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DOT HS–802 021

DEVELOPMENT OF IMPROVED INFLATION TECHNIQUES

Volume I

Contract No. DOT–HS–345–3–691

September 1976

Final Report

PREPARED FOR:
U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Washington, D.C. 20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS-802 021		

4. Title and Subtitle	5. Report Date
Development of Improved Inflation Techniques Volume I	September 1976
	6. Performing Organization Code
7. Author(s) J. T. Johnson	8. Performing Organization Report No.
9. Performing Organization Name and Address Olin Corporation Engineering and Development Marion, Illinois 62959	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. DOT-HS-345-3-691
12. Sponsoring Agency Name and Address U S. Department of Transportation National Highway Traffic Safety Admin. Washington, D.C. 20590	13. Type of Report and Period Covered Final Report July 1974 - Sept. 1975
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report summarizes the effort to develop an improved inflatable restraint system. The objective was to provide up to 50 mph frontal crash protection for front seat passengers without undue hazards to out-of-position occupants.

The inflation concept for this program consisted of a dual bag design - a low pressure aspirator filled head bag and a high pressure augmented filled torso bag. The knees were cushioned by a fixed crushable restraint.

Based on the results of 39 sled tests and 6 full scale vehicle tests it is concluded that this system probably can be effective in meeting MVSS 208 injury criteria at speeds to 45 mph.

17. Key Words	18. Distribution Statement
Automotive Safety, Air Bags, Improved Passive Restraint Systems Aspiration	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	55	

PREFACE

This final report presents the results of a study conducted under the sponsorship of the DOT entitled, "Development of Improved Inflation Techniques." The activities reported herein were conducted over the period from July, 1974 to September 30, 1975.

Olin wishes to acknowledge the efforts of Michael Walsh of Calspan in conducting the sled tests and the efforts of Keith Friedman of Minicars in conducting the Vehicle Tests.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2 5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0 9	meters	m
mi	miles	1 6	kilometers	km
		AREA		
in^2	square inches	6 5	square centimeters	cm^2
ft^2	square feet	0 09	square meters	m^2
yd^2	square yards	0 8	square meters	m^2
mi^2	square miles	2 6	square kilometers	km^2
	acres	0 4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0 45	kilograms	kg
	short tons (2000 lb)	0 9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0 24	liters	l
pt	pints	0 47	liters	l
qt	quarts	0 95	liters	l
gal	gallons	3 8	liters	l
ft^3	cubic feet	0 03	cubic meters	m^3
yd^3	cubic yards	0 76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5 9 (after subtracting 32)	Celsius temperature	C

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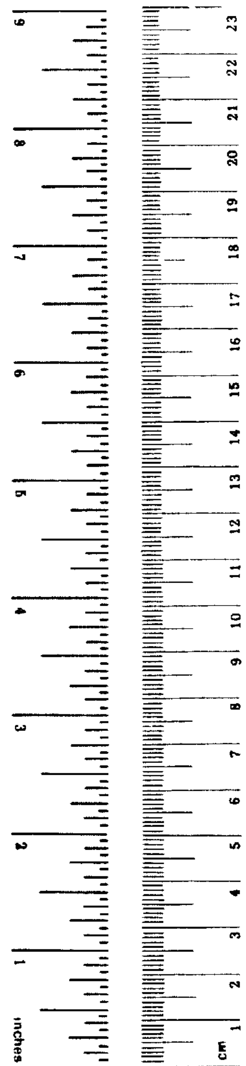
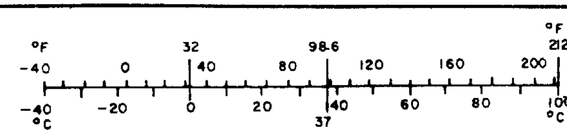


Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0 04	inches	in
cm	centimeters	0 4	inches	in
m	meters	3 3	feet	ft
m	meters	1 1	yards	yd
km	kilometers	0 6	miles	mi
		AREA		
cm^2	square centimeters	0 16	square inches	in^2
m^2	square meters	1 2	square yards	yd^2
km^2	square kilometers	0 4	square miles	mi^2
ha	hectares (10 000 m^2)	2 5	acres	
		MASS (weight)		
g	grams	0 035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1 1	short tons	
		VOLUME		
ml	milliliters	0 03	fluid ounces	fl oz
l	liters	2 1	pints	pt
l	liters	1 06	quarts	qt
l	liters	0 26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1 3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

The objective of the Development of Improved Inflation Techniques Program Task III was to refine the performance of the system developed under Task II, the basic dual bag system, and to evaluate system performance by sled testing and full scale vehicle tests.

The air cushion restraint system that was developed under Task II consisted of a dual bag design utilizing a low pressure head bag inflated with an aspirator and a high pressure torso bag inflated with an augmented inflator. The knee and femur loads were cushioned with a fixed crushable element.

Some twenty-six static tests (to determine inflation time and pressure) were conducted during the program to refine the system prior to the sled series with anthropomorphic dummies. Another eleven static tests were conducted, essentially at the end of this study, to develop a pure pyrotechnic inflator to replace the augmented inflator (used throughout most of the study) for the torso bag.

Four sled test series with a total of thirty-nine sled tests were conducted during Task III. The final sled test series was conducted in the middle of the vehicle tests to refine the system for the remaining crash tests. Based on the results of the sled tests it was demonstrated that this system probably can be effective in meeting MVSS 208 injury criteria at speeds to 45 mph.

Six full scale vehicle tests were conducted during Task III. The vehicle tests demonstrate that this system can probably be effective in meeting MVSS 208 at speeds up to 45 mph into a flat barrier and 40 mph into a 30° angled barrier.

SUMMARY AND CONCLUSIONS

The table below summarizes the results of the sled tests and full scale vehicle tests conducted during Task III. Results of sled tests with both the required and alternate deceleration profiles are shown. For a comparison of the deceleration profiles see Figure 8, Page 44.

Occupant Size	Velocity mph	Type of Test	HIC	Chest Res. g's **	Femur lbs.
50th	50	Sled	500	48	1200
50th	50 A*	Sled	600	56	1200
Out-of-Position	50	Sled	363	48	-
6 Yr. Old	50 A*	Sled	400	48	-
6 Yr. Old	0	Sled	68	40	-
6 Yr. Old	0 A*	Sled	270	35	-
50th	30	Vehicle	121	33	800
50th	45	Vehicle	414	57	1250
50th	40	∠ Barrier Vehicle	154	41	1200

A* - Alternate sled pulse.

