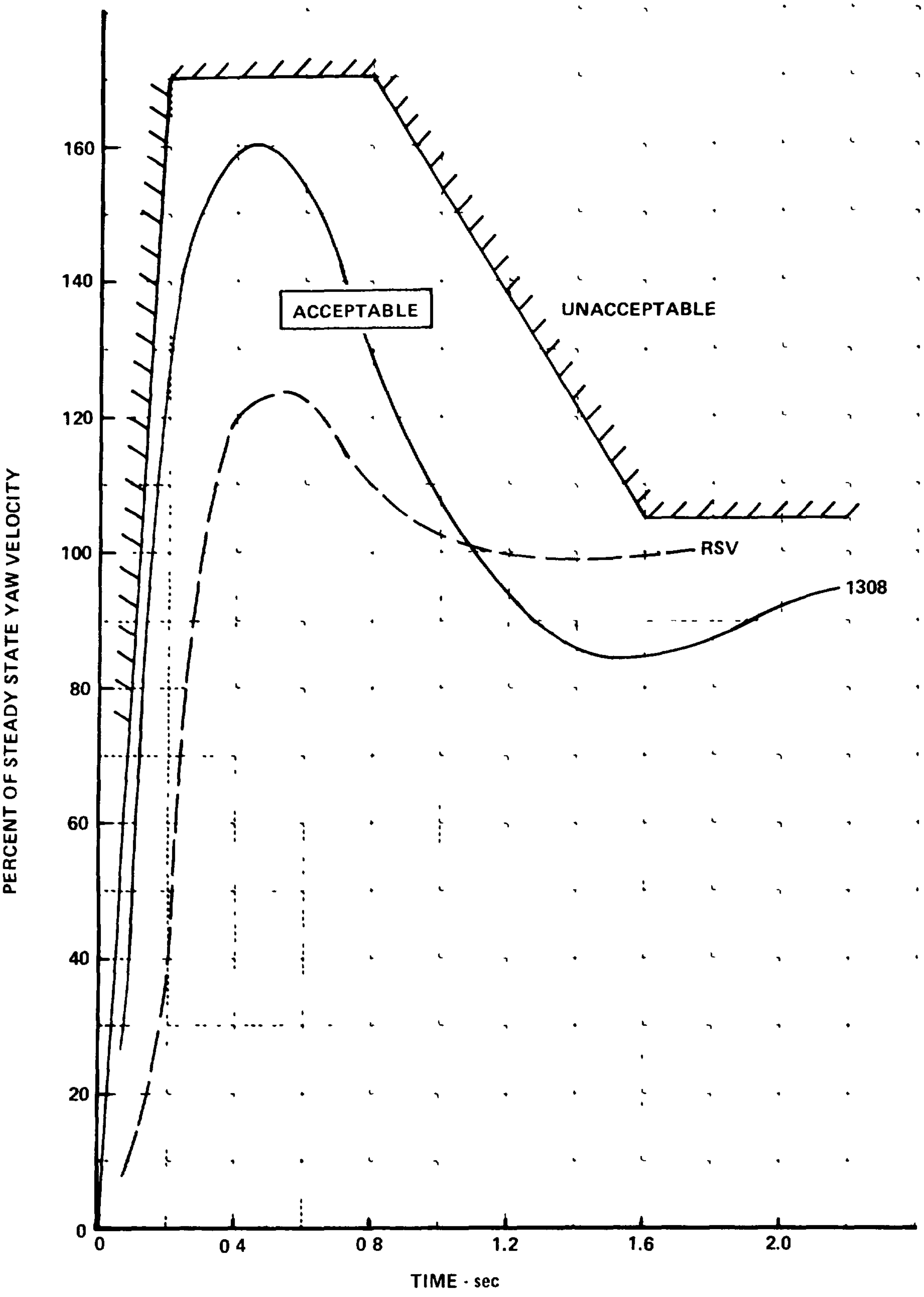

Figure 32 POSITION CONTROL TRANSIENT YAW RATE RESPONSE

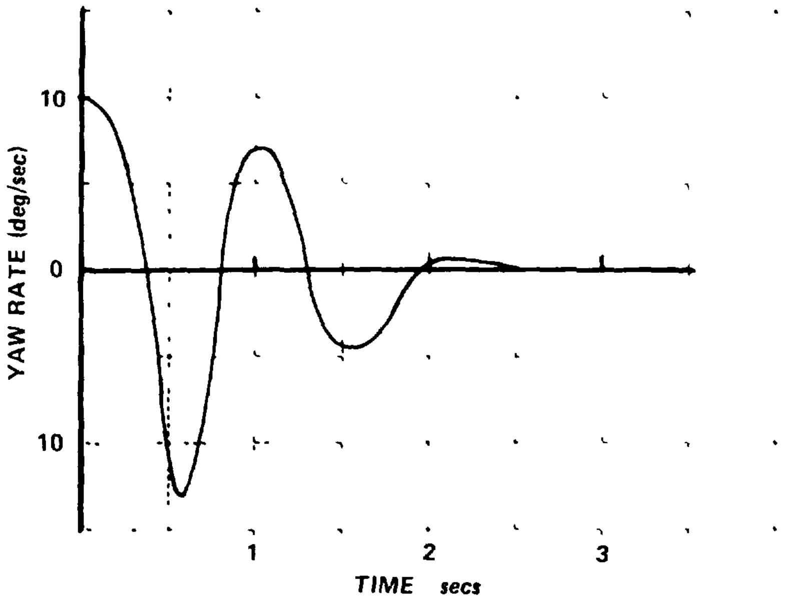

Figure 33 FREE CONTROL TRANSIENT YAW RATE RESPONSE

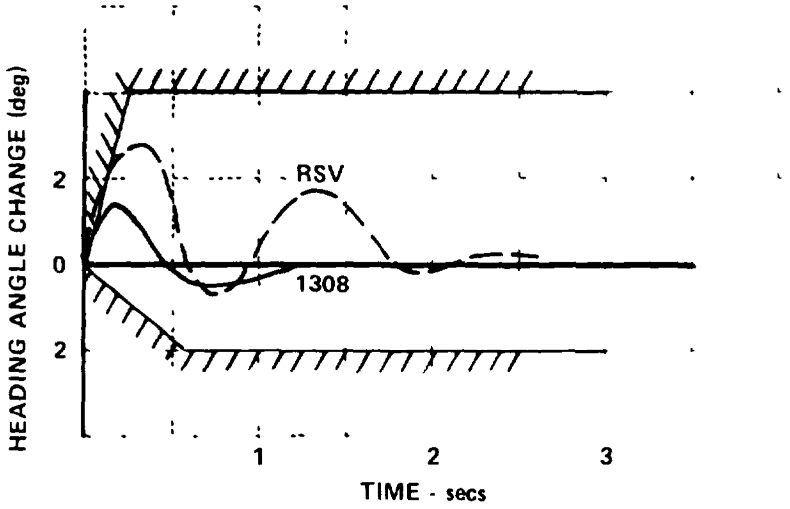

Figure 34 TYPICAL FREE CONTROL RESPONSE (RETURNABILITY) AT 50 MPH

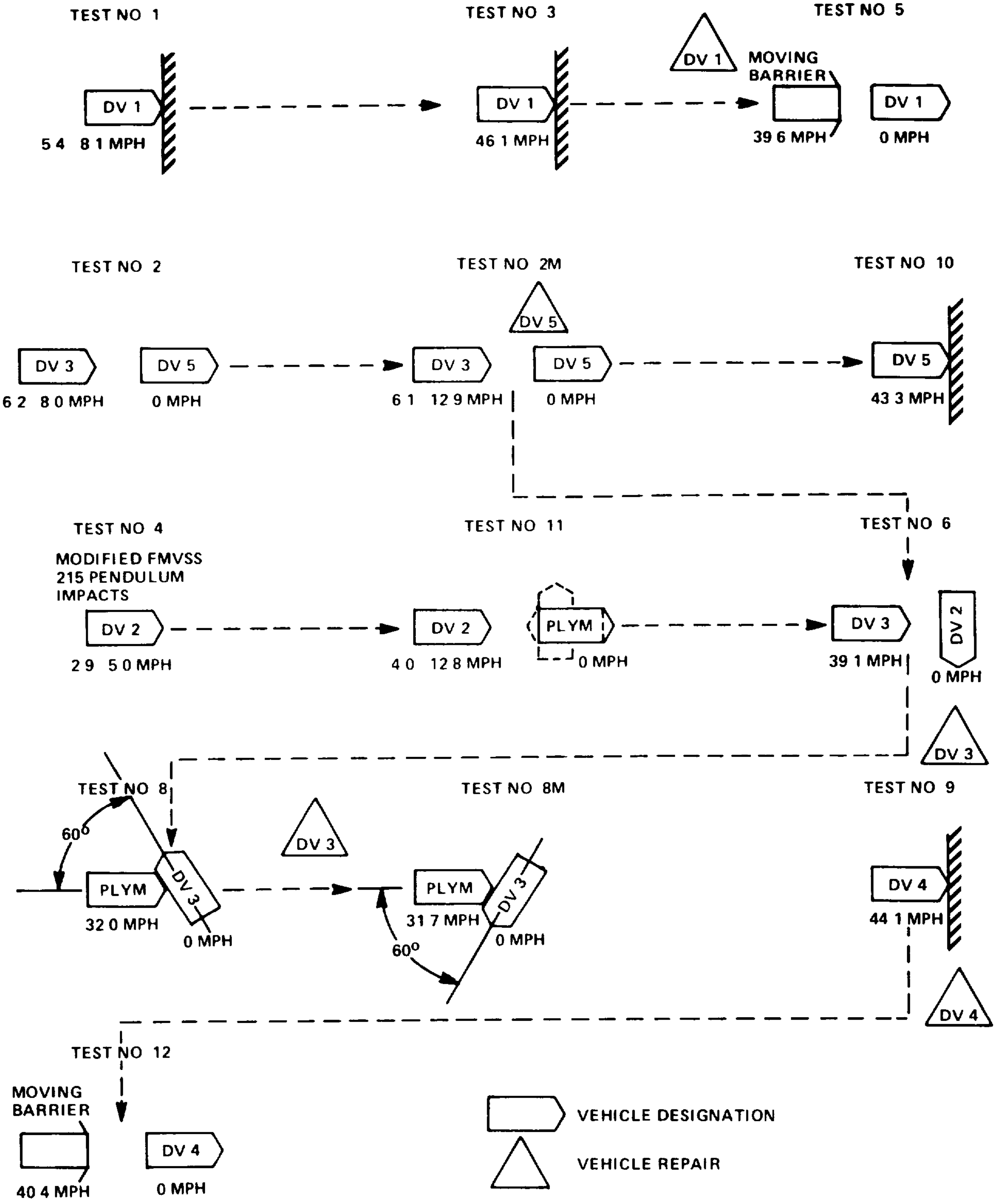

Figure 35 RSV PHASE III INTEGRATED SYSTEMS VALIDATION TESTING SCHEME

The Phase III cars were utilized in a multiple impact test scheme in order to obtain a maximum amount of useful information from each vehicle. As indicated in Figure 35, the test execution sequence was planned to use unimpaired portions of the cars in subsequent collisions. Table 6 lists the Phase III tests in numerical order and provides a description, the test date, the impact speed, as well as pertinent remarks. Several impact configurations were repeated as explained in the "Remarks" portion of Table 6. It should also be noted that low-speed tests[22] (Nos 1, 2, 2M, 4 and 11)[22,26] actually consisted of a number of impacts and/or test configurations run over a range of impact speeds

Complete results of the Phase III tests are documented in References 22 through 30, these reports should be consulted for a detailed description of test conditions and results.

One of the objectives of this section of the report is to provide a comparison of the overall crashworthiness performance of the RSV achieved during Phase III relative with that of the Phase II baseline Simca 1308[*] Tables 7 and 8 include the following high-speed crash test configurations frontal flat barrier, 90 degree front-to-side, oblique front-to-side, and front-to-rear colinear impacts Table 7 provides summaries of significant vehicle data, Table 8, the dummy-related responses Information pertaining to Phase II baseline Simca tests is listed under columns labled "BASE", while corresponding Phase III RSV information appears under the heading "RSV". References are included in the tables to enable detailed review of data

Inspection of Table 7 shows that the test conditions used in corresponding baseline and RSV collisions differ somewhat with respect to impact speed, angularity (in front-to-side oblique impacts) and bullet vehicle employed. Whereas all base vehicle car-to-car impacts were conducted exclusively with Simca's, the RSV tests utilized a 1975 Plymouth Fury and a rigid

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[*] A similar comparative assessment of low-speed damageability performance could not be made because such testing was not conducted with the base vehicle.

Table 6
RSV PHASE III INTEGRATED SYSTEMS VALIDATION TESTS

TEST CATEGORY	TEST NO	DATE	TEST DESCRIPTION	IMPACT SPEED (mph/kph)	REMARKS	REFERENCES
Low speed damageability	1	1/13/78	Frontal Flat Barrier (low-speed vehicle damageability 4 impacts)	5 4 8 1/8 7 13	Acceptable at 7 3 mph minor damages at 8 mph	22
