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VEHICLE FRONT END STRUCTURE CRASH EVALUATION PROGRAM

Volume III Appendices

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May 1974
Final Report

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16. Abstract

This report presents the results of a research program conducted to determine the crash response characteristics of two front end structure systems. Computer simulations of each structure and crash environment were conducted using an existing computer crash simulation program. The two front end structures, a ramped fixed-force system and a variable stroke velocity-sensitive system, were incorporated into bogey vehicles which were crashed into a rigid barrier, a variable rigidity barrier, and production vehicle front and side structures. The test results provided data by which computer simulation of the crash conditions was verified, providing a high degree of confidence in analytical representation of the structural crash responses. The empirical data were extended to other crash environments using the computer simulation techniques. Parametric studies were conducted to study the effects of bumper weight and structural stiffness on vehicle and structure system responses.

The report is presented in three volumes:

Volume I - Summary Report
Volume II - Technical Report
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FOREWORD

This final report details an extensive analytical and crash test program conducted by Ultrasystems, Inc., the Dynamic Science Division, for the National Highway Traffic Safety Administration under Contract DOT-HS-046-2-486. The Contract Technical Manager for the program was Mr. Glen F. Brammeier of NHTSA.

The program was devoted to determining the crash response characteristics of two front end structure systems, a ramped fixed-force system and a variable stroke velocity-sensitive system.

The opinions and findings expressed in this publication are those of the authors and not necessarily those of the National Highway Traffic Safety Administration.

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APPENDIX A

TEST PROCEDURES

In this appendix, where similar or identical procedures are used in different tests, they have been grouped under general categories rather than being introduced repeatedly. The photographic requirements for all tests form one such grouping. For the rigid barrier tests, the variable rigidity barrier tests, the vehicle-to-vehicle tests, and production vehicle structural characterization tests, the Test Facility Preparation Procedures and Pre-test Checklist vary only slightly and so have been similarly grouped.

Following these sections, each of the five test procedures is presented in detail.

A.1 PHOTOGRAPHIC REQUIREMENTS

A.1.1 Still Photography

For the components tests, still photographs were taken to document the overall test setup. Pre- and post-test views of the honeycomb stack used in each test were required.

For all the remaining tests, the following still photographs were obtained in both black-and-white (negative) and 35mm color slides (direct positive) both prior to and following each test.

1. Overall side view - both sides
2. Overall rear view
3. Vehicle right front three-quarter view
4. Vehicle left front three-quarter view
5. Views to show instrumentation installation
6. Close-up views of the following:
    a. Tow shoe attachment
    b. Abort cable attachment
    c. Frame accelerometer installations
    d. Umbilical cable attachment

7. Underside view of front end structure

8. Front and side views of the variable rigidity barrier (for VARB tests only)

9. Interior view of vehicle front end structure (for vehicle-to-vehicle tests only)

In addition, the following still photographs were obtained for the vehicle-to-vehicle test overview in both black-and-white (negative) and 35mm color slides (direct positive) both prior to and following each test:

1. Overall side view - both sides

2. Overall end view - both ends

3. Overall top view

4. Underside view of vehicle front structure

A.1.2 <u>High-Speed Photography</u>

For the components tests, one LowCam camera running at 500 frames per second was positioned to obtain a front view of the impact surface and the complete movable portion of the energy absorber.

For all other tests, 3 Photosonics 1B cameras running at 1,000 frames/second were used to provide a color record of the crash dynamics. All high-speed cameras provided 100 Hz timing records on the film. These cameras were located as follows:

1. A ground-based camera positioned to yield an overall side view, including the complete movable portion of the energy absorber(s).

2. An overhead camera showing a close-up of the bumper and movable portion of the energy-absorption system(s) for the rigid barrier tests, variable rigidity barrier tests, and production vehicle structural characterization tests; an overhead camera showing the impact area for the vehicle-to-vehicle tests.

3. A pit camera having the same field of view as the overhead camera. If required , 2 pit cameras for the vehicle-to-vehicle tests and the production vehicle structural characterization tests.

A.1.3 Documentary Motion Picture Photography

Motion picture documentation was not required for the components tests.

For all other tests, a panning camera was used to provide overall coverage. Pre-test and post-test coverage of the general configuration of the vehicle, barrier (if applicable), and impact area was also obtained.

A.2 PREPARATION OF THE TEST FACILITY

A.2.1 Component Tests

1. The weight of the drop mass (±5 pounds) was determined.
2. The sand was removed from the concrete base of the drop tower facility.
3. The drop tower was readied for testing; guide cable tension and grease cables were checked; hoist cable and pulleys were checked; drop release and safety were checked out.

A.2.2 Rigid Barrier, VARB, Vehicle-to-Vehicle and Production Vehicle Structural Characterization Tests

1. Tow system was prepared for use.
2. Abort system was prepared for use.
3. Readiness of data acquisition and test control system was confirmed.
4. Umbilical and control cable(s) were laid out as required.
5. a. SLAM barrier with load cells was installed (rigid barrier tests only).

   b. VARB barrier with load cells and accelerometers was installed. Two energy absorbers were loaded into the VARB (VARB tests only).

c. Barrier with 6 load cells was installed. The load cell was pre-loaded per established procedure (production vehicle structural characterization tests only).

6. High-speed cameras were installed per Section A.1.2.

7. The appropriate abutment was mounted onto the barrier face (production vehicle structural characterization tests only).

A.3 PRE-TEST CHECKLIST

The following steps were taken prior to each of the following tests - rigid barrier, VARB, vehicle-to-vehicle, and production vehicle structural characterization:

1. Vehicle and facilities preparation was verified.
2. Vehicle(s) was secured to tow and guidance system.
3. Umbilical and control cables were secured to vehicle.
4. Abort shoe was secured to vehicle(s).
5. Pre-test photographs were taken as specified in Section A.1.1 and as directed by the Project Engineer.
6. Readiness of tow system, guidance system, instrumentation system, and high-speed cameras was verified.
7. Vehicle was moved to starting point.

A.4 COMPONENT TESTS

The test consisted of assembling the test item into the drop test fixture, raising a weight to a height corresponding to the desired energy, and dropping the weight onto the fixture. Impact force was inferred from the measured weight deceleration, and the stroke was determined by several means. The output data were the force versus the stroke.

The drop test fixture is shown in Dynamic Science Drawing DSL000331-402.* This fixture was positioned directly under the

*All Dynamic Science Drawings referenced in this section are presented at the end of this appendix.

drop tower with the orientation as defined in the drawing. (The fixture was mounted on the concrete base of the drop tower facility requiring removal of the sand.)

The height to which the weight was raised was calculated from the following equation:

$$H = \frac{63,400}{W} \tag{42}$$

where H = drop height in feet

W = weight in pounds

A.4.1 INSTRUMENTATION REQUIREMENTS

The parameters measured during this test series are listed in Table A-I.

TABLE A-I. INSTRUMENTATION REQUIREMENTS

Measurand	Type Transducer	Manufacturer	Model Number	Number Required
Vertical Acceleration of Drop Weight	Accelerometer	Statham	A69	2 (primary and redundant)
Impact Time	Contact Switch	Dynamic Science	-	1

A.4.2 DATA ACQUISITION REQUIREMENTS

The accelerometers were mounted on the drop weight with data being transmitted through a trailing umbilical. Signals were recorded on a ground-based tape recorder in a form compatible with automated reduction using the existing processing program.

A.4.3 PREPARATION OF TEST FIXTURE

1. Fixture was fabricated and assembled per Drawing DSL000331-402.

2. Fixture was installed in drop tower as shown in Drawirg DSL000331-402.

3. The base of the energy absorber (Items 13 and 38 of Drawing DSL000331-313) was fabricated and assembled.

4. Honeycomb stacks were fabricated and/or assembled per direction of the Project Engineer. Dimensions of the nominal stack are shown in Table A-II. A test sequence for the first six (6) tests is contained in Table A-III. Initially, the honeycomb stacks were fabricated only for Tests 1 and 2.

5. Assembly of test honeycomb stack energy absorber and test fixture was completed.

TABLE A-II. NOMINAL HONEYCOMB STACK GEOMETRY

Element Number	Thickness* (in.)	Length** and Width (in.)
1	5	2-1/2
2	5	4-3/8
3	5	5-5/8
4	5	6-5/8
5	5	7-1/2
6	5	8-1/4
7	5	9
8	13	9-1/4

*Thickness was measured parallel to the cells. For a 5-inch nominal thickness, the sheet was sawed into two equal halves. The 13-inch thickness consisted of a 10-inch thickness and a 3-inch thickness.

**Tolerance on length and width dimensions was ±1/8-inch. The 9-1/4 and the 9-inch sheet were chamfered to clear the corners of the 10-inch square tube.

TABLE A-III. TEST CONDITIONS FOR INITIAL TESTS			
Test Number	Stack Description (1)	Faceplate (2) Bonding Material	Weight Drop Height
1	Non-shaped (3)	Epoxy	Nominal (6)
2	Nominal Shaped Stack (4)	Epoxy	Nominal (6)
3	Modified Shaped Stack (5)	Epoxy	Nominal (6)
4	Modified Shaped Stack (5)	RTV	Nominal (6)
5	Modified Shaped Stack (5)	TBD (7)	Nominal (6)
6	Modified Shaped Stack (5)	TBD (7)	.563 Nominal

(1) An aluminum sheet faceplate (.060 nominal thickness) was inserted between each honeycomb stack element. The honeycomb was 3/16-5052-.003 (crush strength = 750 psi).
(2) Detailed material specification was determined by Project Engineer.
(3) Non-shaped stack consisted of 4 pieces 10 inches thick and one piece 8 inches thick; all 9-1/4 inches square.
(4) Elements were stacked per Table A-II.
(5) Geometries of stack elements were modified based on the results obtained in Test 2.
(6) Per Equation (1).
(7) Bonding material was selected by Project Engineer based on results of previous tests.