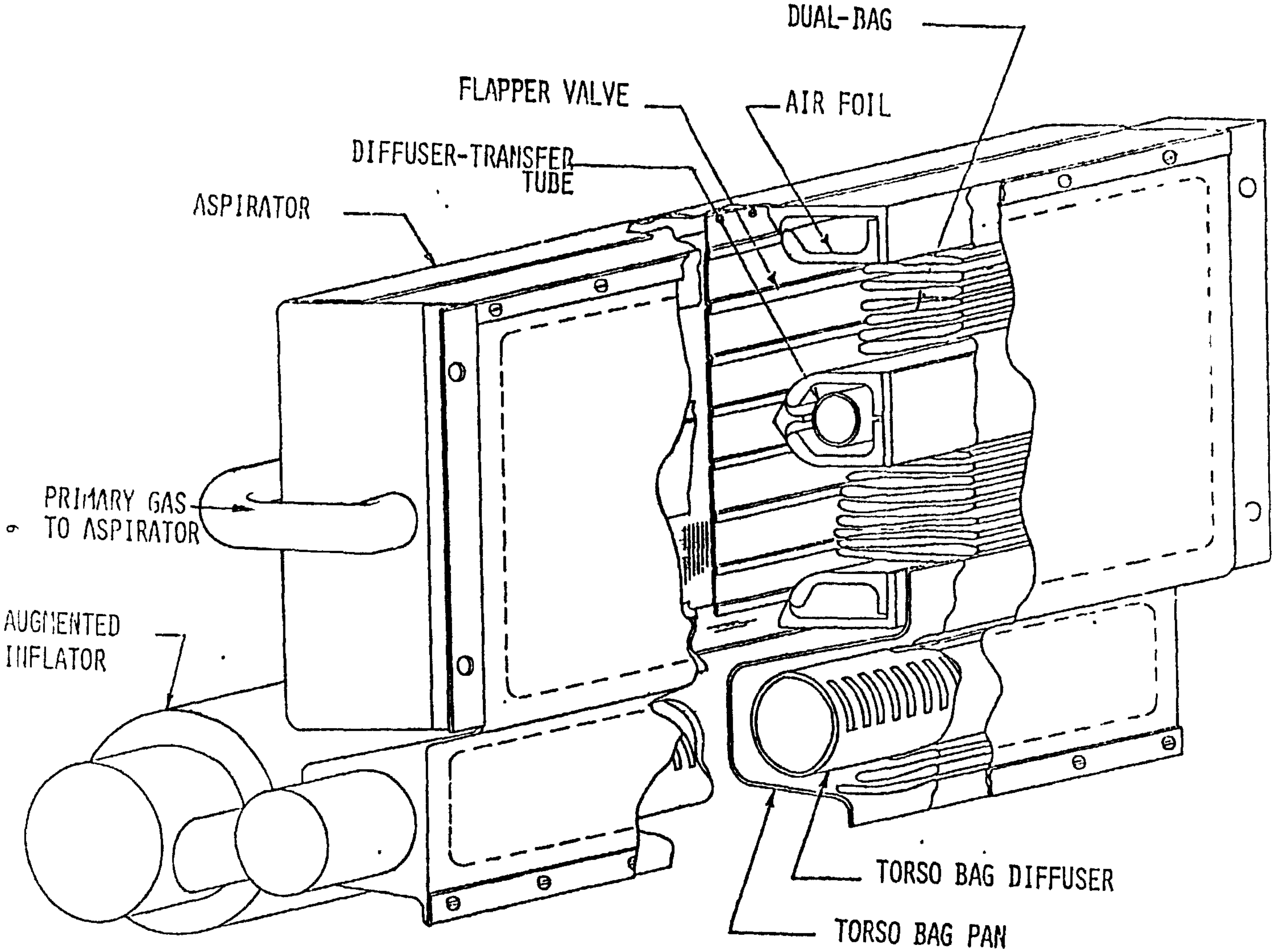
** - All readings are with a 3 msec. cumulative clip.

When sled testing was conducted with the Task III deceleration profile the injury data was reduced to minimal values by optimizing the restraint system, and the results were well within the injury criteria as noted in the above table. After conducting three of the full scale vehicle tests, it was noted that the system was not optimized for both the Task III sled pulse and the vehicle crash pulse. At this point there were two alternatives; 1) Conduct sled tests with an alternate deceleration profile similar to the vehicle crash pulse or 2) Conduct further tests with the Task III deceleration profile which did not simulate the vehicle crash pulse, and gain no confidence that the restraint system would meet the injury criteria in the vehicle tests. Option number one was chosen. Based on the sled test data with both of the deceleration profiles it is very possible that the same restraint system could have been optimized for both profiles; however, further improvement would have required additional testing which was beyond the scope of the current investigation. As noted in the table all of the injury criteria of MVSS 208 were met with both the alternate deceleration profile on the sled and full scale vehicle tests. Based on this data it is probable that the final dual bag system can meet the requirements of MVSS 208 in a standard size (B Body) vehicle at speeds up to and including 45 mph.

SYSTEM DESIGN

The components which make up the dual bag system consist of the following items· the aspirator inflator, the augmented inflator, the gas distributor manifold, and the dual bag air cushion. Another component utilized in most of the dual bag systems was a gas generator to furnish the primary gas for the aspirator when it was not furnished by the augmented inflator. Figures 1 and 2 show a schematic of the dual bag system and its position in the vehicle.

The aspirator unit is a Coanda type which operates as follows: Pressurized gas is piped into the aspirator inlet and passed over an annular gap. The gas attaches itself to a curved air-foil surface which forms the throat of the aspirator. The expansion of this gas and its subsequent acceleration over the air-foil surface create a low pressure region which induces air into the throat. This secondary or induced flow mixes at the outlet. A measured efficiency of 20:1 induced air to primary gas is obtained under ideal conditions (i.e., no load pressure). However, due to resistance of moving the bag from its stowed position outward and the short time required to completely fill the bag, the obtainable efficiency is reduced to approximately 5:1. The actual efficiency obtained by the aspirator used for this study was approximately 2:1.



OLIN DUAL-BAG SYSTEM
FIGURE 1

DUAL BAG SYSTEM IN VEHICLE

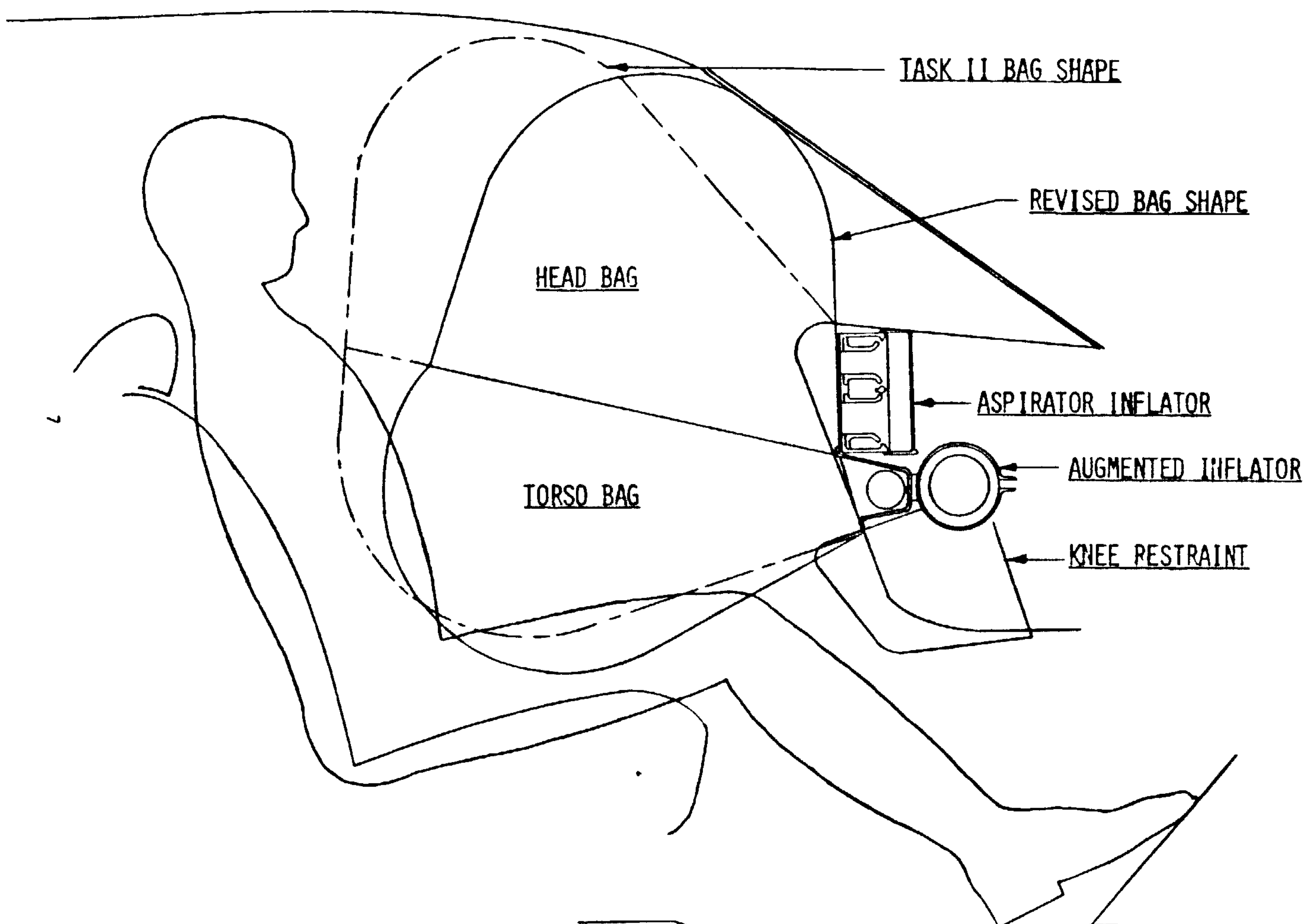


FIGURE 2

The primary gas source can be from either an augmented inflator or a solid propellant gas generator. The primary gas flows into the diffuser-transfer tube and out through radial holes in the tube, thus pressurizing the three primary chambers to the optimum aspiration pressure (10-30 psig). All three chambers are interconnected by the manifold and are consequently pressurized to the same pressure. The pressurized gas flows through the slit into the throat section of the aspirator where the bag is initially stowed. The pressure in this section rises rapidly and starts the bag deployment. As the bag is deployed out of the throat the pressure drops, and the flow through the slit attaches to the airfoil surface and creates a low pressure in the throat section. The resulting vacuum opens the flapper valves and induces ambient air (vehicle compartment air) into the gas stream. After the bag has inflated to atmospheric pressure, the aspirator flow backs up and the flapper valves close. The primary gas further fills the bag to the required fill pressure. The aspirator bag (head bag) deployment is also assisted by the faster augmented inflator (torso bag) deployment. The two bags are attached at the junction, and as the lower bag deploys, it assists the upper bag deployment.