	2	3/31/78	Front to rear colinear (low-speed vehicle damageability 2 impacts)	6 2-8 0/10 12 9	Testing terminated because of unacceptable damage to original phase III rear panel/crossmember assembly	22
	2M	4/13/78	Front to rear colinear (low-speed vehicle damageability 5 impacts)	6 1 12 9/9 8 20 8	Repeat of Test 2 with modified rear panel/crossmember assembly Marginal damage to striking car at 11 4 mph	22
	4	1/26/78 1/27/78	Modified FMVSS 215 pendulum impacts (low-speed vehicle damageability 8 impacts at various locations along front and rear bumper surfaces)	2 9 5 0/4 7 8 0	Tests conducted with original Phase III-design rear panel/crossmember assembly No damage to front bumper head lamps sheet metal Apparent damage to rear prior to modification	22
	11	4/6/78 4/7/78	Low speed RSV impacts into stationary Plymouth Fury • 90° front to-side (3 impacts) • Front to rear colinear (2 impacts) • Front to front colinear (3 impacts)	4 0 8 1/6 4 13 5 2 8 1/8 4 13 9 1 12 8/14 6 20 6	No damage to RSV front at 8 mph into Plymouth side and rear Front to front damage to RSV at 10 8 mph	26
Flat frontal barrier	3	1//19/78	Frontal flat barrier	46 1/74 2	Unsuitable collapse model and pitch by original Phase III front structure Front seat occupants restrained by two point torso air belts exceeded allowable maximum	23
	9	3/15/78	Frontal flat barrier	44 1/71	Repeat of Test 3 with modified front structure Front seat occupants restrained by two point torso air belts Restraint system component failure prevented air belt inflation Structure performance and pitch adequate	28
	10	6/28/78	Frontal flat barrier	43 3/69 7	Phase III RSV equipped with Phase IV prototype front structure Driver and right front passenger dummies restrained by RSV-design air bag and air belt systems respectively Structure results similar to Test 9 deceleration greater, driver protected by air bag exceeded injury criteria Passenger air belt failure allowed excessive HIC number	29
Rear moving Barrier	5	1/31/78	Colinear rear impact by moving barrier	39 6/63 7	Fuel tank overflow vent tube rupture and loss of fuel filler cap during impact led to fuel leakage which exceeded FMVSS 301 75 limits	24
	12	5/15/78	Colinear rear impact by moving barrier	40 4/65	Repeat of Test 5 with rerouted overflow vent tube breakaway fuel filler pipe support and modified rear panel/crossmember assembly No fuel leakage but one rear femur high	30
Front to-side	6	4/21/78	90° front to-side	39 1/62 9	Excellent crashworthiness all occupants survive	25
Vehicle Compatibility	8	4/26/78	60° front to side impact by Plymouth Fury	32 0/51 5	Front door hinge weld failure produced unacceptable loss of side structure integrity	27
	8M	5/3/78	60° front to side impact by Plymouth Fury	31 7/51	Repeat of Test 8 with strengthened door hinge attachment Excellent (9) side crush & intrusion (5) control Occupant injury levels well below maximum	27