A.4.4 PREPARATION OF INSTRUMENTATION AND PHOTOGRAPHY

1. Tape recorder, signal conditioning electronics and test control panel were set up in suitable location.

2. All elements required for test were connected and checked out. It was ensured that adequate slack existed in the lead to the drop weight accelerometers.

3. High-speed camera was positioned.

A.4.5 TEST PERFORMANCE

A.4.5.1 Pre-Test Checks

1. The honeycomb stack required for the test was installed. Pre-test still photographs of stack were taken.

2. Drop tower facility (cable tension, guide cable lubrication, weight release and safety) was checked.

3. Camera was loaded and readiness check was performed.

4. Pre-test cals and zeros were obtained. Instrumentation and control system readiness check was performed.

5. Area was cleared and safety check was performed prior to raising drop weight.

A.4.5.2 Test

1. Weight was raised to desired height.

2. Tape recorder was started, weight was released, and high-speed camera was started.

A.4.5.3 Post-test

1. Post-test zeros and electrical cals were obtained.

2. The drop weight was secured.

3. Post-test still photographs were obtained.

A.5 RIGID BARRIER

A.5.1 Test Description

The test consisted of mounting the appropriate front end structure on a bogey test vehicle, propelling it along a monorail at the required test speed, and impacting it into a flat-faced, load-measuring barrier. All impacts were normal (0° obliquity) to the barrier face. The data obtained were impact forces, decelerations, and bumper displacement as a function of time. Vehicle stability and system characterization tow tests were conducted prior to the initiation of this test program.

The bogey vehicle is shown in Dynamic Science Drawing DSL000331-313, formerly DSL000558. The bumper and pistons for the "fixed-force" front end structure are shown in Drawing DSL000557. The honeycomb energy absorber was inserted into the 10 x 10-inch tube behind the pistons. Dimensions of the nominal honeycomb stack are shown in Figure A-1.

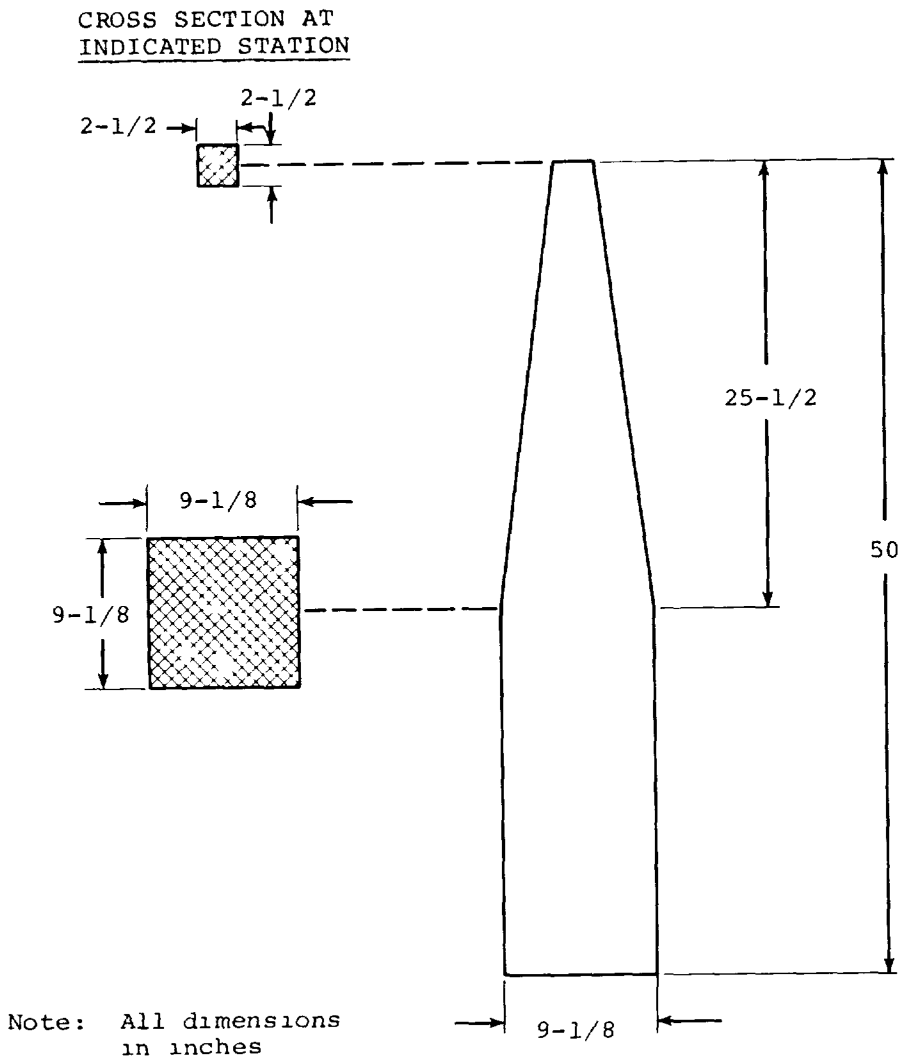


Figure A-1. Geometry of Honeycomb Stack Used in Ramped Fixed-Force Front End Structure.

The configuration of the variable stroke velocity-sensitive front end structure including bumper, hydraulic buffers, and mounting hardware is shown in Drawing DSL000563. Details such as the procedures to be followed in topping the hydraulic cylinders and pre-charging the accumulators were provided later either by the Project Manager or by an AMF consultant.

A.5.2 Instrumentation Requirements

The data obtained from this test series are described in Table A-IV. Specific instrument requirements are defined in Table A-V and instrument mounting locations are illustrated in Figure A-2.

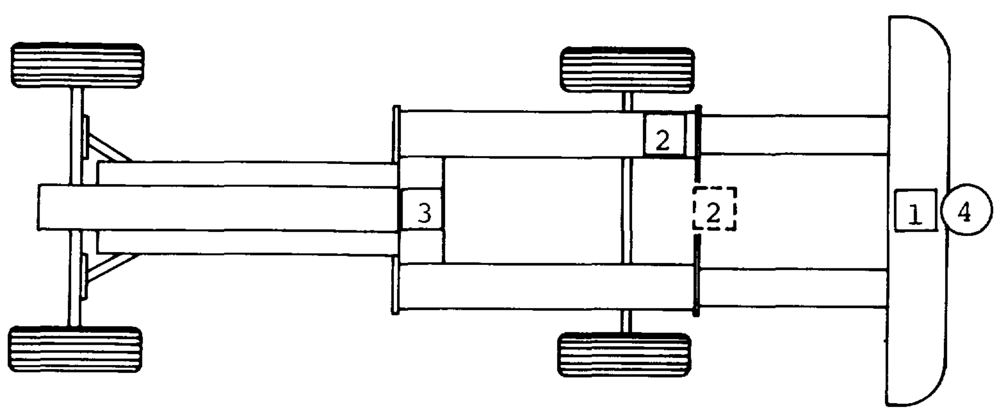
TABLE A-IV. DATA REQUIREMENTS FOR RIGID BARRIER TESTS

Parameter	Measurement Method	Application Method				
		Magnetic Tape	Written Log	Computed	Photographic Analysis	Strip Recorders
Impact Time	Contact Switch Superimposed on Time Base	X				X
Approach Velocity	Tow Cable Velocity Sensor and Speed Traps		X			X
Impact Velocity	Speed Trap		X			X
Rebound Distance	Direct Measurement (post-test)		X			
Rebound Velocity	Calculated From Impact Force Measurements, Vehicle Mass, and Approach Velocity, Cross-checked Photographically			X	X	
Impact Angles	Photographic Reduction of Yaw and Pitch Angles at and Following Impact				X	
Vehicle Deceleration	Accelerometers Mounted at Various Locations	X				
Crush Distance	Computed by Double Integration of Acceleration Pulse Cross-checked Photographically			X	X	
Net Crush	Direct Post-test Measurement; Cross-checked Photographically		X		X	
Vehicle Weight	Pre-test Balance Scale Measurement by Wheel		X			
Impact Force	Load Cells at Barrier Face, Cross-checked by Accelerometer Measurements	X				
Force Versus Displacement	Cross Plot of Above Variables			X		

A.5.3 Data Acquisition Requirements

The data acquisition system used is shown schematically in Figure A-3. Note that redundant signal paths were used between the vehicle and the recorder. The umbilical (hard-line) data were the primary data.

TABLE A-V. INSTRUMENTATION REQUIREMENTS							
Measurand	Type Transducer	Manu-facturer	Model Number	Capacity	Full-Scale Output	Accuracy	Number Required
Test Vehicle							
Bumper Acceleration	Accelerometer	Statham	A69	100G	40-50MV	±1%F.S.	3 (triaxial)
Frame Acceleration	Accelerometer	Statham	A69	100G	40-50MV	±1%F.S.	6 (2 triaxial)
Impact Time	Switch	Dynamic Science	-	-	6.0 Volts	±1.0 msec	1
Ground Based							
Impact Load	Load Cell	Interface	1330	100Klb	40-50MV	±1%F.S.	4
Approach Velcoity	Digital Counter	Dynamic Science	-	>100 mph	10,000 counts	±2 counts	2
Impact Velocity	Digital Counter	Dynamic Science	-	>100 mph	10,000 counts	±2 counts	1
Cable Velcoity	Digital Proximity	Probe Airpax	-	>100 mph	5.0 Volts	±1.5%	1
Impact Time	Switch	Dynamic Science	-	-	6.0 Volts	±1.0 msec	1



1 Bumper Accelerometer (triaxial)

2 Frame Accelerometer (triaxial)

2 Alternate Location for Triax No. 2

3 Frame Accelerometer (c.g.) (triaxial)

4 Impact Switch

Figure A-2. Instrument Mounting Locations.