When the complete restraint system is powered by an augmented inflator, part of the gas is orificed to the aspirator to provide the primary gas flow for filling the head bag. The remaining

FIGURE 3

NOMINAL THERMODYNAMIC DATA

ASPIRATOR SYSTEM

BAG VOLUME - 5.1 FT.^{3}

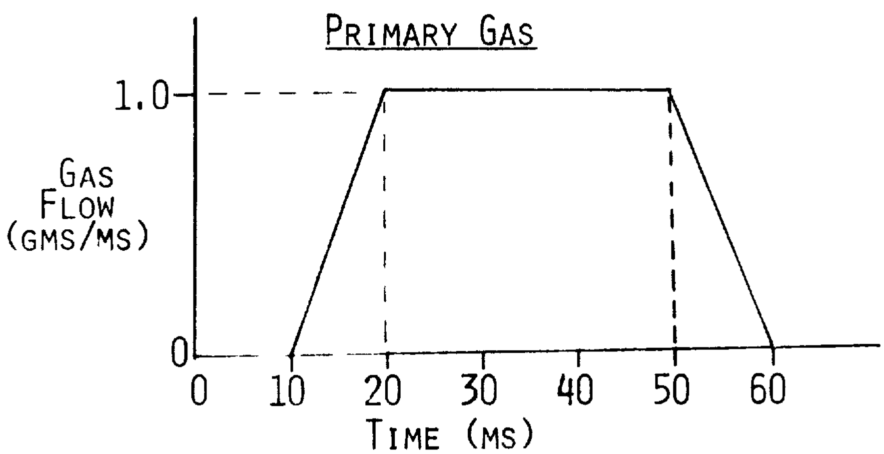
INFLATION PRESSURE - 15.7 PSIA

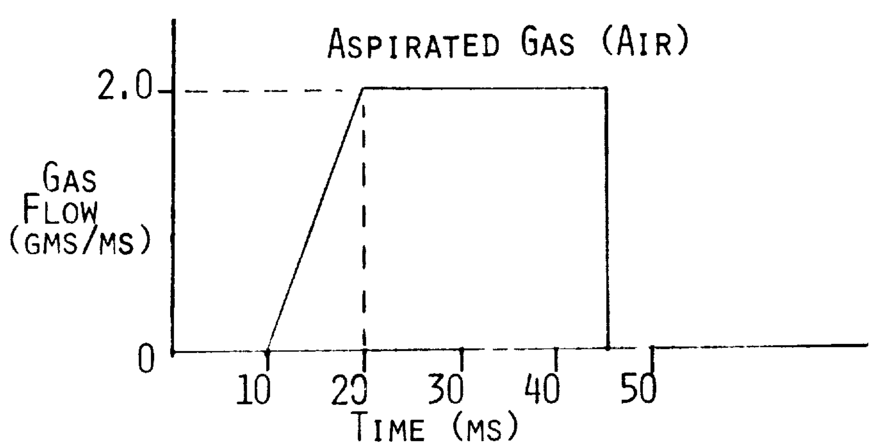
INFLATION TEMPERATURE - 500°F (MEASURED)

PRIMARY GAS - 70 GMS. SF-23 (42 GMS. GAS - MW 30)

ASPIRATED GAS - 60 GMS. (AIR) (CALCULATED)

ASPIRATION RATIO (DURING ASPIRATION - 2/1) (CALCULATED)





inflator gas was orificed to the diffuser and into the chest bag. The augmented system has argon stored in the bottle and a solid propellant gas generator within the bottle which provides increased pressure from the burning of the propellant. The solid propellant can be configured so as to provide increasing or decreasing levels of mass flow.

The nominal thermodynamic data for the aspirator system and augmented system are shown on Figures 3 and 4 respectively.

The final restraint bags for this program were fabricated by sewing from 100% nylon, plain weave, 840 denier material. The upper bag was fabricated from 5.5 $oz/yd.^2$ material and the lower bag from 7.5 $oz/yd.^2$ material. The materials were uncoated and additional breathing was added by making various size breathing holes in the bags to obtain the optimum ridedown characteristics.

All of the knee restraints for Task III were fabricated from DB foam.

FIGURE 4

NOMINAL THERMODYNAMIC DATA

AUGMENTED SYSTEM

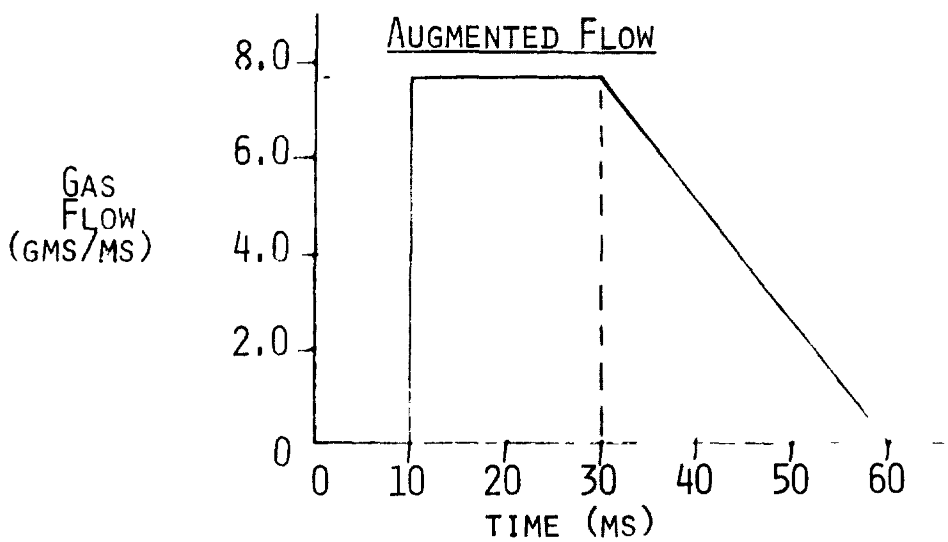
BAG VOLUME - 5.6 FT.^{3}

INFLATION PRESSURE - 20.7 PSIA

INFLATION TEMPERATURE - 250^{o}F (CALCULATED)

STORED GAS - 254 GMS. ARGON

PROPELLANT GAS - 27 GMS. SF-23 (18 GMS. GAS - MW-30)



STATIC TESTING - SYSTEM SIZING

Table 1 summarizes all of the static development tests conducted during Task III of this program. Some specific tests will be referred to and the traces of these tests are included (Figures 5 and 6) to show the type of data obtained on a static development test.

During the initial phase of the program several tests (3396-3401) were conducted to compare the results (inflation time and pressure) of a solid propellant powered aspirator and an augmented powered aspirator. From the static inflation results the two systems appeared to be comparable. Then a series of static out-of-position tests with a six year old child dummy (3405-3408, 3414, 3415) were conducted to compare the two systems. The results with the augmented powered system (3408) appeared to be slightly more severe from the standpoint of the child riding back into the seat. During this series of static tests it was also noted that bag packing also affected the ride back into the seat of the child. When the bag was folded under, the child would tend to get airborne during the rideback; whereas, when the bag was folded over, the child was pushed downward.

During the first series of sled tests, the dual bag aspirator system resulted in neck bending for the 50th percentile male dummy and unacceptably high loads for the out-of-position six year old child dummy.