Table 7

COMPARISON OF RSV AND SIMCA CRASHWORTHINESS PERFORMANCE – VEHICLE DATA

TEST		TEST DESCRIPTION	STRIKING VEHICLE DATA								STRUCK VEHICLE DATA						REMARKS		REFERENCES
			IMPACT SPEED (mph)		DESCRIPTION/TEST WEIGHT (lbs)		MAX EXTERIOR CRUSH ~ in		MAX PASS COMP T INTRUSION ~ in		DESCRIPTION/TEST WEIGHT (lbs)		MAX EXTERIOR CRUSH ~ in		MAX PASS COMP T INTRUSION ~ in				
BASE	RSV		BASE	RSV	BASE	RSV	BASE	RSV	BASE	RSV	BASE	RSV	BASE	RSV	BASE	RSV			
A	9	Frontal flat barrier	45 9	44 1	SIMCA/2520	DV 4/3070	32	21 5	6 6	4 38	-	–	-	-	-		BASE	Windshield ejected and shattered on impact Vehicle experienced excessive crush and pitch	2k
																	RSV	Excellent structural performance relative to collapse mode crush space utilization *passenger compartment* structural integrity and intrusion control Maximum pitch = 4^{o} at 30 pitch dynamic crush maximum deceleration = 58 g	28
	10			43 3		DV 5/3070		25 3		6							RSV	Structural performance similar to previous Test 9 but stiffer final crush Maximum pitch reduced to 3 1/2^{o} at dynamic crush of 31 4 peak longitudinal decelerations ranged from 63 to 77 g (72 g average)	29
G	6	90^{o} front to side	39 6	39 1	SIMCA/2320	DV 3/3080	6 3	14 4	3 8	0 3	SIMCA/2720	DV 2/3080	20 5	7 3	14 5	4 5	BASE	Struck car experienced massive sidewall exterior crush and intrusion	21
																	RSV	Excellent front to-side vehicle compatibility • Striking Car max crush confined to Zone 2 structure • Struck Car effective side crush and intrusion control	25
H	8M	Oblique front to side Baseline Test $\theta = 45^{o}$ RSV Test $\theta = 60^{o}$	39 7	31 7	SIMCA/2350	1975 Plymouth Fury/ 4210	13	8	0 8	0	SIMCA/2690	DV 3/3080	16 3	9 2	12 6	5 3	BASE	Struck vehicle sustained substantial side wall exterior crush and intrusion struck side front door hinge partially separated from A Pillar	2m
																	RSV	Struck RSV demonstrated significantly improved sidewall structural integrity and intrusion control	27
L	12	Front to rear colinear	50 5	40 4	SIMCA/2320	Moving barrier with SAE contoured impact surface/3210	16 8	0	0 5	–	SIMCA/2500	DV 4/3160	19 5	24 8	1 3	5	BASE	Struck car right front seat back failed as a result of dummy inertial loading Fuel filler tube ruptured	2n
																	RSV	Struck car demonstrated satisfactory crashworthiness performance in a severe (rigid barrier impact) test condition Minor but acceptable fuel leakage (1/2 oz/min) occurred due to filler tube motion relative to fuel tank Seats performed adequately	30

[1] Based on a comparison of pre and post test vehicle measurements

[2] Test conducted by Dynamic Science Inc

Table 8

COMPARISON OF RSV AND SIMCA CRASHWORTHINESS PERFORMANCE DUMMY DATA

TEST		TEST DESCRIPTION	IMPACT SPEED (mph)		DUMMY DATA – STRIKING VEHICLE												DUMMY DATA STRUCK VEHICLE												REMARKS	
					DUMMY LOCATION		RESTRAINT SYSTEM		HEAD INJURY CRITERIA (HIC)		MAX RESULTANT CHEST ACCELERATION[1] ~ g's		MAX FEMUR LOAD[2] lbs.				DUMMY LOCATION		RESTRAINT SYSTEM		HEAD INJURY CRITERIA (HIC)		MAX RESULTANT CHEST ACCELERATION[1] ~ g's		MAX FEMUR LOAD[2] lbs.					
													BASE		RSV										BASE		RSV			
BASE	RSV		BASE	RSV	BASE	RSV	BASE	RSV	BASE	RSV	BASE	RSV	LEFT	RIGHT	LEFT	RIGHT	BASE	RSV	BASE	RSV	BASE	RSV	BASE	RSV	LEFT	RIGHT	LEFT	RIGHT		
A	9	Frontal flat barrier	46.9	44.1	LF RF	LF RF	Std. 3-pt. belt Std. 3-pt. belt	2 pt air belt 2 pt air belt	1056 2056	2363 2482	80 60	90 98	1700 2400	1850 900	2200 2100	1800 2900	–	–	–		–	–	–	–	–	–	–	–	BASE RSV	RF dummy head struck hood (windshield ejected prior to head/hood contact) Manifold failure precluded belt inflation allowed excessive head rotation and contact with instrument panel Load limiting of belt kept chest acceleration tolerable Passenger outboard femur load high.
	10			43.3		LF RF		Air bag 2-pt air belt		1080 1801		68 50			3000 2100	1650 1600													RSV GENERAL	The 72 g average deceleration pulse environment, about twice that used in development testing on sled proved too severe for restraints. High inflation of air bag and air belt seam failure contributed to failures. Although all FMVSS 208 injury criteria were not satisfied in either test the RSV demonstrated significantly improved occupant protection performance over the baseline vehicle
G	8	90° front-to-side	30.6	30.1	LF	LF RF	Std. 3-pt. belt	2-pt air belt 2-pt air belt	397	468 379	26	34 34	1230	670	1000 400	600 780	RF RR	RF RR	Std. 3-pt. belt Std 3-pt. belt	2-pt. air belt[4] RSV 3-pt. belt	333 127	280 440	62 24	40 81	– –	– –	– –	– –	BASE RSV GENERAL	Struck car RF dummy experienced excessive (62 g's) chest acceleration and an extremely high (110 g's) lateral pelvic acceleration as a result of extensive sidewall collapse All applicable FMVSS 208 occupant injury criteria satisfied Struck vehicle occupants experienced reasonable (approx 50 g's) pelvic accelerations. Struck vehicle dummy femur loads not recorded. (X component accelerations small)
H	8M	Oblique front to-side Baseline test $\theta = 45°$ RSV test $\theta = 60°$ (different striking vehicles employed—see Table I)	30.7	31.7	LF	LF RF	Std 3-pt. belt	Std. 3-pt belt Std. 3-pt belt	120	39 74	21	16 15	140	190	190 220	180 140	LF LR	RF RR	Std. 3-pt belt Std 3-pt. belt	2-pt. air belt[4] RSV 3-pt belt	106 278	262 266	40 36	36 50	375 100	130 420	– –	– –	BASE RSV GENERAL	Struck vehicle occupants sustained low injury indications despite unacceptably large compartment intrusions All applicable FMVSS 208 occupant injury criteria satisfied struck RSV provided enhanced sidewall structural integrity and reasonable (50 g maximum) pelvic accelerations Struck RSV dummy femur loads not recorded. (as in Test 6 above)
L	12	Front to-rear oblique (different striking vehicles employed—see Table I)	30.5	40.4	LF	–	Std 3-pt. belt	–	100		24		480	150			RF LR	LF RF RR	Std. 3-pt. belt Std. 3-pt. belt	2-pt. air belt[4] 2-pt air belt[4] RSV 3-pt belt	98 191	104 142 113	14 38	NA[5] 42 28	200 430	80 430	180 200 2800	140 200 340	BASE RSV	Satisfactory occupant injury criteria All injury indications except one femur loading within acceptable limits in this rigid moving barrier impact

[1] Defined as values exceeding a cumulative duration of 3 milliseconds.

[2] Negative (tensile) loads reflect dummy inertial effects.

[3] Test conducted by Dynamic Science Inc

[4] Gas generator not installed in air bag system.

[5] The LF dummy registered a 21 g chest acceleration in a similar test (No 5) at 30.6 mph (see Ref 3)

moving barrier as striking vehicles in 60 degree side and front-to-rear impacts, respectively. Bullet vehicle impact speeds in the Phase III tests reflect estimates (provided by computer simulation predictions) for kinetic energy dissipation equivalent to 40 mph RSV-to-RSV collisions.

It should be noted that failures or malfunctions in RSV restraint system components adversely affected occupant survivability in the frontal flat barrier impacts (Test Nos. 9 and 10). Although survival was not achieved in either test, data from both are included to provide a broader base of information. The earlier barrier Test No. 3 was not included because of its dissimilar front structure (whose modifications were discussed above in Section 4.1). In RSV DV-4 (Test No. 9) the front structure had been modified to simulate the final design, while DV-5 (Test No. 10) was the first prototype built with the new front structure actually made on the final tooling. In addition, DV-5 carried an air bag restraint for the driver. These and the other tests, listed in Tables 7 and 8, are discussed in somewhat more detail below.

Frontal Flat Barrier Tests

The performance of the RSV front structure in Test Nos. 9 and 10 was superior to that demonstrated in the earlier Simca Test A. The objective of its design was first to increase the retarding force during compression of the soft bumper to about 20 g's (the first five to ten inches of crush), retain it at that level through Zone 2 (10 to 20 inches of cumulative total crush) to minimize the aggressiveness of the RSV, and then in the final 20 to 36 inches of total crush (Zone 3) increase the deceleration to absorb the remainder of the energy of the crash. The modifications to the rail (discussed in Paragraph 4.1 above) to overcome the pitch and intrusion problems observed in frontal barrier Test No. 3 were successful. However, as indicated in Figure 20, the structure built with the final RSV tooling (used in Test No. 10) turned out to be somewhat less stiff than desired in Zone 2 and stiffer in Zone 3. Consequently, the retarding force decreases after the initial bumper peak of around 16 g's and then abruptly rises in the final zone to a peak of about 72 g's. In view of this performance, as well as the fact that the parts for the final RSVs had already been fabricated on the new front end Phase III final tooling in order to minimize the delay in the program schedule, the decision was made to modify the restraint system to improve its dynamic response. The aim was to accommodate the high decelerations rather than to further change the structure in an effort to increase the resistance in Zone 2 (and RSV aggressiveness) as well as the total crush distance even though satisfactory occupant protection for such a crash signature would require virtually flawless restraint system performance.