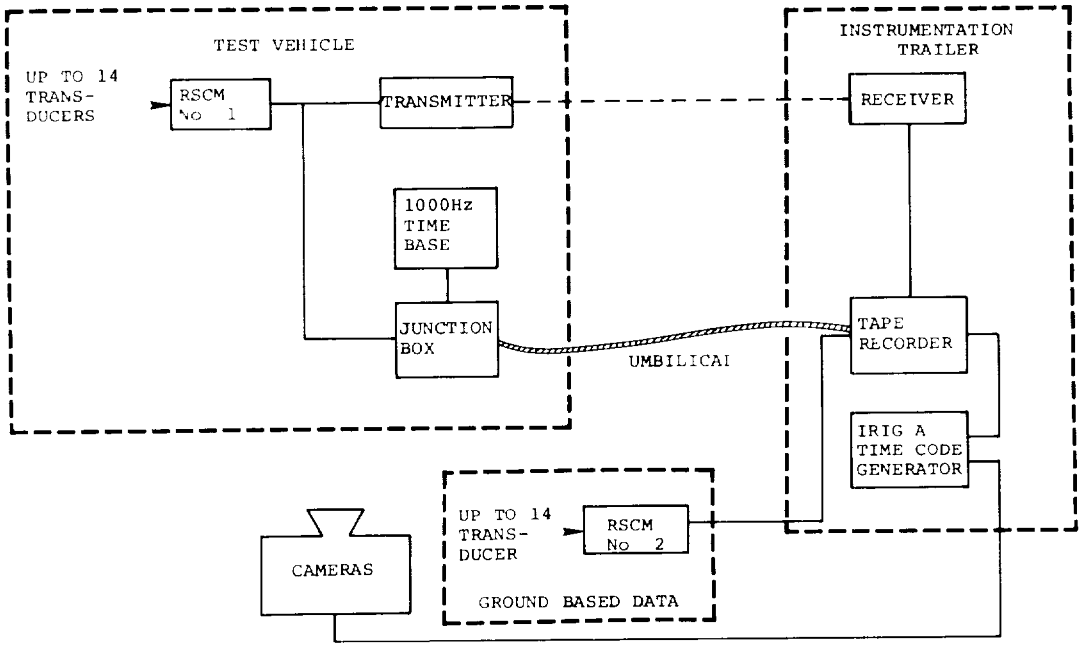


Figure A-3. Data Acquisition.

A.5.4 Vehicle Preparation

The following steps were taken to prepare the vehicles:

1. Vehicle curb weight was determined by wheel and axle.
2. Vehicle underside was painted to color code undercar components as shown below:

   Main Frame Members - Light Pink
   Bumper - Yellow
   Front and Rear Axle - Pale Green

3. Traction bar for umbilical cable was fabricated and attached to rear of vehicle.
4. Mounting brackets for vehicle accelerometers were installed. Frame accelerometer mounts were installed on plates drilled and tapped to accept the mounts. The mounting plates were welded to the frame. Specific details on location were supplied by the Project Engineer.
5. Accelerometers were installed.

6. Instrumentation was installed in the rear half of the front ballast compartment consisting of RSCM, junction box, and battery pack as required. These items were installed on a 3/4-inch-thick plywood base which was in turn bolted to the vehicle frame.

7. All instrumentation, power, and control cables, were installed, routed, and secured.

8. Level line on each side of vehicle was marked. Five-inch-diameter camera targets were applied at 1-foot intervals along the full length of the vehicle (both sides). Additional marking was provided per directions from Project Engineer.

9. Tire pressure was set at 24 psi.

10. Ballast was installed in vehicle as required to obtain test weight of 4,000 pounds and so that vertical c.g. location was maintained.

11. Instrumentation battery was charged to full capacity; charge was maintained.

A.5.5 Test Performance

The following steps were performed during the conduct of this test series:

1. Tow system was started.

2. Vehicle was accelerated to desired test speed and allowed to impact barrier.

3. Post-test photographs were taken as specified in Section A.2.3 and as directed by Project Engineer.

4. Vehicle was inspected for damage, and photographs of damage were made.

A.6 VARIABLE RIGIDITY BARRIER

A.6.1 Test Description

The test consisted of mounting the appropriate front end structure on a bogey test vehicle, propelling it along a monorail at the required test speed (±1.0 mph), and impacting it into a flat-faced, load-measuring movable barrier. All impacts were normal (0° obliquity) to the barrier face. The data obtained were impact forces, decelerations, and barrier and bumper displacements as a function of time.

The bogey vehicle is shown in Dynamic Science Drawing DSL000331-313. The bumper and pistons for the fixed-force front end structure are shown in Drawing DSL000557. The honeycomb energy absorber was inserted into the 10- x 10-inch tube behind the pistons. Dimensions of the nominal honeycomb stack for the bogey vehicle are shown in Figure A-1.

The configuration of the variable stroke velocity-sensitive front end structure including bumper, hydraulic buffers, and mounting hardware is shown in Drawing DSL000563. Details such as the procedures to be followed in topping the hydraulic cylinders and pre-charging the accumulators were provided later by the Project Engineer or by an AMF consultant.

The variable rigidity barrier is shown in Dynamic Science Drawing DSL000331-314. Basically, the device consisted of a 3- x 6-foot rigid steel impact surface which acted as a beam between the two horizontal aluminum honeycomb energy absorbers. The barrier facepiece was mounted in a track to eliminate both side loads and an overhanging moment on the absorber pistons. The absorbers were adjustable in the vertical direction to accommodate impact center lines between 18 inches and 30 inches above the ground datum. The absorber loads were reacted on an existing J850 concrete barrier. The preliminary weight estimate was 600 pounds for the barrier face plus approximately 100 pounds for each of the wheels and tracks. The moving "piston" element of either the hydraulic or honeycomb versions weighed 125 pounds per absorber for a total moving-element weight of approximately 1,100 pounds including the load cells.

The absorbers were designed to dissipate a portion of the energy of an impacting vehicle in a controlled manner, thereby simulating the conditions experienced during a vehicle-to-vehicle crash. The force-versus-stroke profiles shown in Figure A-4 simulated the side structure stiffnesses of compact, standard, and advanced vehicles (ESVs). Dimensions of honeycomb stacks configured to achieve these profiles are shown in Figure A-5.

A.6.2 Instrumentation Requirements

The data to be obtained from this test series are described in Table A-VI. Specific instrument requirements are defined in Table A-VII, and instrument mounting locations on the vehicle are illustrated in Figure A-6. The two barrier triaxial accelerometers were mounted on the face of the barrier in the vicinity of the respective North and South load cells.

A.6.3 Data Acquisition Requirements

The data acquisition system used is shown schematically in Figure A-3. Note that redundant signal paths were used between the vehicle and the recorder. The umbilical (hard-line) data were the primary data.

A.6.4 Vehicle Preparation

The following steps were taken to prepare the vehicles:

1. Vehicle curb weight was determined by wheel and axle.
2. Vehicle underside was painted to color code undercar components as shown below:

Main Frame Members	- Light Pink
Bumper	- Yellow
Front and Rear Axle	- Pale Green

3. Traction bar for umbilical cable was fabricated and attached to rear of vehicle.

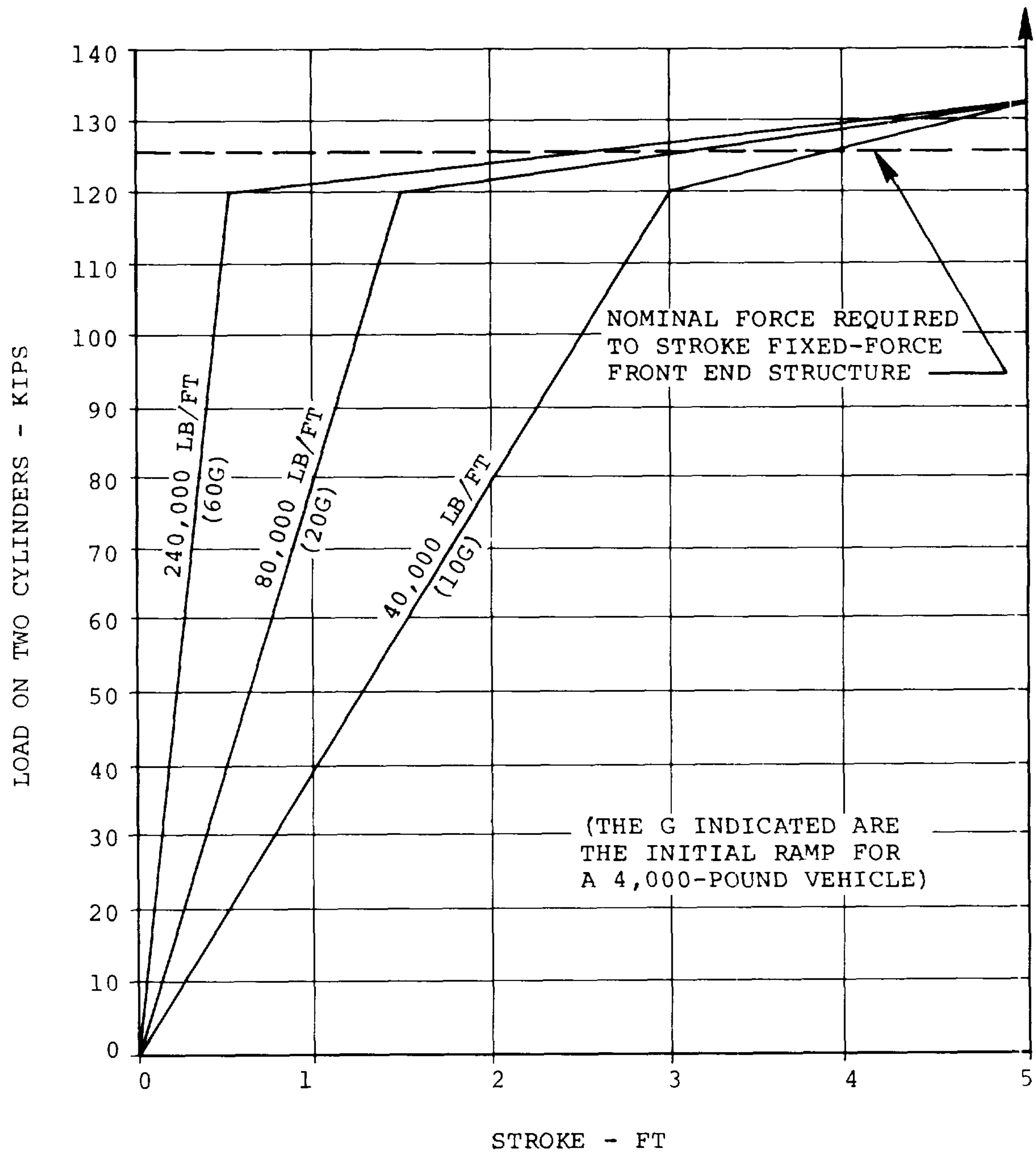
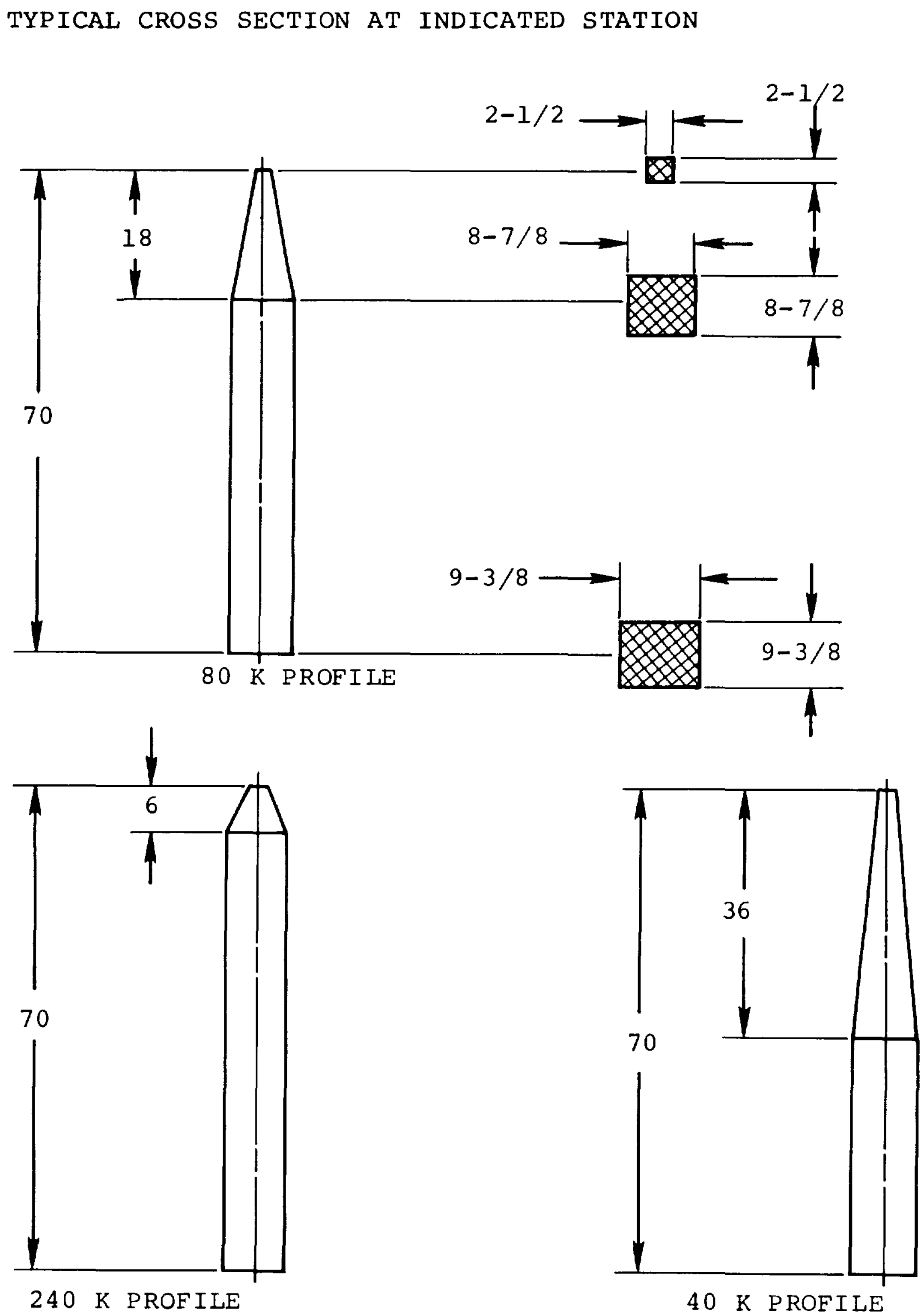


Figure A-4. Variable Rigidity Barrier Force/Stroke Profile.

4. Mounting brackets for vehicle accelerometers were installed. Frame accelerometer mounts were installed on plates drilled and tapped to accept the mounts. Specific details on location were supplied by the Project Engineer.



Note: All dimensions in inches.

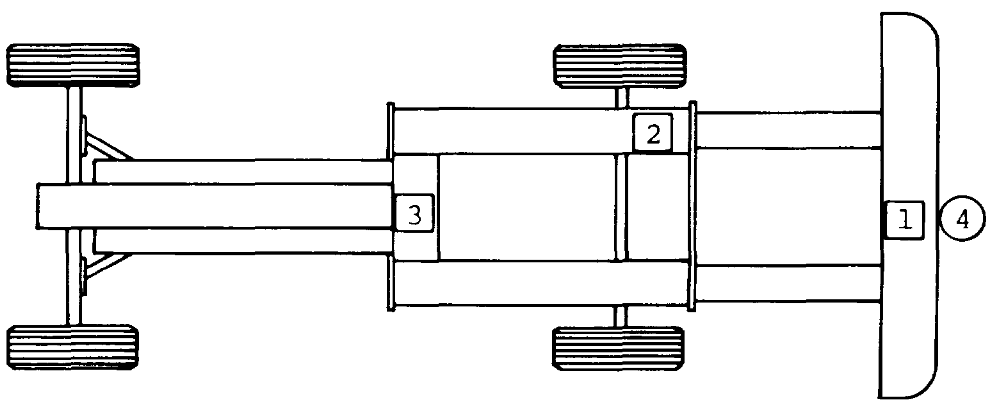
Figure A-5. Geometry of Honeycomb Stacks.

TABLE A-VI. DATA REQUIREMENTS FOR RIGID BARRIER TESTS

Parameter	Measurement Method	Application Method				
		Magnetic Tape	Written Log	Computed	Photo-graphic Analysis	Strip Recorders
Impact Time	Contact Switch Superimposed on Time Base	X				X
Approach Velocity	Tow Cable Velocity Sensor and Speed Traps		X			X
Impact Velocity	Speed Trap		X			X
Rebound Distance	Direct Measurement (post-test)		X			
Rebound Velocity	Calculated From Impact Force Measurements, Vehicle Mass, and Approach Velocity; Cross-checked Photographically			X	X	
Impact Angles	Photographic Reduction of Yaw and Pitch Angles at and Following Impact				X	
Vehicle Deceleration	Accelerometers Mounted at Various Locations	X				
Barrier Acceleration	Accelerometers Mounted on the Barrier Face	X				
Crush Distance	Computed by Double Integration of Acceleration Pulse, Cross-checked Photographically			X	X	
Net Crush	Direct Post-test Measurement, Cross-checked Photographically		X		X	
Vehicle Weight	Pre-test Balance Scale Measurement by Wheel		X			
Impact Force	Load Cells at Barrier Face; Cross-checked by Accelerometer Measurements	X				
Force Versus Displacement	Cross Plot of Above Variables			X		

TABLE A-VII. INSTRUMENTATION REQUIREMENTS

Measurand	Type Transducer	Manu-facturer	Model Number	Capacity	Full-Scale Output	Accuracy	Number Required
<u>Test Vehicle</u>							
Bumper Acceleration	Accelerometer Accelerometer	Statham Statham	A53 A69	±500G ±200G	40-50MV 40-50MV	±1%F.S. ±1%F.S.	1 (Longitudinal) 2 (Transverse and Vertical
Frame Acceleration	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.	6 (2 Triaxial)
Impact Time	Switch	Dynamic Science	-	-	6.0 Volts	±1.0 msec	-
<u>Ground Based</u>							
Impact Load	Load Cell	Interface	1330	100Klb	40-50MV	±1%F.S.	2
Barrier Acceleration	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.	6 (2 Triaxial)
Approach Velocity	Digital Counter	Dynamic Science	-	>100 mph	10,000 counts	±2 counts	2
Impact Velocity	Digital Counter	Dynamic Science	-	>100 mph	10,000 counts	±2 counts	1
Cable Velocity	Digital Proximity	Probe Airpax	-	>100 mph	5.0 Volts	±1.5%	1
Impact Time	Switch	Dynamic Science	-	-	6.0 Volts	±1.0 msec	1



1 Bumper Accelerometer (triaxial)

2 Frame Accelerometer (triaxial)

3 Frame Accelerometer (c.g.) (triaxial)

4 Impact Switch

Figure A-6. Instrument Locations.

5. Accelerometers were installed.

6. Instrumentation was installed in the rear half of the front ballast compartment consisting of RSCM, junction box, and battery pack as required.