Figure 4

NOMINAL THERMODYNAMIC DATA

Augmented System

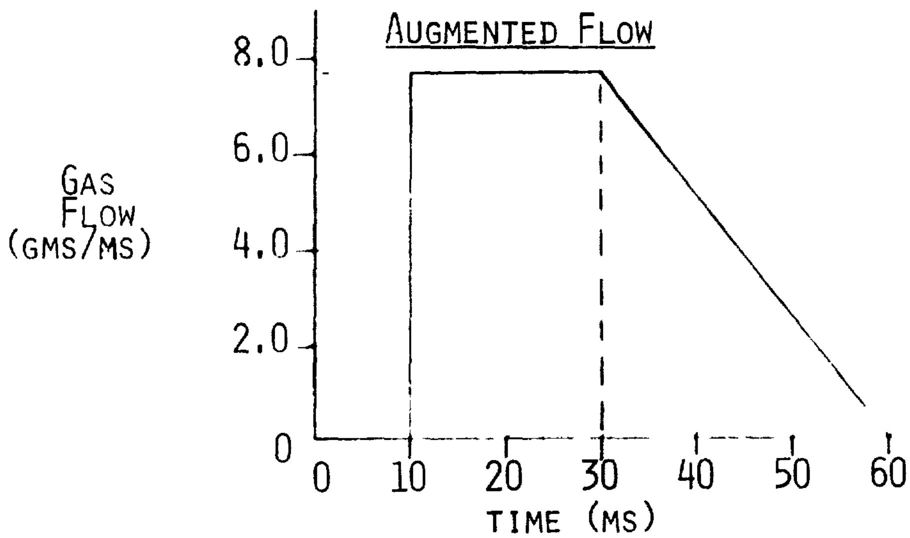
Bag Volume - 5.6 ft.^{3}

Inflation Pressure - 20.7 psia

Inflation Temperature - 250°F (calculated)

Stored Gas - 254 gms. Argon

Propellant Gas - 27 gms. SF-23 (18 gms. Gas - MW-30)



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During the first series of sled tests, the dual bag aspirator system resulted in neck bending for the 50th percentile male dummy and unacceptably high loads for the out-of-position six year old child dummy.

TABLE 1

STATIC TESTING

Test No.	Date	Inflation System	Bag	Bag Pressures	Remarks
3396	9-11-74	6 x 22 Aspirator, .070 gap 77 in.^{3} Mod IV Aug. Bottle 2000 psi Argon 43 gms. SP-23, .95 x .50	4.5 ft.^{3} Aug. 6.5 ft.^{3} Asp.	Aug. - Asp. -	.56 orifice to Aug. Diffuser .30 orifice to Aspirator
3397	9-12-74	"	"	Aug. 0 psig @ 55ms .25 " @ 60ms. Asp. -	.56 orifice to Aug. Diffuser .312 " to Aspirator
3397A	9-12-74	"	"	Aug. 0 psig @ 50ms. 1.7 " @ 60ms.	.56 orifice to Aug. Diffuser .312 " to Aspirator
3398	9-13-74	"	"	Aug.2.5psig @ 70ms. Asp.0.5 " @ 65ms.	.56 orifice to Aug. Diffuser .312 " to Aspirator
3399	9-13-74	" 2200 psi Argon	"	Aug. 0 psig @ 40ms. 4 psig @ 65ms. Asp. 0 psig @ 50ms. 0.5 " @ 65ms.	.56 orifice to Aug. Diffuser .312 " to Aspirator
3400	9-16-74	6 x 22 Aspirator, .070 gap 77 in.^{3} Mod IV Aug. Bottle 2200 psi Argon 43 gms SP-23, .95 x .57	"	Aug. 0 psig @ 35ms. 3.7 " @ 65ms. Asp. 0 psig @ 50ms 0.5 " @ 60ms.	.56 orifice to Aug. Diffuser .312 " to Aspirator
3401	9-19-74	" 45 gms SP-23 .95 x 625	"	Aug. 0 psig @ 35ms. 3.7 " @ 65ms. Asp. 0 psig @ 50ms. 0 3 " @ 55ms.	.60 orifice to Aug. Diffuser .312 " to Aspirator

TABLE 1 (Cont'd)

STATIC TESTING

Test No	Date	Inflation System	Bag	Bag Pressures	Remarks
3405	10-1-74	6 x 22 Aspirator, .070 gap Solid propellant powered 70 gms. SF-23 .95 x .37 Aug. - 60 in ^{3} Mod. IV 2200 psi, Ar., 30 gm.SF-23 .95 x .57	4.5 ft.^{3} Aug. 6.5 ft.^{3} Asp. Bag rolled under. 2" dia. port in Aug. bag to Atmos	Aug. - 5 psig max. Asp - 1 psig max	Out-of-position 6 yr. old child test Child was thrown against top part of seat and slid on over seat. Head and chest accelerations were within limits
3406	10-2-74	6 x 22 Aspirator, .070 gap Solid propellant powered 70 gms. SF-23 .95 x .37 Aug. - 60 in.^{3} Mod IV 2200 psi Ar., 25 gms.SF-23 .95 x .57	4.5 ft.^{3} Aug. 6.5 ft.^{3} Asp. Bag Rolled under. 2" dia. port in Aug. Bag to Atmos 3" dia. between bags.	Aug - 3 psig max. Asp. - 1 psig max.	Out-of-position 6 yr. old child test Child was thrown against top of seat and remained balanced on top of seat Head and chest accelerations were within limits.
3407	10-2-74	6 x 22 Aspirator, .070 gap Solid propellant powered 70 gms. SF-23 .95 x .37 Aug. 60 in.^{3} Mod IV 2100 psi Ar., 25 gms.SF-23 .95 x .57	4.5 ft.^{3} Aug. 6.5 ft.^{3} Asp. Bag rolled down and up 2" dia. Port in Aug. Bag to Atmos 3" dia. between bags	Aug. - 4 psig max. Asp. - 1 psig max.	Out-of-position 6 yr. old child test. Child was thrown against seat and remained upright in seat. Head and chest accelerations were within limits.
3408	10-3-74	6 x 22 Aspirator, .070 gap Augmented powered Augmented 77 in.^{3} Mod IV 2200 psi Ar. 43 gms.SF-23 .95 x .57	"	Aug. - 6 psig max. Asp. - 1 psig max.	Out-of-position 6 yr. old child test. Child was thrown over seat. Head and chest accelerations were within limits.

TABLE 1 (Cont'd)

STATIC TESTING

Test No.	Date	Inflation System	Bag	Bag Pressures	Remarks
3409	10-4-74	" 35 gms SF-23 95 x .57	4.5 ft.^{3} Aug. 6.5 ft.^{3} Asp. Bag rolled down and up 2" dia. port in Aug. Bag to Atmos 3" dia. between bags.		Inflation test Aug. Bag Pressure malfunctioned.
3410	10-4-74	"	"	Aug. 0 psig @60ms 2.5 " @75ms Asp. - No significant pressure.	Inflation Test
3411	10-7-74	" 39 gms. SF-23, .95 x .50 2400 psi Argon	"	Aug. 0 psig @ 52ms. 3.5 " @ 75ms. Asp. 0.5" @ 55ms.	Inflation Test
3412	10-7-74	6 x 22 Aspirator, .070 gap Solid propellant powered 70 gms SF-23, .95 x .37 Aug. - 60 in.^{3} Mod IV 2200 psi Ar., 25 gms SF-23 .95 x .57	"	Aug. 0 psig @ 50ms. 3 " @ 70ms. Asp. 0 psig @ 60ms.	Inflation Test
3413	10-7-74	" Aug. - 2400 psi Ar. 28 gms. SF-23, 95 x .57	"	Aug. 0 psig @ 45ms. 4 5 " @ 70ms. Asp 0 psig @ 60ms.	Inflation Test

TABLE 1 (Cont'd)