As indicated in Tables 7 and 8, adequate restraint system performance was not achieved in Test Nos. 9 or 10. The gas generator manifold failed in Test No. 9 so the air belts did not inflate, in Test No. 10, a seam in the passenger air belt failed during inflation, releasing the restraint on the occupant's head in a manner that resulted in an excessive HIC number Although all FMVSS 208 injury criteria were not satisfied, the measured RSV occupant levels indicated the potential of demonstrating of occupant survival. As noted later in Section 15, results of tests conducted in Phase IV showed satisfactory performance in a head-on collision with each car going 40 mph (80 mph closing speed).

90 Degree Front-to-Side Tests

Despite massive sidewall exterior crush and interior intrusions sustained by the base car in Test G, its occupants suffered relatively modest injury exposure. With the exception of a measured 62 g resultant chest acceleration for the right front passenger, all other injury indicators remained within acceptable limits. The extensive deformation, however, creates an extremely hazardous environment for actual human occupants in such a collision. The lack of adequate sidewall structural stiffness and load transfer capability was manifested by an extremly high (118 g's) lateral pelvic acceleration recorded for the right front passenger dummy. (FMVSS 208 does define limits to lateral pelvic accelerations.)

In marked contrast, the struck RSV in Test No. 6 displayed excellent structural integrity with substantially reduced exterior/interior sidewall penetration. Occupant injury criteria were all well below allowable FMVSS 208 limits. Peak pelvic accelerations for both occupants did not exceed 52 g's.

Oblique Front-to-Side Tests

Unacceptably large sidewall collapse again characterized base vehicle performance in the oblique (45 degree) side impact mode (Test H) In addition, struck door retention was severely compromised by an incipient door hinge failure at the A pillar location. All dummy occupants in the target Simca survived the impact according to FMVSS 208 criteria.

The Phase III RSV in the 60 degree side impact, struck by the Plymouth Fury (Test No 8M), again provided excellent structural integrity, including door retention. All occupant injury exposure levels were well within acceptable limits. Hinge weld failure in the initial run of Test No. 8 pointed out the need for a higher than normal level of quality control in the manufacture of the RSV in order to insure retaining its high performance capability.

Front-to-Rear Colinear Tests

Both the Simca and the RSV exhibited similar vehicle and occupant responses in the rear impact collision mode (Tests L and 12, respectively). Indeed, such similarity was expected in view of the minimal crashworthiness-related modifications made to the base car rear structure. The somewhat greater rear structural collapse sustained by the RSV in Test No. 12 (compared to corresponding Simca damage in Test I) most likely stemmed from the more severe test condition inherent in the RSV impact, i e., use of an essentially rigid impacting moving barrier instead of a bullet vehicle with a compliant front structure

Fuel tank integrity did not constitute a problem in either test. Modifications incorporated in the RSV rear end did, however, eliminate the fuel filler pipe rupture and associated fuel leakage observed in Test L.

Modifications to reinforce the structure supporting the backs of the front seats combined with the heavy-duty seat tracks to eliminate the seat collapse evident in the Simca Nevertheless, one of the RSV rear seat dummy femur loads exceeded the limit That femur load in Test No. 12 was ascribed to contact between the right rear dummy left knee and the reinforced support for the back of the occupied right front seat. No directly comparable data are available for the Simca since only two dummies, positioned diagonally in the right front and left rear seating positions, were utilized in Test L.

Preliminary results of Phase IV tests of the Calspan/Chrysler RSV are included in Section 15. They essentially verify the Phase III results.

7.0 EMISSIONS/FUEL FLOW TESTS

Relatively early in Phase III, a production Dodge Omni with manual transmission and California emission package was tested to simulate RSV emissions and fuel economy performance. The Omni was ballasted to RSV weight and tested at a 3000 pound inertia weight and a 4.5 hp dynamometer setting. The 4.5 rolls horsepower setting was interpolated from test results of the low drag RSV mule car (0.42 Cd) with 35 psi flatproof tires. Testing was conducted with the Omni in "as received" condition with no attempt to optimize engine carburetor or ignition settings. EPA test cycles were run at odometer readings of both 400 and 1900 miles to test both repeatability and possible engine break-in effects. Results are summarized below.

Odometer	Emissions			Fuel Economy		
	HC	CO	NOx	City	Hwy	Comb
400	.253	2.46	1.174	23.48	36.66	28.01
1900	.233	1.80	1.463	22.46	38.34	27.61

The vehicle emissions were within the 1978 California standards and RSV target of .41 HC, 9.0 CO and 1.5 NOx. While fuel economy did not meet the RSV goal of 30 mpg (combined cycles), it did exceed the Federally mandated 1985 standard of 27.5 mpg. Since the Chrysler L-car (Omni) had been certified for emission compliance at 50,000 miles, the above data was considered sufficient to indicate the feasibility of RSV emissions certification.[10]

More recently, just before Phase IV Car No. 8 was shipped to Japan, additional emission and fuel economy test results were obtained. Results are shown below. Note that the dynamometer setting is higher and again the engine is new and no attempt was made to tune it to optimize performance. An EPA composite fuel economy calculated from the averages of the city and highway figures is 26.1 mpg. Other fuel consumption information obtained at the same time is included.

EMISSIONS ROLLS RESULTS

(IW = 3000 lbs., DPA - 5.0 Hp)

	HC*	CO*	NOx*	MPG
1978 California Standard	0.41	9.00	1.50	
1983 U.S.	0.41	3.40	1.50	
CCVS No. 1		--INVALID--		
CCVS No. 2	0.33	4.32	1.05	21.7
CCVS No. 3	0.35	5.05	1.04	22.2
HWFE No. 1	0.06	1.57	1.34	33.6
HWFE No. 2	0.05	0.35	1.16	35.1
HWFE No. 3	0.05	0.40	1.35	32.8

---

*gms/mi

SAE Road Economy (mpg)

Urban	21.7
I-55	30.9
Composite	25.0

EPA Rolls Economy (mpg)
(3000 IWC, 5.0 Hp)

CCVS (Avg. of 2 tests)	21.9
HWFF (Avg. of 3 tests)	33.8
Composite	26.1

Idle Fuel Consumption

Pts./Hour	2.6
@ rpm	990

8.0 FMVSS COMPLIANCE EVALUATION

The compliance of the final design of the RSV with current FMVSS was assessed in Phase III on the basis of available information generated during the program.[35] The results of that study indicate that the Calspan/Chrysler RSV meets most of the requirements specified in 41 current FMVSS passenger car regulations. As shown in the summary table below, 39 of these standards was directly applicable to the RSV. Of this number, the RSV exhibited full or probable compliance with 28 safety standard either by actual measured performance or by implication via application of state-of-the-art design practice

EXTENT OF RSV COMPLIANCE WITH 41 PASSENGER CAR FMVSS

FULL		PROBABLE	PARTIAL	NON	NOT APPLICABLE
DEMONSTRATED	INFERRED				
9	16	3	9*	2	2
Σ = 25					
Σ = 28					

*INCLUDES TWO STANDARDS FOR WHICH RSV COMPLIANCE COULD NOT BE FULLY ASCERTAINED

Partial compliance was demonstrated for an additional nine vehicle standards Two regulations in this group were incompatible with the RSV front bumper system, which provides superior pedestrian protection, but was not specifically designed to meet FMVSS vehicle low-speed damageability test requirements. Two other standards were so rated only because data generated in the program was insufficient to make a full assessment of RSV compliance with all requirements in the specific regulations. The two vehicle subsystems did, however, fully comply with those requirements which were capable of evaluation. The remaining five standards receiving a partial compliance classification were unrelated to vehicle structural integrity or occupant protection considerations.

The RSV failed to comply completely with the requirements of two safety standards, both of these addressed non-impact-related criteria and compliance with one would have reduced pedestrian protection and fuel economy

9.0 COLLISION REPAIRABILITY STUDY

One measure of the increased cost of the RSV is the cost to repair collision damage. In an effort to assess the cost of such repair relative to that for a standard automobile, RSV No 5 was sent to the Motor Insurance Repair Research Centre in Thatcham, England so that it might carry out their standardized series of impact tests under the same conditions that were utilized in previous tests on a base Simca. At Thatcham, the RSV has been impacted six times by a Ford Cortina at speeds and positions similar to those used in the Alpine study. The configurations consist of (1) full frontal, (2) right frontal, (3) A post on the left side, (4) full right side, (5) half offset, and (6) full rear The tests have been completed and a separate report will be prepared This study is one of the three incomplete items shown on the program schedule, Figure 5.

10.0 MAINTAINABILITY/SERVICEABILITY EVALUATION

This is another task that required the use of one of the final RSVs built for testing in Phase IV in order to provide meaningful results. The unavailability of such a vehicle has made the accomplishment of this planned evaluation impossible. As indicated in Section 3, the task has been eliminated from the schedule, Figure 5.