7. All instrumentation, power, and control cables were installed, routed, and secured.

8. Level line was marked on each side of vehicle. Five-inch-diameter camera targets were applied at 1-foot intervals along the full length of the vehicle top, bottom, and side. Five-inch-diameter targets were applied at 1-foot intervals to top, bottom, and side toward camera of the "piston" portion of the VARB. Additional marking was provided per directions from Project Engineer.

9. Tire pressure was set at 24 psi.

10. Ballast was installed in vehicle as required to obtain test weight of 4,000 ±20 pounds with a 50/50 ±0.5 percent front-to-rear distribution and so that longitudinal c.g. location was maintained.

11. New honeycomb absorber stacks were installed as required.

12. The DSL000557 bumper assembly was replaced by a lighter-weight member as required.

13. Instrumentation battery was charged to full capacity; charge was maintained.

A.6.5 Test Performance

The following steps were performed during the conduct of this test series:

1. Tow system was started.

2. Vehicle was accelerated to desired test speed (±1.0 mph) and allowed to impact barrier.

3. Post-test photographs were taken as specified in Section A.3.3 and as directed by the Project Engineer.

4. Vehicle was inspected for damage; rebound and stroke were recorded; and damage was documented photographically.

5. Barrier was inspected for damage, and stroke was recorded.

A.7 VEHICLE-TO-VEHICLE

A.7.1 Test Description

The vehicle-to-vehicle front end impact tests consisted of mounting the appropriate front end structure on a bogey test vehicle (Vehicle 1), propelling the test vehicles (Vehicles 1 and 2) along a monorail at the required closure speed, and then impacting them into each other in a zero offset, 0° obliquity frontal impact. Vehicle 2 was either a bogey vehicle with a different front end structure from Vehicle 1 or a 1968 Plymouth Fury sedan. The data obtained were vehicle decelerations and displacements as functions of time.

The vehicle-to-vehicle side impact tests consisted of mounting the appropriate front end structure on the bogey test vehicle, propelling the bogey vehicle along a monorail at 30 ±1.0 mph, and impacting it into the side of a second vehicle. The front-to-side tests were normal (0° obliquity) to the impacted vehicle side, centered on the occupant compartment length. The data obtained were vehicle decelerations (or accelerations), bogey vehicle displacements, and impacted vehicle side displacements as functions of time.

The bogey vehicle is shown in Dynamic Science Drawing DSL000331-313. The bumper and pistons for the fixed-force front end structure are shown in Drawing DSL000557. The honeycomb energy absorber was inserted into the 10- x 10-inch tube behind the pistons. Dimensions of the nominal honeycomb stack are shown in Figure A-5.

The configuration of the variable stroke velocity-sensitive front end structure including bumper, hydraulic buffers, and mounting hardware is shown in Drawing DSL000563. The procedures followed in topping the hydraulic cylinders and pre-charging the accumulators were defined in "AMF Bumper System Installation and Maintenance Procedures" by R. Schwarz, dated 29 December 1972.

A.7.2 Instrumentation Requirements

The data obtained from this test series are described in Table A-VIII. Specific instrument requirements for the bogey vehicles are defined in Table A-IX. Bogey vehicle instrument mounting locations are illustrated in Figure A-7. Automotive vehicle instrument mounting locations are nominally illustrated in Figures A-8 and A-9. Specific instrument requirements for standard vehicles are defined in Tables A-X and A-XI for frontal and side crash tests, respectively.

A.7.3 Data Acquisition Requirements

The data acquisition system used for each vehicle is shown schematically in Figure A-3. Note that redundant signal paths were used between the vehicle and the recorder. The umbilical (hard-line) data were the primary data.

A.7.4 Vehicle Preparation

The following steps were taken to prepare the vehicles:

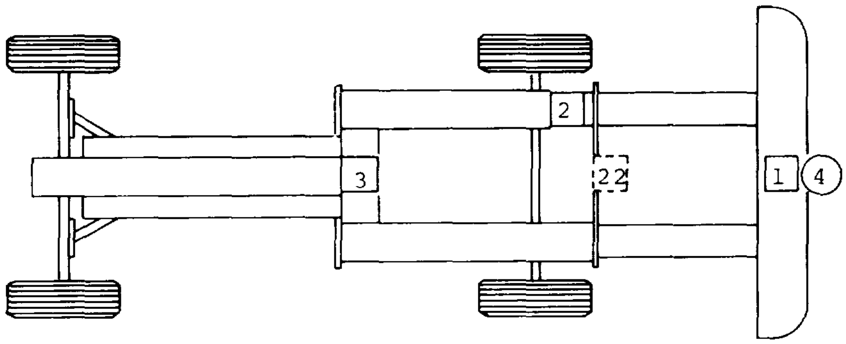
1. Vehicle curb weight was determined by wheel and axle.
2. Vehicle underside was painted to color code undercar components as shown below:

Main Frame Members	- Light Pink
Bumper	- Yellow
Front and Rear Axle	- Pale Green

3. Traction bar for umbilical cable was fabricated and attached to rear of vehicle.

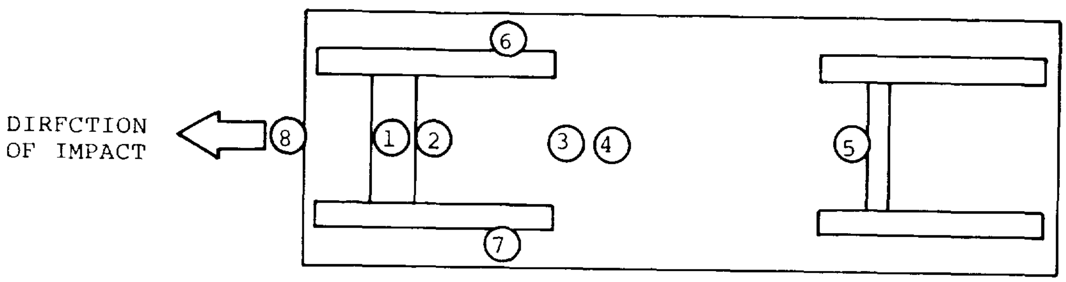
TABLE A-VIII. DATA REQUIREMENTS FOR VEHICLE-TO-BOGEY TESTS						
		Application Method				
Parameter	Measurement Method	Magnetic Tape	Written Log	Computed	Photographic Analysis	Strip Recorders
Impact Time	Contact Switch Superimposed on Time Base	X				X
Approach Velocity	Tow Cable Velocity Sensor and Speed Traps		X			X
Impact Velocity	Speed Trap(s)		X			X
Rebound Distance	Direct Measurement (post-test)		X			
Rebound Velocity	Calculated From Impact Force Measurements, Vehicle Mass, and Approach Velocity; Cross-checked Photographically			X	X	
Impact Angles	Photographic Reduction of Yaw and Pitch Angles at and Following Impact				X	
Vehicle Deceleration	Accelerometers Mounted at Various Locations	X				
Crush Distance	Computed by Double Integration of Acceleration Pulse, Cross-checked Photographically			X	X	
Net Crush	Direct Post-test Measurement; Cross-checked Photographically		X		X	
Vehicle Weight	Pre-test Balance Scale Measurement by Wheel		X			
Force Versus Displacement	Cross Plot of Above Variables With Load Computed From Accelerations			X		

TABLE A-IX. INSTRUMENTATION REQUIREMENTS FOR BOGEY VEHICLES							
Measurand	Type Transducer	Manufacturer	Model Number	Capacity	Full-Scale Output	Accuracy	Number Required
Test Vehicle							
Bumper Acceleration	Accelerometer	Statham	A53	±500G	40-50MV	±1%F.S.	1 (Longitudinal)
Frame Acceleration	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.	6 (2 Triaxial)
Impact Time	Switch	Tape Switch	-	-	6.0 Volts	±1.0 msec	-
Ground Based							
Approach Velocity	Digital Counter	Dynamic Science	-	>100 mph	10,000 counts	±2 counts	2
Impact Velocity	Digital Counter	Dynamic Science	-	>100 mph	10,000 counts	±2 counts	1
Cable Velocity	Digital Proximity	Probe Airpax	-	>100 mph	5.0 Volts	±1.5%	1



1	Bumper Accelerometer (Longitudinal)
2	Frame Accelerometer (Triaxial)
22	Alternate Location for Triaxial No. 2
3	Frame Accelerometer (c.g.) (Triaxial)
4	Impact Switch

Figure A-7. Instrumentation Mounting Locations, Bogey Vehicle(s).



1 Engine Accelerometer (Triaxial)

2 Front Stub Frame Cross Member Accelerometer (Longitudinal)

3 Vehicle C G. Accelerometer (Triaxial)

4 Vehicle C.G. Accelerometer, Backup (Longitudinal)

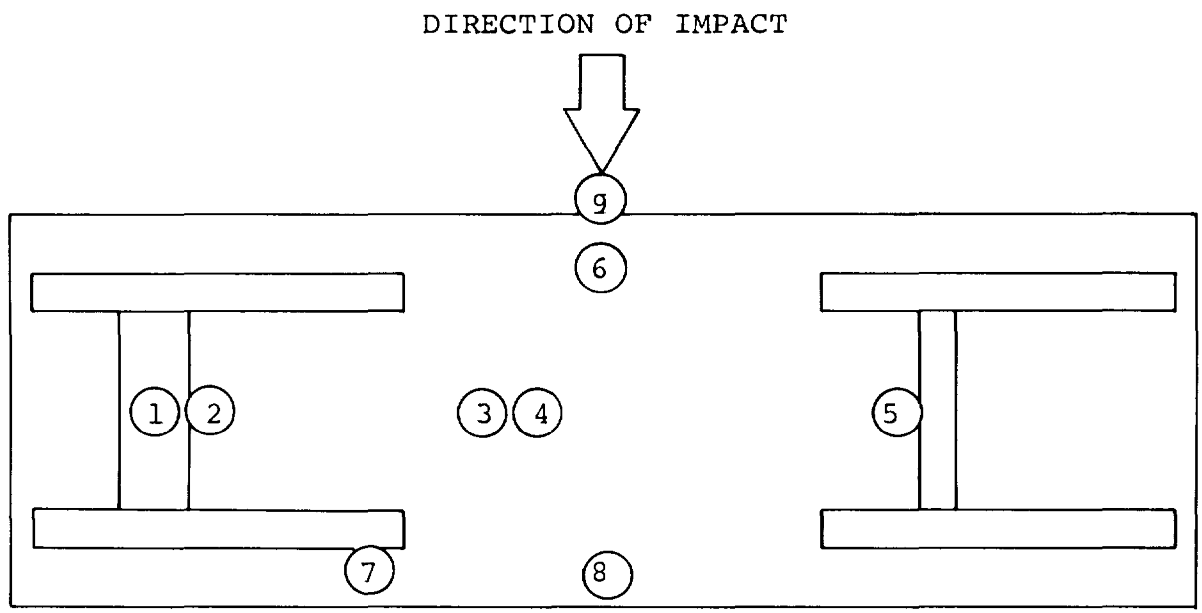
5 Rear Stub Frame Cross Member Accelerometer (Longitudinal)

6 Right Stub Frame Torque Box Accelerometer (Longitudinal)

7 Left Stub Frame Torque Box Accelerometer (Longitudinal)

8 Impact Switch

Figure A-8. Instrumentation Mounting Locations, 1968 Plymouth, Frontal Impacts.