STATIC TESTING

Test No	Date	Inflation System	Bag	Bag Pressures	Remarks
3414	10-8-74	6 x 22 Aspirator, .070 gap Solid propellant powered 70 gms. SP-23, .95 x .37 Aug. - 2400 psi Ar. 28 gms. SP-23, .95 x .57	" Bag rolled over	Aug. - 2.5 psig max. Asp - 2.0 psig max	Out-of-position 6 yr. old child test. Child pushed against seat back and bounced back into floorboard. Chest accelerations were within limits but head results were marginal
3415	10-9-74	" Aug. - 2300 psi Ar. 26 gms. SP-23, .95 x .57	"	Aug. - 2.0 psig max. Asp. - 1 psig max.	Out-of-position 6 yr. old child test. Chest accelerations were within limits but head results were marginal.
3420	11-1-74	6 x 22 Aspirator, .070 gap, 70 gms. SP-23, .94 x .37 Aug. - 60 in.^{3} Mod IV 2100 psi Argon 23 gms SP-23 .94 x .57	5.1 ft.^{3} Asp. 5.1 ft.^{3} Aug.	Asp. 0 psig @40ms. 1.5 " @58ms. Aug. 0 psig @38ms. 6 " @58ms.	Inflation test. Redesigned bag shape and size.
3422	11-21-74	"	5.1 ft.^{3} Asp. 5.6 ft.^{3} Aug.	Asp. 0 psig @42ms. 1.2 " @53ms. Aug. 0 psig @42ms. 4 " @65ms.	"
3423	11-21-74	6 x 22 Aspirator, .070 gap, 70 gms. SP-23 .94 x .37 Aug. - 60 in.^{3} Mod IV 2100 psi Argon 25 gms SP-23 .94 x .57	"	Asp. 0 psig @43ms. 1 psig @57ms. Aug. 0 psig @40ms. 5 psig @60ms.	"

TABLE 1 (Cont'd)

STATIC TESTING

Test No	Date	Inflation System	Bag	Bag Pressures	Remarks
3424	1-10-75	6 x 22 Aspirator, 70 gms. SF-23, .95 x .37 4 gms. IB-43 Aug. - 60 in.^{3} Mod IV, 2300 psi Argon, 25 gms SF-23, 95 x 57, 4 gms. IB-43	5 1 ft.^{3} Asp. 5.6 ft.^{3} Aug.	Asp 0 psig @55ms. .7 psig @62ms. Aug 0 psig @42ms. 1.5 psig @60ms.	Complete bag fabricated from 5.5 oz. material. Total bag weight 1.63 lbs Double panel between bags.
3425	1-13-75	" Aug. - 60 in.^{3} Mod IV, 2300 psi Argon, 33 gms SF-23, .94 x .44, 4 gms. IB-43	"	Asp. 0 psig @45ms. .7 psig @50ms. Aug. 0 psig @52ms. 1.5 psig @65ms.	"
3426	1-14-75	"	"	Asp. 0 psig @45ms. 1 psig @60ms. Aug. 0 psig @48ms. 2.5 psig @60ms.	Complete bag fabricated from 5.5oz. material except for Aug. bag torso panel. Single panel between bags Total bag weight 1.63 lbs
3427	1-15-75	" Aug. - 60 in.^{3} Mod IV, 2300 psi Argon, 27 gms. SF-23, .94 x .57, 4 gms. IB-43	"	Asp 0 psig @45ms. 1 psig @55ms. Aug. 0 psig @37ms. 5.5 psig @60ms.	Complete bags fabricated from 7.5 oz. material. Total bag weight 2.23 lbs.
3428	1-15-75	"	"	Asp. 0 psig @48ms 1 psig @57ms Aug 0 psig @34ms 6.0 psig @53ms	"

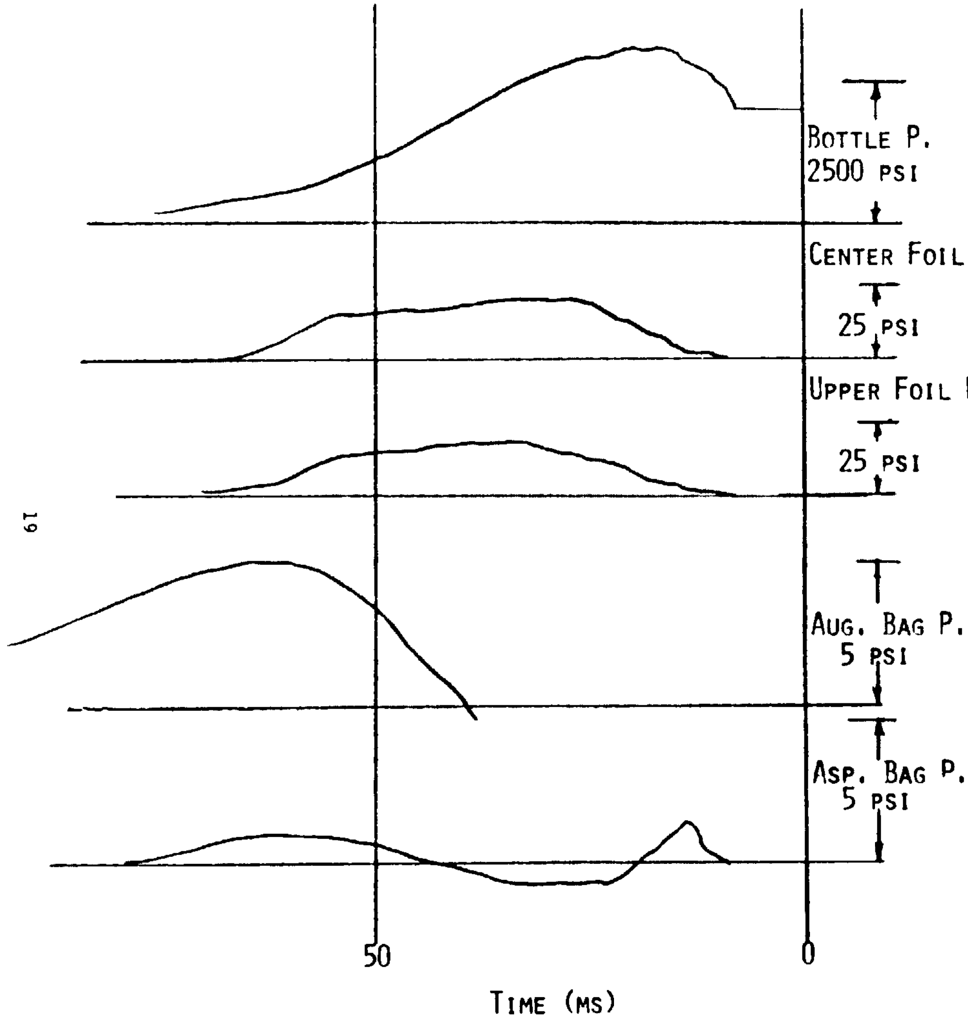
After the first sled test series the bag was redesigned for shape and size. (See Figure 2) The head bag was increased in size from 4.5 $ft.^3$ to 5.1 $ft.^3$ and the torso bag was reduced in size from 6.5 $ft.^3$ to 5.6 $ft.^3$. This was done to reduce the loading on the out-of-position child. The bag shape was changed (such that the head bag is positioned closer to the windshield) to reduce some of the neck bending evidenced in the test series. The static inflation test for the redesigned bag is depicted by Figure 5. This test (3423) had an inflation time of 40 ms and maximum bag pressure of 5 psig for the torso and 1 psig for the head bag. (Note: All sled tests were conducted with a sensor time of 5 ms.)

During the second series of sled tests, the dual bag aspirator system resulted in borderline loading of the 50th percentile male dummy and unacceptably high loads for the out-of-position six year old child dummy.

After the second sled test series, the results indicated a need for 1) reducing the bag weight to further lower the out-of-position child loads and 2) decreasing the inflation time in order to reduce the chest loadings on the 50th percentile dummy. A static inflation test for the reduced inflation time system is depicted by Figure 6. This test (3428) had an inflation time of 34 ms, compared to the 40 ms for test (3423). The torso bag inflation pressure was also higher, 6 psig versus 5 psig.

Static tests with an all-pyrotechnic inflator were conducted at the end of Task III. These tests are discussed in another section.

STATIC INFLATION TEST NO. 3423



Date 11/21/74

Shot No. 3423

Propellant 70 GMS. SF-23
25 GMS. SF-23

Charge No. 9266

Temperature AMB.