11.0 PRODUCIBILITY/COST STUDY

As alluded to in previous sections, the materials selected and designs developed for the components of the Calspan/Chrysler RSV have been carefully chosen to facilitate mass production. Since the base Simca 1308 is already a mass produced vehicle, a majority of the RSV parts can be automatically so characterized. Most revised parts were designed to use a different material thickness in the same tooling or HSLA steel in order to retain that producibility. Where new designs had to be developed (as in the front suspension lower control arm, the tunnel reinforcement, and the door beams), the designs were reviewed in Phase III to insure minimum number of parts and total manufacturing labor content both for ease of manufacture and price.[37,40]

On the basis of a complete set of RSV drawings, an assumed production of 300,000 cars per year, and normal amortization, Chrysler cost analysts developed a detailed estimate of the increase in RSV suggested retail price to the consumer because of its added safety features over that for a Simca 1308 with minimum FMVSS compliance.[17,39,40] Since the Simca is neither manufactured nor sold in the U.S., and the French manufacturing facilities, procedures, and labor rates are not specific to the U.S., an actual total consumer price for a federalized RSV is not available. However, cost differentials between the RSV and a car of the same size and general features meeting current U.S. standards (a federalized Simca) were derived as summarized in Figure 36. The total differential in suggested consumer retail price including research and development, facilities, tooling, and other expenses associated with bringing such a car into production is shown to be $1795 in 1979 dollars.

Although a major number of items are the type Chrysler presently fabricates, a disproportionately large portion of the cost estimate is associated with a limited number of components that are not now in production and would have to be purchased Vendors' estimates were used in assembling the costs for the passive restraint systems, anti-skid brakes, and flatproof tires which comprise the high technology category of the RSV features, as shown in Figure 37.

PART GROUP	ADDITIONAL CONSUMER COST
BODY-IN-WHITE	$ 203
FRONT SHEET METAL	23
GLASS	28
PAINT, SEALERS & DEADENERS	—0—
BUMPERS	107
GRILLE & LIGHTS	31
EXTERIOR ORNAMENTATION	54
INSTRUMENT PANEL	—0—
STEERING WHEEL	—0—
INTERIOR TRIM	138
FRONT RESTRAINTS & KNEE BLOCKER	642
REAR RESTRAINTS	34
CHASSIS & ELECTRICAL	22
FLATPROOF TIRES & SENSOR SYS.	102
ADAPTIVE BRAKE SYSTEM	325
HEADLAMP LEVELING SYSTEM	45
MISCELLANEOUS	41
TOTAL	$1795

Figure 36 ADDITIONAL SUGGESTED RETAIL PRICE SUMMARY

	CONSUMER COST	
HIGH TECHNOLOGY FEATURES		
FRONT PASSENGER RESTRAINTS, INCL. KNEE BLOCKER	$ 642	
FLATPROOF TIRES & LOW PRESSURE WARNING	102	
ADAPTIVE BRAKING SYSTEM	325	
	$1069	(60%)
DISCRETIONARY FEATURES		
4-PLY WINDSHIELD	$ 28	
REAR SPOILER	30	
HALOGEN HEAD LAMPS & COVERS	14	
HEADLAMP ADJUSTING SYSTEM	45	
HIGH LEVEL REAR LAMPS	21	
RUB STRIP MOLDING	24	
SOFT WHEEL COVERS	30	
ALUMINUM HOOD & HATCH LID	16	
	$ 208	(11%)
BASIC FEATURES		
BODY STRUCTURE & HARDWARE	$ 210	
SOFT FRONT & REAR BUMPERS	77	
INTERIOR TRIM & PADDING	138	
3-POINT REAR BELTS	34	
MISCELLANEOUS OTHER ITEMS	59	
	$ 518	(29%)
TOTAL	$1795	(100%)

Figure 37 RSV CONSUMER ADDITIONAL SUGGESTED RETAIL PRICE FEATURE CATEGORIZATION

The vendor-supplied costs for these three elements represent 60 percent of the total incremental cost. Note that the basic vehicle features which are closely related to parts currently being manufactured account for 29 percent of the total, with the optional or discretionary features constituting the remaining 11 percent of the cost difference.

13.0 PHASE IV VEHICLE FABRICATION

For testing during Phase IV, ten vehicles were fabricated by Creative Industries of Detroit. They consisted of two pedestrian test bucks and eight driveable cars manufactured in accordance with the Build Definition identified in Section 13.1 below. The fabrication of all test cars was completed by April 1979 and delivery of the last RSV to NHTSA on 8 May 1979. Delivery dates are indicated on Figure 5, the RSV Phase III Schedule, and in Section 14. The car is shown in Figures 1 through 4, Figure 38 shows one of the pedestrian test bucks just prior to completion

13.1 Vehicle Build Definition

Table 9 provides a definition of the major features and components utilized in each of the ten vehicles fabricated.

13.2 Fabrication

The Bidder's Conference was conducted on 15 December 1977. The contract for fabricating the ten vehicles and spares was negotiated with Creative on 17 March 1978 and work started later that month.[11] The unit, a test buck, was accepted on 9 November 1978 and shipped to Battelle;[15] the last car, No. 10, was completed at Creative and sent to Chrysler in April, then to Calspan for final review and subsequently delivered to the Government on 8 May 1979.[17]

The Bodies-in-White (BIW) were fabricated at Creative's Pine Woods Facility from the components in the completely-knocked-down (CKD) kits (purchased from Chrysler/France) along with the new parts fabricated to RSV drawings at Creative. An assembly fixture purchased from Chrysler/France was modified for use in fabricating the RSV BIW. After assembly, each BIW was rust proofed and sealed at Chrysler and then transferred to Creative's Outer Drive plant where a small assembly line had been set up and the

Figure 38 SIDE VIEW OF PEDESTRIAN CRASH BUCK WITHOUT BUMPER, WINDSHIELD OR MIRRORS

RSV PHASE IV BUILD DEFINITION

DATE 12 14-78
REV NO 7

		BODY(12)								CHASSIS(13)												TRIM(14)					
		RESTRAINTS					LIGHTS													LINKAGE							
CAR NO	USAGE	DRIVER	PASS	REAR(1)	SOUND(2) INSULATION	COLUMN A-BAG MTG PROVISIONS	FRONT	REAR	INST PANEL	RUNNING	TRANS-MISSION	CATALYSTS	AIR COND	WIRING	PASSIVE BELT MECHANISM	FLOOR CONSOLE	MODIFIED STEERING KNUCKLES	STEERING GEAR	BRAKES	THROTTLE CLUTCH SHIFT	COLUMN STALK	FINISH(11)	CARPET	RETRACTOR AND INFLATOR COVERS	DOOR TRIM PANELS	SEAT COVERING	WHEEL COVERS
1	PEDESTRIAN CRASH BUCK	NONE	NONE	NONE	NONE	NONE	RECT	NONE	NONE	NO	MANUAL	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	UTILITY	NONE	NONE	NONE	NONE	NONE
2	PEDESTRIAN CRASH BUCK	NONE	NONE	NONE	NONE	NONE	RECT	NONE	NONE	NO	MANUAL	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	UTILITY	NONE	NONE	NONE	NONE	NONE
3	DURABILITY/MAINTENANCE (CRASH)	AIR BAG	AIR BELT	PHASE III	FULL	PHASE III	CIBIE(3)	HI LEVEL PHASE III	PHASE III	YES(5)	MANUAL	MAIN MINI	NONE	PHASE III	RT FRONT	M-C-6(7)	SPECIAL(8)	MOD MANUAL	PHASE III(9)	FULL(10)	PHASE III	UTILITY	PHASE III	PHASE III	PHASE III	PHASE III	PHASE III
4	HANDLING/FUEL ECON (CRASH)	AIR BAG	AIR BELT	PHASE III	FULL	PHASE III	CIBIE	HI LEVEL PHASE III	PHASE III	YES(5)	MANUAL	MAIN MINI	NONE	PHASE III	RT FRONT	M-C-6	SPECIAL	MOD MANUAL	PHASE III	FULL	PHASE III	UTILITY	PHASE III	PHASE III	PHASE III	PHASE III	PHASE III
5	THATCHAM (CRASH)	AIR BAG	AIR BELT	PHASE III	FULL	PHASE III	RECT (4)	HI LEVEL PHASE III	PHASE III	YES(5)	MANUAL	MAIN MINI	NONE	PHASE III	RT FRONT	M-C-6	SPECIAL	MOD MANUAL	PHASE III	FULL	PHASE III	UTILITY	PHASE III	PHASE III	PHASE III	PHASE III	PHASE III
6	CONSUMER DEMONSTRATION	AIR BAG	AIR BELT	PHASE III	FULL	PHASE III	CIBIE	HI LEVEL PHASE III	PHASE III	YES(5)	MANUAL	MAIN MINI	NONE	PHASE III	RT FRONT	M-C-6	SPECIAL	MOD POWER	PHASE III	FULL	PHASE III	SHOW	PHASE III	PHASE III	PHASE III	PHASE III	PHASE III
7	CRASH – DOMESTIC	AIR BAG	AIR BELT	PHASE III	FULL	PHASE III	RECT	HI LEVEL PHASE III	PHASE III	YES(5)	MANUAL	MAIN MINI	NONE	PHASE III	RT FRONT	M-C-6	SPECIAL	MOD MANUAL	PHASE III	FULL	PHASE III	UTILITY	PHASE III	PHASE III	PHASE III	PHASE III	PHASE III
8	CRASH – DOMESTIC	AIR BAG	AIR BELT	PHASE III	FULL	PHASE III	CIBIE	HI LEVEL PHASE III	PHASE III	YES(5)	MANUAL	MAIN MINI	NONE	PHASE III	RT FRONT	M-C-6	SPECIAL	MOD MANUAL	PHASE III	FULL	PHASE III	UTILITY	PHASE III	PHASE III	PHASE III	PHASE III	PHASE III
9	CRASH – DOMESTIC	AIR BAG	AIR BELT	PHASE III	FULL	PHASE III	RECT	HI LEVEL PHASE III	PHASE III	YES(5)	MANUAL	MAIN MINI	NONE	PHASE III	RT FRONT	M-C-6	SPECIAL	MOD MANUAL	PHASE III	FULL	PHASE III	UTILITY	PHASE III	PHASE III	PHASE III	PHASE III	PHASE III
10	CONSUMER DEMONSTRATION	AIR BAG	AIR BELT	PHASE III	FULL	PHASE III	CIBIE(3)	HI LEVEL PHASE III	PHASE III	YES(5)	AUTO	MAIN MINI	YES(6)	PHASE III	RT FRONT	M-C-6	SPECIAL	MOD POWER	PHASE III ANTI SKID	FULL NO CLUTCH	PHASE III	SHOW	PHASE III	PHASE III	PHASE III	PHASE III	PHASE III