(1) Engine Accelerometer (Triaxial)

(2) Front Stub Frame Cross Member Accelerometer (Lateral)

(3) Vehicle C.G. Accelerometer (Triaxial)

(4) Vehicle C.G. Accelerometer, Backup, (Lateral)

(5) Rear Stub Frame Cross Member Accelerometer (Lateral)

(6) Right Occupant Compartment Accelerometer (Lateral)

(7) Left Stub Frame Accelerometer (Lateral)

(8) Left Occupant Compartment (Lateral)

(9) Impact Switch

Figure A-9. Instrumentation Mounting Locations, Side Impacted Vehicles.

4. Mounting brackets for vehicle accelerometers were installed. Frame accelerometer mounts were installed on plates drilled and tapped to accept the mounts. Specific details on location were supplied by the Project Engineer.

5. Accelerometers were installed.

TABLE A-X. INSTRUMENTATION REQUIREMENTS FOR 1968 PLYMOUTH, FRONTAL IMPACTS						
Measurand	Type Transducer	Manu-facturer	Model Number	Capacity	Full-Scale Output	Accuracy
Test Vehicle						
Front Stub Frame Acceleration (3 Longitudinals)	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.
Engine Acceleration (Triaxial)	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.
Vehicle Center-of-Gravity Acceleration (Triaxial and Longitudinal)	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.
Rear Stub Frame Acceleration (Longitudinal)	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.
Impact Time	Switch	Tape Switch	-	-	6.0 Volts	±1.0 msec
Ground Based						
Approach Velocity	Digital Counter	Dynamic Science	-	>100 mph	10,000 Counts	±2 Counts
Impact Velocity	Digital Counter	Dynamic Science	-	>100 mph	10,000 Counts	±2 Counts
Cable Velocity	Digital Proximity	Probe Airpax	-	>100 mph	5.0 Volts	±1.5%

TABLE A-XI. INSTRUMENTATION REQUIREMENTS FOR SIDE IMPACTED VEHICLES						
Measurand	Type Transducer	Manu-facturer	Model Number	Capacity	Full-Scale Output	Accuracy
Test Vehicle						
Engine Acceleration (Triaxial)	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.
Front Stub Frame Acceleration (2 Laterals)	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.
Vehicle Center-of-Gravity Acceleration (Triaxial and Lateral)	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.
Rear Stub Frame Acceleration (Lateral)	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.
Occupant Compartment Acceleration (2 Lateral)	Accelerometer	Statham	A69	±200G	40-50MV	±1%F.S.
Impact Time	Switch	Tape Switch	-	-	6.0 Volts	±1.0 msec

6. In each vehicle instrumentation consisting of RSCM, junction box, and battery pack was installed as required.

7. All instrumentation, power and control cables were installed, routed, and secured.

8. Level line was marked on each side of vehicle. Five-inch-diameter camera targets were applied at one-foot intervals in impact area (front or side as appropriate). Additional markings were provided per directions from Project Engineer.

9. Tire pressure was set at 24 psi on bogey vehicle(s) and the manufacturer's specification for the standard vehicles.

10. Ballast was installed in bogey vehicle as required to obtain test weight of 4,000 ±20 pounds with a 55/45 ±1 percent front-to-rear distribution and so that longitudinal c.g. location was maintained. Ballast was installed in standard vehicle to pre-test curb weight.

11. If required, new honeycomb absorber stacks were installed.

12. Instrumentation batteries were charged to full capacity; charge was maintained.

A.7.5 Test Performance

The following steps were performed during the conduct of this test series:

1. Tow system was started.

2. Vehicles were accelerated to desired test speed and allowed to impact each other.

3. Post-test photographs were taken as specified in Section A.4.3 and as directed by Project Engineer.

4. Vehicles were inspected for damage; rebound and dynamic stroke were determined; and damage was documented photographically.

A.8 PRODUCTION VEHICLE STRUCTURAL CHARACTERIZATION

A.8.1 Test Description

The test consisted of preparing the vehicles as described, propelling them along a monorail at the required test speed (±0.5 mph), and impacting them into a load-measuring barrier. All impacts were normal (0° obliquity) to the barrier face. The data obtained were impact forces and vehicle decelerations as a function of time. The test conditions are defined in Table A-XII, and the tests are discussed in greater detail on the following pages.

TABLE A-XII. PRODUCTION VEHICLE STRUCTURAL STIFFNESS TEST SERIES

Item* Number	Test Type	Impact Speed (mph)	Test Vehicle	Barrier Interface	Comments
1	Frontal Impact	10	1968 Fury 4-Door Sedan	Flat	Engine and front stub frame removed
2	Frontal Impact	15	1968 Fury 4-Door Sedan	Rectangular	Barrier does not engage frame rails. Front sheet metal not installed.
3	Frontal Impact	20	1968 Fury 4-Door Sedan	Flat	
4	Frontal Impact	52	1968 Fury 4-Door Sedan	Bogey Vehicle Bumper Geometry	Production vehicle configuration
5	Right Side Impact	17	1968 Fury 4-Door Sedan	Bogey Vehicle Bumper Geometry	Production vehicle configuration
6	Right Side Impact	20	1967 Dart 4-Door Sedan	Bogey Vehicle Bumper Geometry	Production vehicle configuration
7	Right Side Impact	17	1971 Pinto 2-Door Sedan	Bogey Vehicle Bumper Geometry	Production vehicle configuration

*The sequence in which the tests are run will depend upon the availability of the (used) production vehicles for the supplier.

The frontal vehicle testing to determine the absorber characteristics for a four-mass model was accomplished with three test configurations, as shown in Figure A-10. Precise details on how the vehicles were modified were specified by the Project Engineer during the test buildup phase. In these tests, the vehicle occupant compartment consisting of components aft of the firewall was reused, requiring the purchase of only one vehicle for these three tests. As necessary, damaged front structure components were replaced from parts which were not damaged in previously conducted side impact tests.

The first test evaluated the load/deflection characteristic of the front sheet metal. The second test determined the characteristic between the engine/radiator, engine/firewall-drive train, and motor mounts. The third test determined the load/deflection characteristic of the stub frame. The impact speeds had been estimated so that the deformation was nominally limited to the component absorber whose load/deflection characteristic was desired. The test sequence had also been designed to minimize test damage for components required for subsequent testing. This included selection of impact energies that were compatible with estimated structural deformation capabilities. A load-measuring barrier was used for all tests. During the second test, an abutment was added to the barrier as indicated schematically in Figure A-10 so that the deformation was limited to the engine/driveline components. Details on the design and mounting of this abutment were provided by the Project Engineer. To complete the series, a frontal impact of a 1968 Fury sedan into a load-measuring barrier was accomplished. The vehicle was in a production configuration for this test. The test speed was 52 ±1 mph in order to ensure comparable total deflection with those from the frontal vehicle-to-vehicle tests.

Accurate component weights, representing each mass in the simulation, were determined. Test information consisted of barrier loads and vehicle acceleration from appropriately placed accelerometers.