Breech 60 IN.^{3} MOD. IV 2100 PSI AR

Nozzle Data .265
.189

Igniter OS-1706

6 x 22 ASP. .070 GAP
5.1 FT.^{3} ASP. BAG
5.6 FT.^{3} AUG. BAG
.625 DIA. ORIFICES IN ELBOW

FIGURE 5

STATIC INFLATION TEST NO. 3428

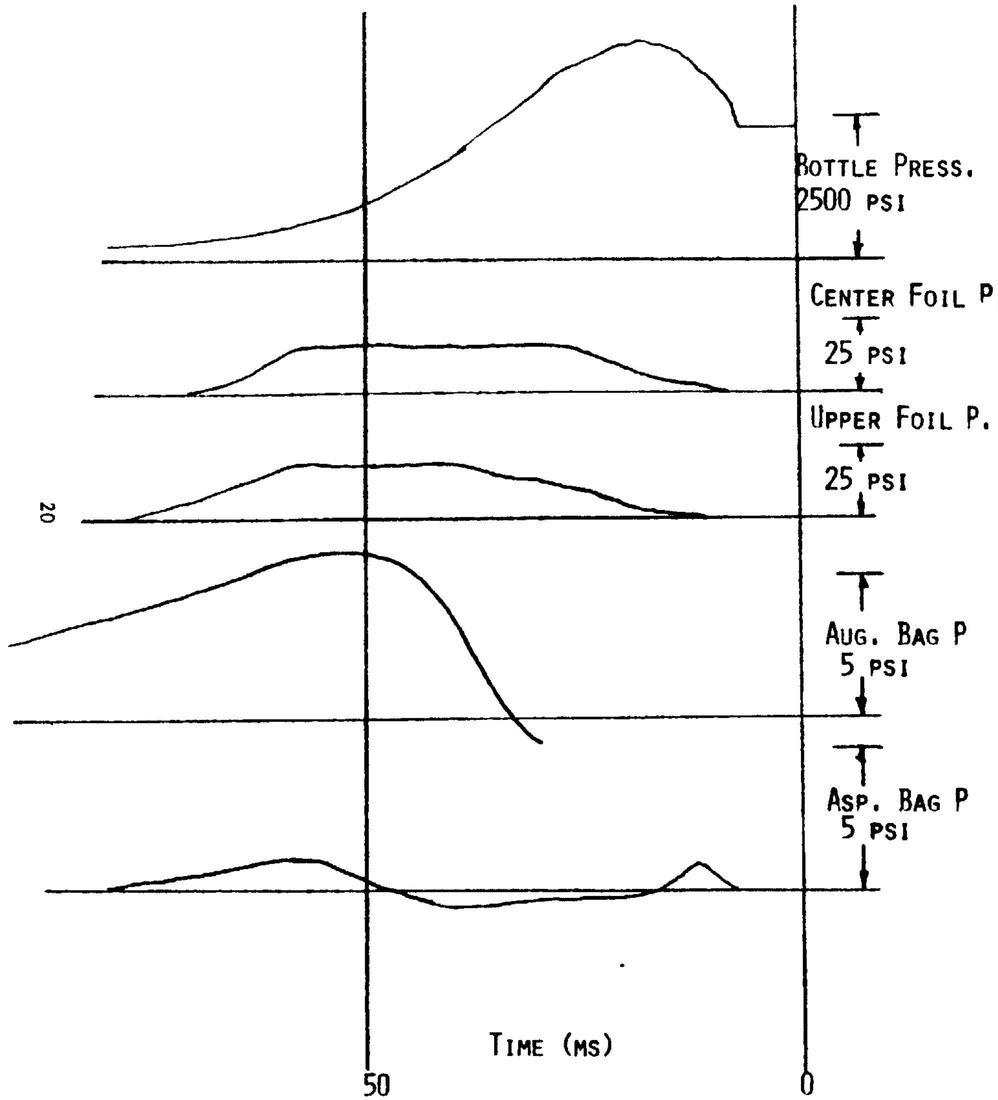


FIGURE 6

Date 1/15/75

Shot No. 3428

Propellant 70 GMS. SF-23
27 GMS. SF-23

Charge No. 9266

Temperature AMBIENT

Breech 60 IN.^{3} MOD. IV 2300 PSI AR.

Nozzle Data .182
.265

Igniter OS-170G

6 x 22 ASP. .070 GAP
5.1 FT.^{3} ASP. BAG
5.6 FT.^{3} AUG. BAG
.625 DIA. ORIFICE IN ELBOW

SLED TESTING - DUMMY DYNAMIC PERFORMANCE

Four sled test series with a total of thirty-nine sled tests were conducted during Task III. The first three sled test series were conducted prior to the first three vehicle tests and the fourth sled test series was conducted after the third vehicle crash to refine the inflation for the final three vehicle tests. The details of the sled testing are discussed in the following sections.

First Sled Test Series

Nine sled tests were conducted during the first sled test series. Table 2 summarizes the results of these tests and Table 3 summarizes the changes in system parameters for each test.

Test numbers 1238 - 1242 are a series of tests with the 50th percentile, wherein the changes consisted of reducing the bag fill time, increasing the fill pressure and increasing the bag venting. The resulting system, test number 1242, produced results with an acceptable degree of margin within the specifications. Excessive neck bending was observed when viewing the films of these tests. The same system produced very acceptable results with the out-of-position, six year old child in the static (Static #1) condition, however, the 50 mph test (1244), with the child, recorded marginal chest loadings. Test number 1245 was a 50 mph test with the child where the bag was rolled toward the center from top and bottom. This method of bag folding caused excessive loads on the head and

TABLE 2

IIT SLED TESTING

OCT. 14-17, 1974

Run No	1238	1239	1240	1241	1242	1243	1244	1245	Static #1
Sled Parameters									
Velocity (MPH)	49.1	49.6	49.8	49.8	49.8	49.8	50.6	50.6	-
Acceleration (g's)	32.8	32.6	34.3	33.3	32.7	32.8	32.3	32.0	-
Pulse Duration (ms)	103	102	102	102	101	100	100	100	-
Sensor Time (ms)	5	5	5	5	5	5	5	5	-
Dummy									
Size	50% Sierra	→	→	→	→	→	6 yr. old	→	→
Seating Position	Mid	→	→	→	→	→	Front	→	→
Head Resultant (g's)	110	94	77	80	76	72	145	130	39
HSI	1540	1520	1064	1139	990	1121	768	2030	418
HIC	-	-	805	829	794	812	423	1524	285
Chest Resultant (g's) (minus accumul 3ms)	75	64	62	60	46	48	65	75	46
X - direction	70	60	60	59	44	46	60	75	45
Y - direction	5	12	12	8	6	12	12	25	15
Z - direction	25	16	16	15	20	20	20	20	12
CSI	1040	800	670	660	500	570	600	880	60
Femur Loads (lbs)									
Left	800	900	800	900	800	1050	-	-	-
Right	850	900	750	900	800	850	-	-	-
Rebound Velocity (ft/sec)	15	6	6	7	5	5	negligible	3.5	15

TABLE 3

IIT SLED TESTING

SYSTEM PARAMETERS

Run No.	Aspirator	Augmented	Dual Bag	Bag Venting	Knee Restraint	Changes
1238	6" X 22" Propellant Driven 70 gms SP-23 4 gms IB-43	60 IN^3 Bottle 2300 PSI Argon 26 gms SP-23 2 gms IB-43	6.5FT^3 ASP Bag 4.5FT^3 Aug Bag Bag rolled under	3" Dia. Between Bags 2" Dia. Lower Bag to Atmos.	8" Top 6.5" bottom 8" High	
1239	6" X 22" Propellant Driven 70 gms SP-23 4 gms IB-43	60 IN^3 Bottle 2500 PSI Argon 28 gms SP-23 3 gms IB-43	6.5FT^3 ASP Bag 4.5FT^3 Aug Bag Bag rolled under	3" Dia. Between Bags 3" Dia. Lower Bag to Atmos.	8" Top 6.5" bottom 8" High	Increased stored gas, Aug. propellant and lower bag venting.
1240	"	"	"	3" Dia. Between Bags 3" Dia. Lower Bag to Atmos. 2" Dia. Upper Bag to Atmos.	"	Added venting to upper bag.
1241	"	"	"	3" Dia. Between Bags 3.25" Dia. Lower Bag to Atm. 2.5" Dia. Upper Bag to Atmos.	"	Increased venting in both bags.
1242	"	60 IN^3 Bottle 2600 PSI Argon 30 gms SP-23 4 gms IB-43	"	"	"	Increased stored gas, and Aug. propellant. Increase elbow orifice .60 to .625 Dia.
1243	"	"	"	"	6" Top, 4.5" bot. 8" High	Increased dist. between knee and knee restraint 1" to 3"
1244	"	"	"	"	8" Top, 6.5" bot. 8" High	Same as 1242
1245	"	"	Bag Rolled Toward Center from Top and Bottom.	"	"	Bag Folding
Static 1	"	"	Same as 1244	"	"	Same as 1244

chest of the child and the ride back onto the seat was not satisfactory. A test (1243) was conducted with the 50th percentile at 50 mph where the knee/knee restraint gap was increased from 1" to 3". (Distance E in Figure 7) This was done in an attempt to influence the kinematics of the dummy and reduce the neck bending. This small change did not appear to reduce the neck bending.