NOTES – FOOTNOTES APPLY TO SAME TERMINOLOGY IN COLUMN

1 PHASE III ACTIVE SYSTEM OUTBOARD 3 POINT SYSTEMS CENTER LAP BELT
2 FULL SOUND PACKAGE INCLUDES LINERS FOR FLOOR DASH PANEL HOOD AND COWL SIDE ACOUSTICAL COATING ON QUARTER PANELS FENDER SIDE SHIELDS AND REAR WHEEL HOUSE AREAS COMPLETE UNDERCOATING
3 CIBIE – SINGLE BEAM WITH AUTOMATIC LEVEL
4 RECTANGULAR – U S MANUFACTURE – LOW BEAM
5. 1716 CC ENGINE INSTALLED WITH CALIF EMISSION CONTROL EQUIPMENT
6 FULL FUNCTION SYSTEM
7 MODIFIED C 6
8 U S VENDOR MODIFICATION TO STANDARD PART FINAL X RAY INSPECTION
9 DIAGONAL SPLIT
10 FUNCTIONAL
11 EXTERIOR AND INTERIOR – SPECIAL ATTENTION ON SHOW VEHICLES
12 PHASE IV FRONT AND REAR BUMPERS ON ALL VEHICLES
13 P185/70R 13 RUN FLAT TIRES ON ALL VEHICLES
14 PHASE IV A B AND C PILLAR COVERS ON ALL VEHICLES

Table 9

Chrysler RSV staff was in residence to supervise quality control and assembly.[11] There the rest of the purchased chassis and body components were installed and when complete, the finished cars were inspected and road tested Calspan personnel installed the restraint systems, reviewed inspection records, and accepted the vehicles for delivery to the Government. Figures 39 and 40 show the body assembly and the final assembly areas at Creative Industries.