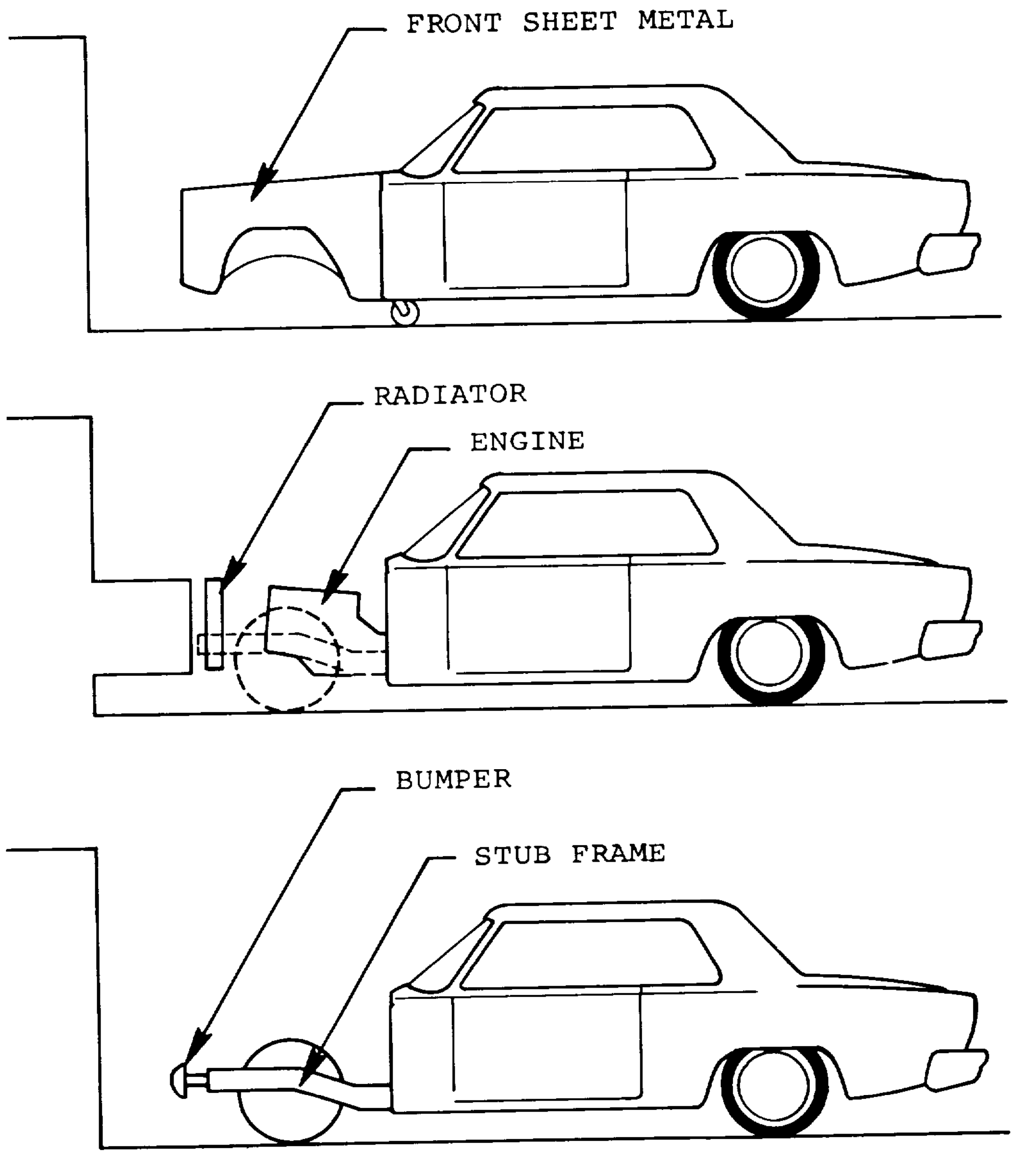


Figure A-10. Test Configurations.

The side impact stiffness of a 1968 Fury four-door sedan, a 1967 Dart four-door sedan, and a 1971 Pinto two-door sedan was also determined in separate impacts. In each case, the barrier was fitted with the non-deforming facepiece which reproduced the standard bogey vehicle bumper. The impact speeds had been selected to yield deflections comparable to those experienced during the side impacts conducted previously.

A.8.2 Instrumentation Requirements

The data obtained from this test series are described in Table A-XIII. Specific instrument requirements are defined in Figures A-11 through A-15 for the tests defined in Table A-XII; Table A-XIV presents the test number and configuration for each figure. The specific instruments are defined in Table A-XV.

A.8.3 Data Acquisition Requirements

The data acquisition system used is shown schematically in Figure A-3. Note that redundant signal paths were used between the vehicle and the recorder. The umbilical (hard-line) data were the primary data.

A.8.4 Vehicle Preparation

The following steps were taken to prepare the vehicles:

1. Vehicle curb weight was determined by wheel and axle.
2. For Tests 1, 2, and 3, Table A-XII, front structure was modified per Figure A-10 in consultation with the Project Engineer.
3. Vehicle underside was painted to color code undercar components as shown below:

Main Frame Members	- Light Pink
Bumper	- Yellow
Front and Rear Axle	- Pale Green

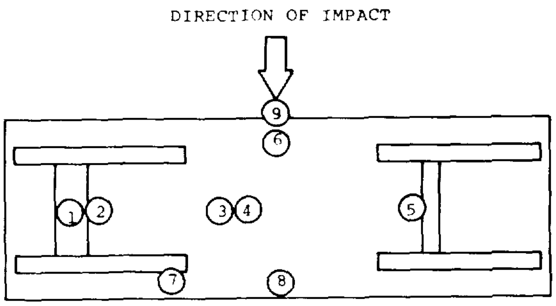
4. Traction bar for umbilical cable was fabricated and attached to rear of vehicle.

TABLE A-XIII DATA REQUIREMENTS FOR RIGID BARRIER TESTS						
		Application Method				
Parameter	Measurement Method	Magnetic Tape	Written Log	Computed	Photo-graphic Analysis	Strip Recorders
Impact Time	Contact Switch Superimposed on Time Base	X				X
Approach Velocity	Tow Cable Velocity Sensor and Speed Traps		X			X
Impact Velocity	Speed Trap		X			X
Rebound Distance	Direct Measurement (post-test)		X			
Rebound Velocity	Calculated From Impact Force Measurements, Vehicle Mass, and Approach Velocity Cross-checked Photographically			X	X	
Impact Angles	Photographic Reduction of Yaw and Pitch Angles at and Following Impact				X	
Vehicle Deceleration	Accelerometers Mounted at Various Locations	X				
Barrier Acceleration	Accelerometers Mounted on the Barrier Face	X				
Crush Distance	Computer by Double Integration of Acceleration Pulse Cross-checked Photographically			X	X	
Net Crush	Direct Post-test Measurement Cross-checked Photographically		X		X	
Vehicle Weight	Pre-test Balance Scale Measurment by Wheel		X			
Impact Force	Load Cells at Barrier Face, Cross-checked by Accelerometer Measurements	X				
Force Versus Displacement	Cross Plot of Above Variables			X		

5. Mounting brackets for vehicle accelerometers were installed. Frame accelerometer mounts were installed on plates drilled and tapped to accept the mounts. Specific details on locations were supplied by the Project Engineer.

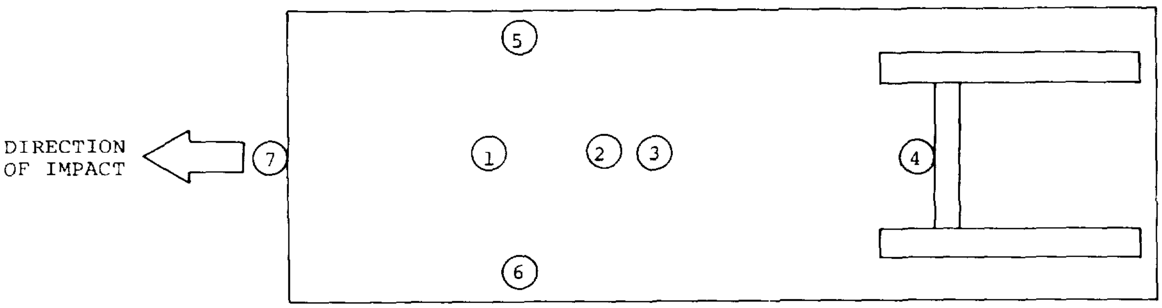
6. Accelerometers were installed.

7. Instrumentation was installed in the passenger compartment consisting of RSCM, junction box, and battery pack as required.



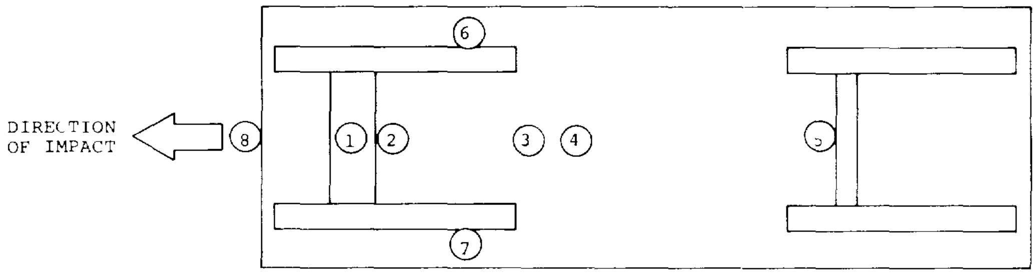
1. Engine Accelerometer (Triaxial)
2. Front Stub Frame Cross Member Accelerometer (Lateral)
3. Vehicle C G Accelerometer (Triaxial)
4. Vehicle C G Accelerometer, Backup, (Lateral)
5. Rear Stub Frame Cross Member Accelerometer (Lateral)
6. Right Occupant Compartment Accelerometer (Lateral)
7. Left Stub Frame Accelerometer (Lateral)
8. Left Occupant Compartment (Lateral)
9. Impact Switch

Figure A-11. Instrumentation Mounting Locations for Side Impacted Vehicle Tests.



1. Firewall Accelerometer (Triaxial)
2. Vehicle C G Accelerometer, Drive Tunnel, (Triaxial)
3. Vehicle C.G. Accelerometer, Cross Member, (Longitudinal)
4. Rear Stub Frame Cross Member Accelerometer (Longitudinal)
5. Right Torque Box Accelerometer (Longitudinal)
6. Left Torque Box Accelerometer (Longitudinal)
7. Impact Switch

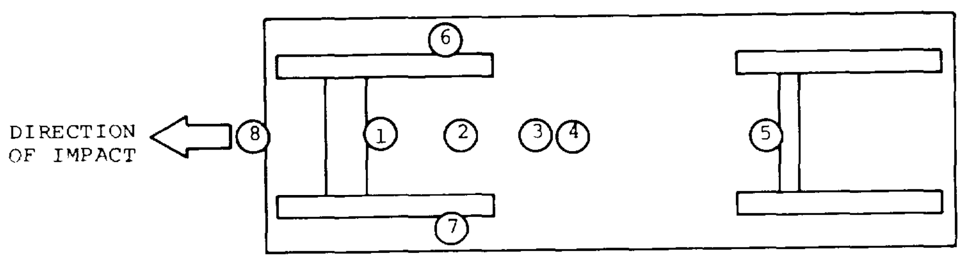
Figure A-12. Instrumentation Mounting Locations for Plymouth Fury Sheet Metal Test.