Second Sled Test Series

Eight sled tests were conducted during the second sled test series. Table 4 summarizes the results of these tests and Table 5 summarizes the change in system parameters for each test.

There were essentially three changes made in the total system after the first sled test series. These were:

1. The bag size and shape were revised in an effort to reduce some of the neck bending which was evidenced with the previous dual bag design. A comparison of the two dual bag sizes and shapes are shown in Figure 2.

2. A reduction in the total dual bag size (especially the reduction in the size of the torso bag) necessitated a reduction in the total gas flow and allowed a lower initial gas flow rate. This lower initial gas flow rate should be effective in reducing the initial chest loadings on the out-of-position child, however, the loadings on the child's chest during the second sled test series were still marginal.

TABLE 4

IIT SLED TESTING

DECEMBER 11-13, 1974

RUN NO	1285	1286	1287	1288	Static-II	1289	1290	1291
Sled Parameters								
Velocity (mph)	48.3	48.5	48.3	50.5	--	49.5	49.4	49.6
Acceleration (g's)	32.3	33.8	33.0	34.4	--	33.8	34.1	34.0
Pulse Duration (ms)	98.7	96	98.8	98.9	--	99 9	99.6	100.4
Sensor Time (ms)	5	5	5	5	--	5	5	5
Dummy								
Size	50% Hybrid II	→	→	6 yr.old	→	50% Hybrid II	→	→
Seating Position	Mid	→	→	Front	→	Mid	→	→
Head Resultant (g's)	65	200	76	93	50	89	60	74
HSI	740	1350	760	640	120	940	620	780
HIC	580	837	615	410	68	671	506	667
Chest Resultant (g's) (Minus Accumul 3ms)	58	60	52	62	40	64	58	65
X-Direction	58	58	52	60	35	61	58	60
Y-Direction	5	15	10	10	15	10	10	10
Z-Direction	8	20	10	10	15	10	10	10
CSI	650	720	670	500	180	880	680	750
Femur Loads (lbs)								
Left	1100	3000	1500	--	--	1900	1800	2000
Right	1200	2800	1200	--	--	1100	1000	900
Rebound Velocity (ft/sec)	5	15	11 5	9.5	12.5	11	11.5	9

TABLE 5

IIT SLED TESTING

SYSTEM PARAMETERS

RUN NO.	ASPIRATOR	AUGMENTED	DUAL BAG	BAG VENTING	KNEE RESTRAINT	SYSTEM CHANGES
1285	6"x22" Propellant Driven 70 gms SF-23 4 gms IB-43	60 in.^{3} Bottle 2100 psi Argon, 25 gm SF-23, 3 gm IB-43	5.1 ft.3 Asp. 5.6 ft.3 Aug. Bag rolled under	3" Dia. Vent between bags 3" " Lower Bag to Atmos. 2" " Upper Bag to Atmos.	1.4" Between Knee and Restraint	
1286	"	"	"	3" Dia Vent between Bags 3.25" Dia. Lower Bag to Atm. 2.5" Dia. Upper Bag to Atmos	3.5" between Knee and Restraint	Increased distance between knee and knee restraint. Increased venting in both bags.
1287	"	"	4.8 ft.^{3} Asp. 5.6 ft.^{3} Aug. Bag rolled under	3" Dia. Vent Between Bags 3.5" Dia. Lower Bag to Atmos. 2.5" " Upper Bag to Atmos.	1.75" Between Knee and Restraint	Changed upper bag. Reduced distance between knee and knee restraint. Increased venting in lower bag.
1288	"	"	5.1 ft.^{3} Asp. 5.6 ft.^{3} Aug. Bag rolled under	3" Dia. Vent between Bags 3.5" Dia. Lower Bag to Atmos. 2" Dia. Upper Bag to Atmos.	Same Knee Restr-aint.	Different upper bag Decreased breathing in upper bag.
Static #2	"	"	"	"	"	No change
1289	"	"	"	"	"	No change
1290	"	"	"	3" Dia. Vent Between Bags 3" Dia. Lower Bag to Atmos. 2" Dia. Upper Bag to Atmos.	"	Decreased breathing in lower bag.
1291	"	60 in.^{3} Bottle, 2100 psi Argon, 33 gm SF-23, 3 gm IB-43	"	3" Dia. Vent Between Bags 3 1/4" Dia. Lower Bag to Atm. 2" Dia. Upper Bag to Atmos.	"	Increased breathing in lower bag. Increased propellant charge from 25 gms to 33 gms and burn time from 35 to 55 ms.

3 The knee restraint support was moved forward in the vehicle to allow for an additional three inches of crushable knee restraint material. This would allow for more penetration of the knee restraint if required.

The first three sled tests (1285-1287) were with the 50th percentile male. The breathing and knee restraint/knee distance were varied to obtain the optimal results. With the tibia 3.5" away from the knee restraint (1286) the occupant rides off the front of the seat. With the tibia 1.5" away from the knee restraint (1285) the occupant rides up in the seat on rebound. In comparing the chest resultant accelerations on 1285 and 1287, the results on 1287 allowed for a larger margin of safety, however, the occupant did ride through the bag and contact the dash area.

The head results on all three tests were well within the specification The femur loads were too high on 1286 which was caused by the top of the knees contacting the bottom of the restraint during ridedown.

A 50 mph test (1288) and a static test (Static II) were conducted with the out-of-position six year old child using a compromised system from the first three tests. All of the results were well within specification except for a marginal chest load on the dynamic test

Test numbers 1289 and 1290 were two more tests with the 50th male which further revealed the system to be marginal on chest loadings with the system inflation rate and pressure.

On test number 1291 the augmented system propellant weight was increased from 25 gms. to 33 gms. The propellant flow rate during the initial 35 ms. of gas flow was comparable to the previous tests. The additional 8 gms. of propellant was burned over the next 15 to 20 ms. in an attempt to provide additional gas flow and prevent the occupant from bottoming out. However, this gas flow was added prior to maximum chest loading and added to the chest resultant.

In summary, the redesigned bag shape did appear to reduce the severity of neck bending and the reduced initial gas flow rate did reduce the initial chest loadings on the out-of-position child; however, the results were still marginal.

Third Sled Test Series

Ten sled tests were conducted during the third sled test series. Table 6 summarizes the results of these tests and Table 7 summarizes the change in system parameters for each test.

There were essentially three changes made in the total system since the previous sled test series. These were:

1. The static inflation time of the augmented bag was decreased from 40 to 35 milliseconds. Also the static inflation pressure of the augmented bag was increased from 5 to 6 psig. These changes were made to reduce the chest loadings on the 50th percentile male.