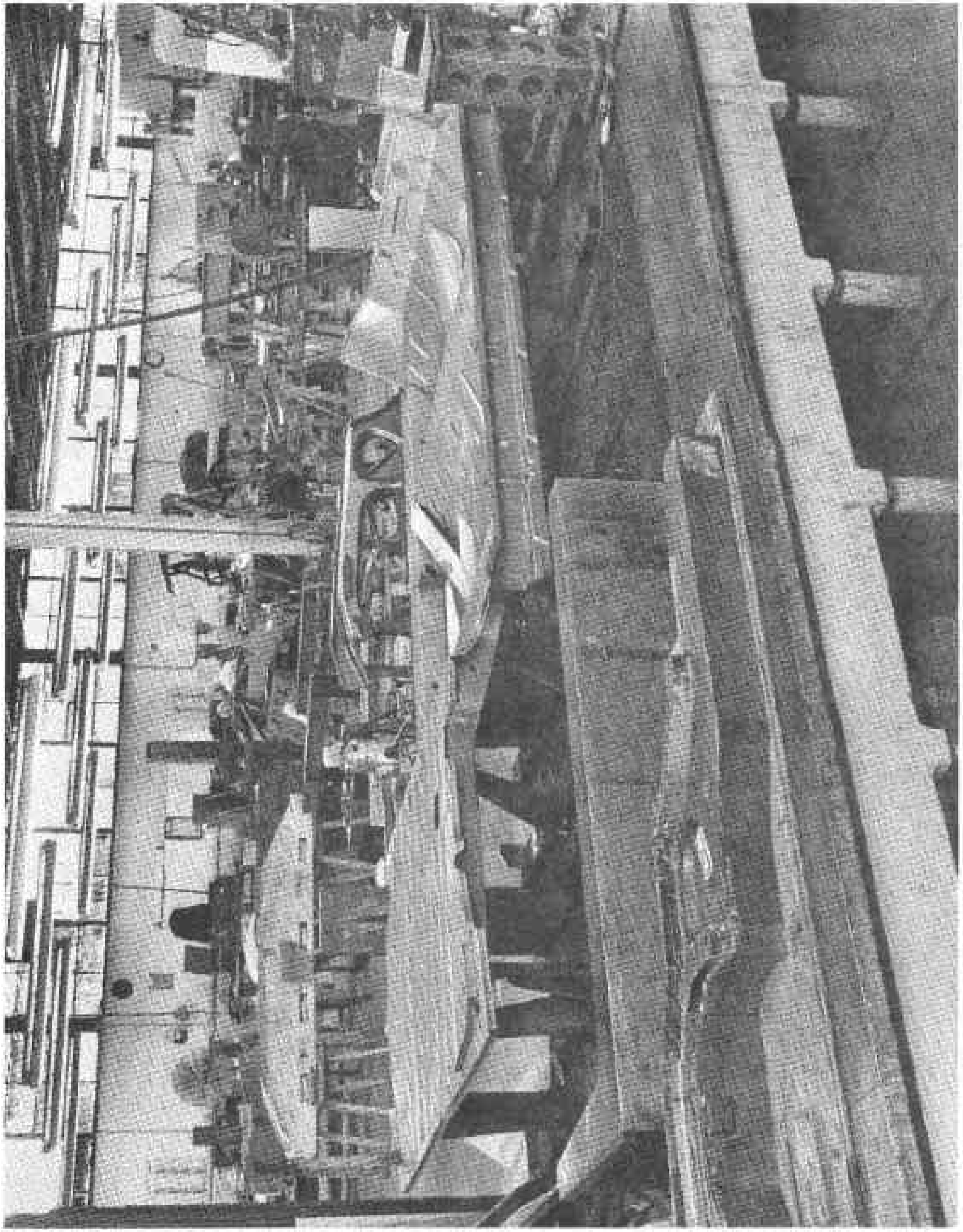

Figure 39 FLOOR PAN IN BODY ASSEMBLY FIXTURE

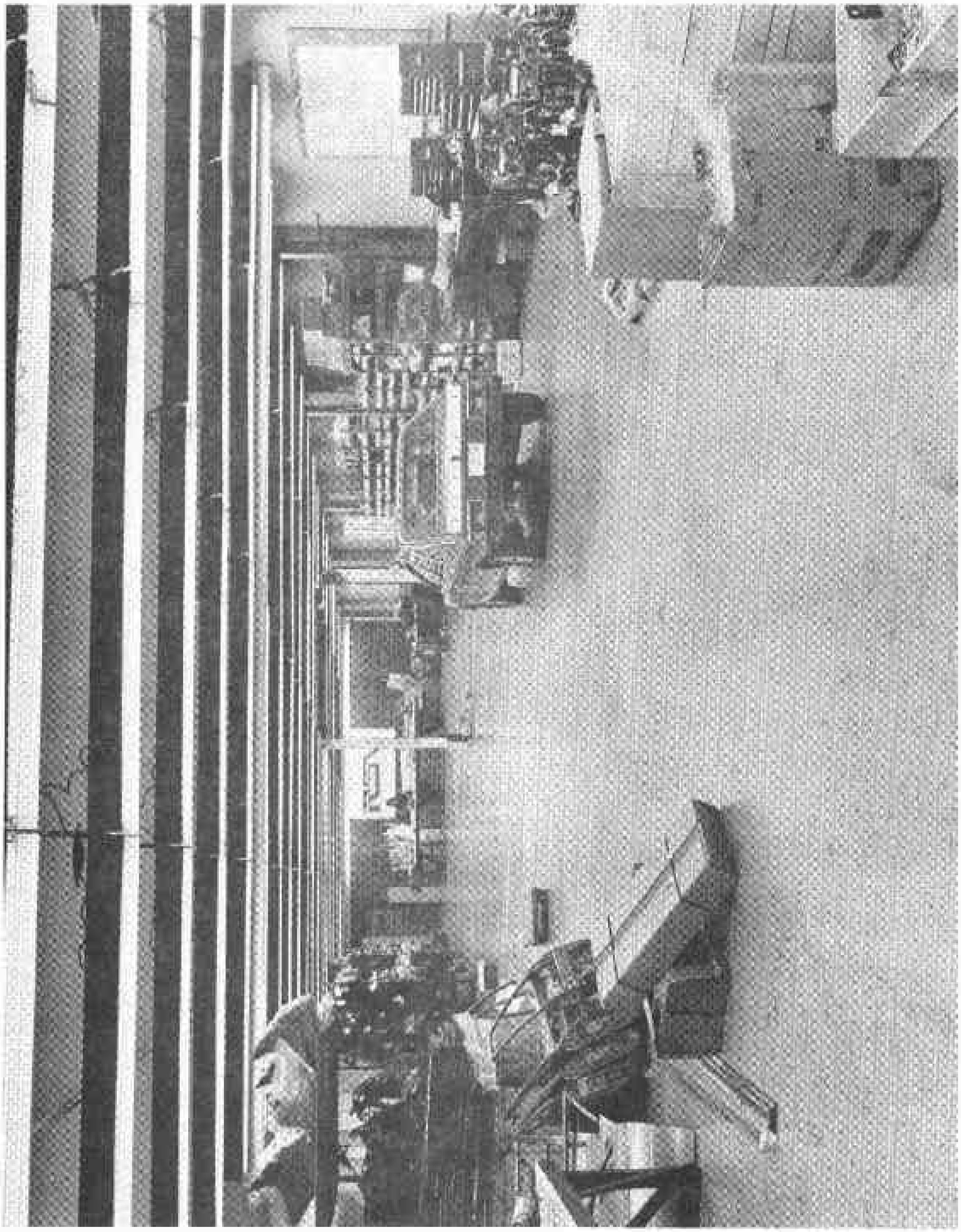

Figure 40 FINAL ASSEMBLY AREA AT CREATIVE

14.0 DELIVERABLE ITEMS

The following items have been delivered in Phase III

	Quantity	Frequency	Date Submitted	Task
Program Plan	15		3/1/77	
Progress Reports	20		Various, Fig. 5	3.3
Program Plan Briefing Charts	2		4/18/77	3.1
Status Briefing Charts	5		6/29/77, 10/25/77 12/15/77, 5/17/78 12/7/78	3.3
Final Briefing Charts	2		12/15/77, 2/2/78	3.2
Design Documentation	1		8/3/78	4.0
Final Design Report	65*		1/29/80	3.4
Final Phase III Report	65*		2/29/80	3.4
In-House Technical Reports	16		Various	3.4
Fabrication Go-Ahead Review	15		12/15/77	3.2
Restraints Review	15		2/2/78	3.2
Integrated Crashworthiness Vehicles (#3, 4, 5, 7, 8 and 9)	6		2/14/79, 2/14/79, 2/14/79, 3/12/79 3/28/79	13 2
Driveline Development Vehicle (#6)	1		3/12/79	13.2
Consumer Demonstration Vehicle (#10)	1		5/8/79	13.2
Pedestrian Crash Bucks (#1 & 2)	2		11/9/78	13.2

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*Reproducible copy also supplied

15.0 PHASE IV TESTING

Support for the Phase IV test program of NHTSA was initiated early in the spring of 1979. A parts depot was established at Creative in Detroit where all the tooling, extra die draws, and spare finished parts and components were stored and could be drawn upon as required for the tests in Europe and Japan. Calspan representatives assisted the vehicle test preparations in France, England, and Japan. Table 10 includes a summary of the results that have so far been reported. The German,[41] French,[42] and Italian[43] results were presented at the Seventh ESV Conference. The other data are based on verbal reports These data substantiate the Phase III tests as well as the achievement of the RSV goals Additional activity included two additional front barrier crash tests,[31,32] handling checkout and tests of Phase IV Car No. 3,[16,34] further development tests of the restraint systems,[17] and support of the NHTSA program to acquaint people with the RSV development

Table 10

PHASE IV RSV TEST RESULTS

	RSV	SPEED	POSITION (STRUCK SIDE)	HIC	H_R	C_R	CSI	PELVIS	PSI	STRIKING
SIDE PROTECTION R 20 TO RSV	#4 (RENAULT)	40 6	FR (R) R (R)	256 730	– –	70 63	506 360	82 45	562 321	R 20
	#4 (PEUGEOT)	32 1	F (L) R (L)	70 314	28 88	48 46	216 170	60 58	162	R 20
J CAR TO RSV	#7 (JAPAN)	35/35	DRIVER R (L)	54 577	30 110	37 99	70 414	20 55	FEMUR L/R 65/93 kg 94/97 kg	TUNNEL Y = 15 g LF SILL Y = 18 g
FRONTAL CAR TO-CAR RSV TO J.CAR	#8 (JAPAN)	40 5/40 1	DRIVER FR (R)	319 444	46 51	50 40	344 297	53 54	1791#/1023# 1089#/1466#	TUNNEL R = 59 g
REAR CAR TO-CAR J CAR TO RSV	#8 (JAPAN) NO FUEL LEAKAGE	45 1/1 0	R (L) R (R)	121 119	58 59	43 31	89 83	46 40	398#/328# 400#/642#	TUNNEL R = 16 g
BARRIER U.S.A.	#3 (CALSPAN)	40.6	F (L) F (R)	792 1312	60 73	64 51	660 580	– –	2200#/1500# 1450#/1500#	TUNNEL X = 80 g
	#9 (DY SCI)	41 0	F (L) F (R)	466 1294	53 81	53 54	590 634	– –	2343#/1849# 1531#/1995#	TUNNEL X = 67 g
FUEL ECONMY	#7 (ITALY) – 30 mpg AT 62 mph STEADY, (BETTER THAN 7 OF 10 COMPARABLE CARS) (JAPAN) – EPA COMPOSITE = 27 1 mpg #8 (USA) – EPA COMPOSITE = 26 1 mpg									

Table 10 (Cont.d)

PHASE IV RSV TEST RESULTS

		HC	CO	NO_x
EMISSIONS	(USA) 1978 CALIFORNIA	0 41	9 0	1 5
	1983 USA	0 41	3 4	1 5
	#8 WORST RSV VALUES	0 35	5 05	1 35
	#7 (JAPAN)	0 526	4 804	1 066

HANDLING & DRIVEABILITY	#3 (USA) #7 (ITALY) #8 (JAPAN)	RSV MET, OR EXCEEDED' ALL DESIGN SPECIFICATIONS FOR STEADY STATE AND TRANSIENT YAW RESPONSE, RETURNABILITY, LATERAL ACCELERATION, CONTROL AT BREAKAWAY, DIRECTIONAL STABILITY AND OVER TURNING IMMUNITY
BRAKING	#3 (USA) #7 (ITALY) #8 (JAPAN)	RSV EXCEEDED SPECIFICATIONS (ALSO BEST OF 11 COMPARABLE CARS TESTED IN ITALY)

	SPECIFICATION	RSV TEST
STOPPING DISTANCE		
FROM 60 mph	190 ft	151 ft
FROM 100 km/h (62 5 mph)		48 1 m (157 9 ft)
WITH BOOSTER FAILED	350 ft	192 ft
WITH PROPORTIONING SYSTEM FAILED	250 ft	157 ft
WITH 1/2 SYSTEM FAILED	400 ft	329 ft
FADE AND RECOVERY	FMVSS 105	FMVSS 105

PEDESTRIAN	#2 (GERMANY)	IN 12 TESTS AT 15, 20, AND 25 mph WITH 50% AND 6 yr OLD CHILD DUMMIES STRUCK BY RSV FRONT BUMPER, ALL SHOWED SURVIVAL OF PRIMARY IMPACT IN REGARD TO HIC, CHEST g, AND CSI ONLY 6 yr OLD CHILD PELVIS AT 25 mph AND ONE OF TWO TESTS AT 20 mph EXCEEDED THE 60 g ALLOWABLE LIMIT