(1) Engine Accelerometer (Triaxial)
(2) Front Stub Frame Cross Member Accelerometer (Longitudinal)
(3) Vehicle C G Accelerometer Drive Tunnel, (Triaxial)
(4) Vehicle C G Accelerometer, Cross Member (Longitudinal)
(5) Rear Stub Frame Cross Member Accelerometer (Longitudinal)
(6) Right Torque Box Accelerometer (Longitudinal)
(7) Left Torque Box Accelerometer (Longitudinal)
(8) Impact Switch

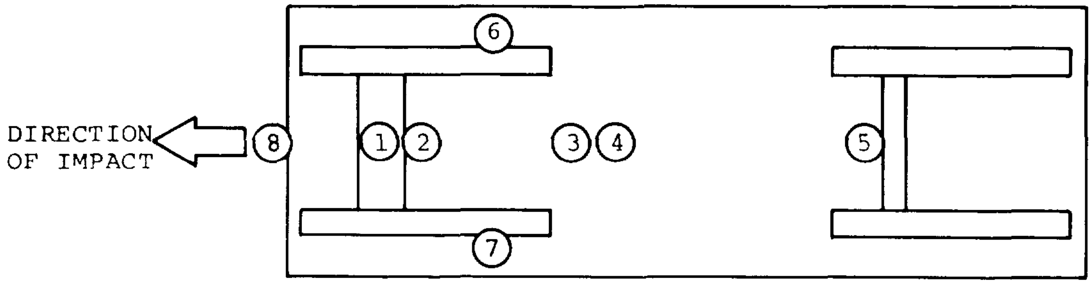
Figure 4 Instrumentation Mounting Locations for Plymouth Fury Engine Test

Figure A-13. Instrumentation Mounting Locations for Plymouth Fury Engine Test.



(1) Front Stub Frame Cross Member Accelerometer (Longitudinal)
(2) Firewall Accelerometer (Triaxial)
(3) Vehicle C.G. Accelerometer, Drive Tunnel, (Triaxial)
(4) Vehicle C.G. Accelerometer, Cross Member, (Longitudinal)
(5) Rear Stub Frame Cross Member Accelerometer (Longitudinal)
(6) Right Torque Box Accelerometer (Longitudinal)
(7) Left Torque Box Accelerometer (Longitudinal)
(8) Impact Switch

Figure A-14. Instrumentation Mounting Locations for Plymouth Fury Frame Test and Plymouth Fury Frame/Sheet Metal Tests.



1 Engine Accelerometer (Triaxial)

2 Front Stub Frame Cross Member Accelerometer (Longitudinal)

3 Vehicle C.G. Accelerometer, Drive Tunnel, (Triaxial)

4 Vehicle C.G. Accelerometer, Cross Member, (Longitudinal)

5 Rear Stub Frame Cross Member Accelerometer (Longitudinal)

6 Right Torque Box Accelerometer (Longitudinal)

7 Left Torque Box Accelerometer (Longitudinal)

8 Impact Switch

Figure A-15. Instrumentation Mounting Locations for Plymouth Fury Full Vehicle Test.

TABLE A-XIV. FIGURES SPECIFYING INSTRUMENTATION LOCATIONS FOR THE PRODUCTION VEHICLE CHARACTERIZATION TESTS

Test Number	Configuration	Figure Number
283-46	Dodge Dart side test	A-11
283-47	Plymouth Fury side test	A-11
283-48	Ford Pinto side test	A-11
283-49	Plymouth Fury sheet metal frontal test	A-12
283-50	Plymouth Fury engine frontal test	A-13
283-51	Plymouth Fury frame frontal test	A-14
283-52	Plymouth Fury full vehicle frontal test	A-15
283-53	Plymouth Fury frame and sheet metal frontal test	A-14

TABLE A-XV. INSTRUMENTATION REQUIREMENTS						
Measurand	Type Transducer	Manu-facturer	Model Number	Capacity	Full-Scale Output	Accuracy
Test Vehicle						
Vehicle Acceleration	Accelerometer	Statham	A69	200G	40-50MV	±1%F.S.
Impact Time	Switch	Dynamic Science	-	-	6.0 Volts	±1.0 msec
Ground Based						
Impact Load	Load Cell	Interface	1330	100Klb	40-50MV	±1%F.S.
Approach Velocity	Digital Counter	Dynamic Science	-	>100 mph	10,000 counts	±2 counts
Impact Velocity	Digital Counter	Dynamic Science	-	>100 mph	10,000 counts	±2 counts
Cable Velocity	Digital Proximity	Probe Airpax	-	>100 mph	5.0 Volts	±1.5%
Impact Time	Switch	Dynamic Science	-	-	6.0 Volts	±1.0 msec

8. All instrumentation, power, and control cables were installed, routed, and secured.

9. Level line was marked on each side of vehicle. Five-inch-diameter camera targets were applied at one-foot intervals along the full length of the vehicle (both sides). Additional marking was provided per directiors from Project Engineer.

10. Tire pressure was set at 24 psi.

11. Vehicle was weighed and weight recorded by wheel.

12. Instrumentation battery was charged to full capacity; charge was maintained.

A.8.5 Test Performance

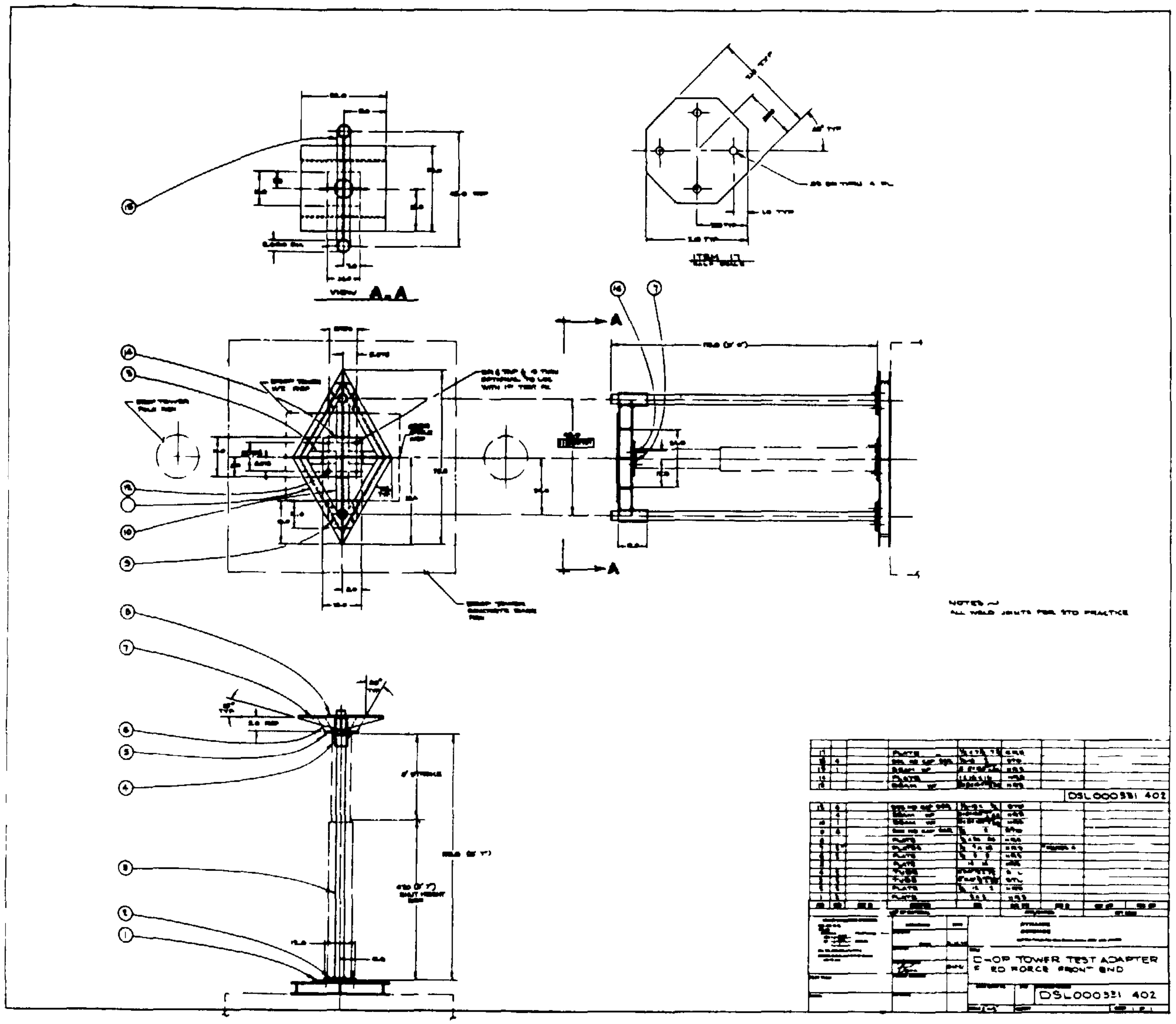
The following steps were performed during the conduct of this test series:

1. Tow system was started.

2. Vehicle was accelerated to desired test speed (±0.5 mph for all tests except No. 4, Table A-XII, which is ±1.0 mph) and allowed to impact barrier.

3. Post-test photographs were taken as specified in Section A.5.3 and as directed by Project Engineer.

4. Vehicle was inspected for damage; rebound and dynamic stroke were determined; and damage was documented photographically.


VIEW A-A
NOTES ~
ALL WELD JOINTS PER STD PRACTICE
DSL000331 402
D-OP TOWER TEST ADAPTER
F ED FORCE FRONT END
DSL000331 402