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APPENDIX

RSV SYSTEM PERFORMANCE SPECIFICATIONS

RSV SYSTEM PERFORMANCE SPECIFICATION (Cont'd)

PERFORMANCE CATEGORY	PROPOSED SPECIFICATION	RSV PERFORMANCE	REFERENCE
1 0 <u>Vehicle Description</u>			
1 1 <u>General Configuration</u>			
Weight (Curb)	2500-3000 lbs	2675 lbs (1213 kg)	16, 39
Payload			40
Occupants	4-5	Family of 5	
Trunk Volume	14-19 ft^3	19 ft^3 (0.538 m^3)	
Test Payload			
1 2 <u>Interior Dimensions</u>			
Head Room - F	37 6 in.	37.5 in. (0.95 m)	9, 16
- R	36 8 in	36.1 in. (0.91 m)	39, 40
Leg Room - F	40.0 in	40.85 in. (1.04 m)	
- R	36 in.	33.85 in. (0.86 m)	
Shoulder Room - F	49 8 in	48.7 in. (1 24 m)	
- R	52.5 in.	50.8 in (1.29 m)	
Engine Description	1400cc Transverse Front Engine and Drive	1716 cc (104.7 $in.^3$) Transverse Front Engine and Drive	
1 3 <u>Exterior Dimensions</u>			
Wheelbase	106 in.	105.7 in (2.68 m)	9, 16
O/A Length	180 in.	177.8 in. (4 52 m)	39, 40
O/A Height	55 in.	53.1 in. (1 35 m)	
O/A Width	72 in.	67 in. (1 70 m)	
Wheel Tread	62 in	55.71/54.72 in. (1.42/1.39 m)	
Turning Circle	42 ft	Less than 38 ft (11.58 m)	4, 43
2 0 <u>Safety Performance Requirements</u>			
2 1 <u>Vehicle Handling</u>			8, 38
2 1.1 <u>Braking Performance</u>			40
Service Braking			Table 4
60 mph/straight, Pedal Force	190 ft	151 ft/150 lbs (46 m/68 kg) .31 g = 26.3 lbs (12 kg) .46 g = 52 lbs (24 kg)	

RSV SYSTEM PERFORMANCE SPECIFICATION (Cont'd)

PERFORMANCE CATEGORY	PROPOSED SPECIFICATION	RSV PERFORMANCE	REFERENCE
Emergency Braking:			
Booster Failure	350 ft	192 ft (58.5 m)	
1/2 System Fail.	400 ft	329 ft (100.3 m)	
Proportion System	250 ft	157 ft (47.9 m)	
Parking Brake	30% Grade	82 lb (37.2 kg)	
Vehicle Jacking	FR 17055	FR 17055	
2.1.2 Steering			16, 33 34, 40
Yaw Response			
.4g, 25 mph		Gain = 30	Figure 31
.4g, 50 mph		Gain = 38	
.4g, 70 mph			
Transient Response			
.4g, 25 mph		Satisfactory	Figure 32
.4g, 70 mph			
Returnability			
.4g, 25 mph		Satisfactory	Figures 33 and 34
4g, 50 mph			
2.1.3 Handling			4, 16, 33 34, 9
Lateral Accel		Exceed Spec .59g Outer R at 5 psi (34 k pascal)	Table 5
Control at Breakaway Dry Pavement	Return in 4 sec	Return in 4 sec.	
Directional Stability			
Steering Control No Power Assist	Torque 5 x power	Satisfactory	
Pavement Irreg.	Deviation 1 ft	Satisfactory	

RSV SYSTEM PERFORMANCE SPECIFICATION (Cont'd)

PERFORMANCE CATEGORY	PROPOSED SPECIFICATION	RSV PERFORMANCE	REFERENCE
2.1.4 <u>Overturning Immunity</u>			16, 33 40, 43
Slalom Course	50 mph	50 mph (80 kph)	
Drastic Maneuvers	50, 60 mph	Satisfactory	
2 1.5 <u>Engine/Driveline</u>			9, 17, 39 40, 43
Passing Time			
30 - 65 mph (48-105 kph)	24 sec	16.3 sec	Table 2
50 - 70 mph (80-113 kph)	22 sec	17.4 sec	
Range at 55 mph (88 kph)	220-250 mi	257 to 390 mi (414-628 km)	10
Lateral Force	Constant Output		
2.1 6 <u>Ride Performance</u>	<u>Frequencies</u> F 9-1.1 Hz R 1.2-1 4 Hz	F = 1.08 Hz R = 1.27 Hz	4, 8 9, 40
2 2 <u>Visibility Systems</u>			26, 39, 40
2.2.1 Driver Visibility			
Direct Field of View	37FR7210	Satisfactory	
Driver Size	---		
Shade Bands	SAE J100		
Light Trans			
I-V	70%		
V	60%		
Obstructions		Satisfactory	
Indirect Visibility	36FR1156	Below Spec	
Backlight	Defog	Heated Backlight	
2 2.2 Lighting	37FR22801	Single Beam F	5
Defrost/defog	FMVSS 103	High Level Rear	
2 2 3 Vehicle Conspicuity	Light Color/ Contrast Stripe	Light Color/ Contrast Stripe	10
2 3 <u>Driver Environment</u>			8, 39, 40
2.3.1 Controls and Displays	S-O-A Practive	SOA	

RSV SYSTEM PERFORMANCE SPECIFICATION (Cont'd)

PERFORMANCE CATEGORY	PROPOSED SPECIFICATION	RSV PERFORMANCE	REFERENCE
2.3.2 Warning Devices	Restraint Status	Restraints Flat Tire	6, 39, 40
2.3.3 Environment	S-O-A	S-O-A	
2.3.4 Emergency Equipment	Standard	STD	
2.4 Crash Energy Management Systems			3, 4, 40
2.4.1 Structural Systems			
2.4.1.1 Front Structure Wide Barrier Impact			
= 0°	40 to 50 mph	43/40 mph (69/65 kph)	29, 30, 31
2.4.1.2 Side Structure Car-to-Car	40 to 45	39.1 mph (62.9 kph)	25
2.4.1.3 Roof Structure	30 mph rollover	Not Tested	
2.4.1.4 Rear Structure Car-to-Car	45-50 mph	40.4 mph (65 kph)	30
2.4.2 Exterior Protection			22, 26
Property Damage Front Barrier	8 mph	8 mph (12.9 kph)	
Front-to-Rear	13 mph	13 mph (20.9 kph)	
2.4.3 Fuel System	No fuel leakage all test conditions	Satisfactory	22

RSV SYSTEM PERFORMANCE SPECIFICATION (Cont'd)

PERFORMANCE CATEGORY	PROPOSED SPECIFICATION	RSV PERFORMANCE	REFERENCE
2.5 Occupant Systems			39, 40
2.5 1 Seating	Primary restraint rear collision	Primary restraint for rear collision	
2.5 2 Restraint	Front - Goal-Passive Restraint, FMVSS No. 208 injury criteria for all crash tests Rear - 30-35 mph barrier.	F - Air Bag Satisfactory. Inflatabelt did not demonstrate 208 compliance in 65 kph (42 mph) barrier test, but passed others R - Satisfactory	7, 8, 9, 14 15, 16, 17, 19 20, 29, 31, 32 39, 40
2.5.3 Flammability	Interior FMVSS No 302 fuel, electrical, exhaust, containment of fuel and exclusion of volatile materials in contact with ignition sources during crash.	Satisfactory	37, 39, 40
2 5 4 Interior Design	FMVSS No 201		8, 35, 39, 40
2.5.5 Emergency Egress	One half doors operable during 35 mph frontal barrier and other crashes	Satisfactory	29, 30, 31 32, 40

RSV SYSTEM PERFORMANCE SPECIFICATION (Cont'd)

PERFORMANCE CATEGORY	PROPOSED SPECIFICATION	RSV PERFORMANCE	REFERENCE
3.0 Vehicle Systems			5, 39, 40
3.1 Engine, Fuel, Cooling, and Exhaust Systems	S-O-A	S-O-A	
Fuel Economy Weight/Power Cruise Grade Start Emissions	20 - 30 mpg. 30 - 40 lbs/bhp 60 mph/5% grade/ 500 lb load 32% Grade/450 lb Compliance with most recent standard	27.6 mpg (8.5 L/100 km) 38.5 lbs/bhp (17.5 kg/bhp) 32% Grade/77 lb (34 kg) HC = 0.34 CO = 4.69 NOX = 1.045	6, 8 10, 17
3.2 Tire and Wheel Systems	"Run Flat" - Tires	Run Flats	5, 7 39, 40
3.3 Electrical	Base vehicle system	S-O-A 12V	40
3.4 Interior Comfort	Base vehicle system	S-O-A	40
3.5 Maintenance	Base vehicle character	S-O-A	40
4.0 Producibility			2, 40