TABLE 6

IIT SLED TESTING

JAN 20-23, 1975

Run No.	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310
Sled Parameters										
Velocity (mph)	49.9	49 1	48.9	48.9	50.0	48.9	49	49.1	50 1	49 2
Acceleration (g's)	33.6	32 9	33.2	32.5	33.7	33.5	32.7	33.8	33.3	33.2
Pulse Duration (ms)	100 9	101 6	101.8	101 8	101.3	102.1	102.2	101.9	102 5	101 0
Sensor Time (ms)	5	5	5	5	5	5	5	5	5	5
Dummy										
Size	6 yr.old	50% Hybrid II	→	→	6 yr.old	50% Hybrid II	→	50% Hybrid II	6 yr.old	50% Hybrid II
Seating Position	Front	Mid			Front	Mid		Front	Front	Mid
Head Resultant (g's)	130	66	88	76	57	60	64	156	46	220
HSI	870	700	1700	950	520	620	700	1250	440	3000
HIC	533	545	-	757	404	450	584	-	363	-
Chest Resultant (g's) (minus 3 ms Accumul.)	50	48	73	56	57	48	54	58	48	130
X-Direction	50	48	72	56	57	48	52	58	48	130
Y-Direction	20	10	5	10	15	5	10	5	15	15
Z-Direction	15	15	20	10	15	15	15	15	15	25
CSI	390	500	1150	660	480	500	620	650	500	1750
Femur Loads (lbs)										
Left	-	950	1250	1300	-	1150	1700	1700	-	1800
Right	-	1050	1000	1100	-	1200	1200	1300	-	1400
Rebound Velocity (ft/sec.)	1.5	16	21	11	4	20	17	18	6	20

TABLE 7

IIT SLED TESTING

SYSTEM PARAMETERS

Run No	Aspirator	Augmented	Dual Bag	Bag Venting	Knee Restraint	System Changes
1301	6 x 22 Prop.Driven 70 gms. SP-23	60 in.3 Mod IV 2100 psi Argon 25 gms SP-23	5.1 ft 3 Asp -5.5 oz/yd.matl. 5.6 ft.3 Aug.-5.5 oz/yd.matl. Total Bag Wt. - 1.40 lbs.	None	12" Deep	Testing 6 yr. old with very light bag and inflation rate from previous series.
1302	"	60 in.3 Mod IV, 2300 psi Argon, 27 gms SP-23	5.1 ft.3 Asp.-7.5 oz/yd.matl 5 6 ft.3 Aug.- " " " Total bag Wt. - 1.95 lbs.	3" Dia.Between Bags 3.25" Dia.-Lower Bag to Atmos.-2" dia.Upper Bag to Atmos.	"	Heavy bag and reduced inflation time system.
1303	"	"	5.1 ft.3 Asp.-5.5 oz/yd.matl 5.6 ft.3 Aug.-7.5 oz/yd.matl Total Bag Wt. - 1.70 lbs.	None	"	Medium weight bag.
1304 and 1305	"	"	"	3.0" Dia.-Lower Bag to Atmosphere	"	Added breathing to Aug. Bag.
1306	"	"	"	3.0" Dia.-Lower Bag to Atmosphere - 1.5" Dia.-Upper Bag to Atmos.	"	Added breathing to Asp. Bag.
1307	"	"	"	"	11.5" Deep	Reduced Knee Restraint Depth
1308	"	"	"	"	9" Deep	Reduced Knee Restraint Depth and Moved Seat to Front Position.
1309 and 1310	"	"	"	"	12" Deep	Repeat of 1306.

2. A lighter weight bag was utilized to lower the initial chest loadings (bag slap) on the out-of-position six year old child. All tests to this point in time were conducted with 7.5 oz/yd.^{2} bag material.

3 The inflation system was raised one inch in the body buck to alleviate the problem of the interference of the knees with the lower portion of the restraint system.

The initial sled test (1301) was conducted with the out-of-position six year old child and a dual bag fabricated completely from 5.5 oz/yd ^{2} material compared to the normally used 7.5 oz/yd.^{2} material. Otherwise, the inflation system was identical to that of the previous sled test series. The purpose of this test was to compare the bag slap g-loads for the two different weight bag materials. In comparing test numbers 1288 and 1301 the initial bag slap peak g-loads were 95 g's versus 50 g's respectively. Therefore, the lighter weight bag material reduced the bag slap g-loads considerably as would be expected.

The second test (1302) was conducted with the 50th percentile male. The inflation system utilized the heavier weight (7.5 oz/yd.^{2}) bag material with the decreased inflation time (35 ms.) inflator. The purpose of this test was to determine if the reduced inflation time would improve the chest loadings on the 50th percentile male. The chest resultant was 48 g's compared to 58-60 g's obtained on the previous sled test series.

Tests number 1303, 1304 and 1306 were tests with the 50th percentile male, a medium weight bag and the reduced inflation time system. The medium weight dual bag consisted of a 5.5 $oz/yd.^2$ material aspirator bag and a 7.5 $oz/yd.^2$ material augmented bag. These three tests consisted of optimizing the bag venting in order to reduce the chest loadings. The optimized system (Test number 1306) produced a 48 g chest load with the other results on this test being well within the injury criteria.

On Tests number 1307 and 1308 the inflation system was identical to 1306 but the knee restraint was modified to allow for more forward movement of the dummy prior to the knees contacting the knee restraint. This was done in an attempt to change the ridedown kinematics (to submarine) of the dummy and reduce some of the neck bending observed on the previous tests. These changes in the knee restraint did not seem to improve the extent of the neck bending.

Tests number 1305 and 1309 were two tests with the out-of-position six year old child. Both of the tests met the injury criteria. The results on 1305 were slightly higher since the system was not fully optimized until test number 1306.

Test number 1310 was a repeat of test number 1306; however, the bag failed at the seam in the side panel. It was the second test for this bag.

In summary, the lighter weight bag and reduced inflation time improved the chest loadings considerably on both the 50th percentile male and out-of-position six year old child.

Fourth Sled Test Series

Twelve sled tests were conducted during the fourth sled test series. Table 8 summarizes the results from the fourth week of sled testing. A different crash pulse was employed for this series (See Figure 8). There were no major changes made to the restraint system from the previous sled test series. Slight changes in bag venting were made during the initial tests of this series to optimize the ride-down characteristics for the longer crash pulse. During the initial car crash test the dummy loadings were very low, and he was riding through the bag and contacting the dash area; therefore, a reduction in bag venting was necessary to build up the loads and prevent the dummy from riding completely through the bag.

Tests number 1384-1387 are four tests with the 50th percentile male in which slight changes were made in bag venting to obtain the optimal ridedown for the longer crash pulse. On test number 1384 the head bag failed to inflate due to an error in loading the system, and the results should not be judged. Of the other three tests 1386 was chosen as having the optimal venting even though 1385 and 1387 produced slightly lower chest results, the head appeared to be penetrating through the bag on those tests. Test 1391 was a repeat of test 1386 and the results are comparable.

TABLE 8

IIT SLED TESTING

April 28 - May 1, 1975

Run No.	1384	1385	1386	1387	1388	1389	Static I	Static II	1390	1391	1392	1393
Sled Parameters												
Velocity (mph)	50.6	50.8	51.0	51.1	52.3	52.2	0	0	52	50.6	50.8	49.9
Acceleration (g's)	36.8	33.5	33.2	33.7	34.2	33.9	-	-	33.7	32.7	33.1	32.5
Pulse Duration (ms)	124.4	124	124	122	123	123.8	-	-	123	125.5	125.5	125.5
Sensor Time (ms)	5	5	5	5	5	5	-	-	5	5	5	5
Dummy												
Size	50% Hybrid II	→	→	→	Out-of-position six yr. old child		→	→	6 yr. old Normally Seated	50% Hybrid II	5% Female	95% Male
Seating Position	Mid	→	→	→	Front				Mid Position	Mid	Front	Rear
Head Resultant (g's)	190	52	65	66	100	140	40	88	86	60	86	110
HSI	>2000	588	776	845	779	905	214	435	1079	695	1101	1324
HIC	-	476	680	686	406	395	163	270	903	582	898	963
Chest Resultant (g's) (Minus 3 ms, Accumul.)	120	48	58	55	50	45	30	35	69	54	54	56
X - direction	115	48	58	55	45	45	30	35	68	54	48	55
Y - direction	5	8	8	8	15	10	15	10	5	8	15	8
Z - direction	25	16	14	15	20	15	15	10	18	15	30	30
CSI	1550	480	630	550	400	360	90	130	760	570	500	820
Femur Loads (lbs.)												
Left	1400	1450	1150	1400	-	-	-	-	-	1400	-	4000
Right	1350	950	1000	1200	-	-	-	-	-	1250	-	1800
Rebound Velocity (ft/sec.)	10	13	7.5	9.5	10	4.8	12	33	9	7.5	6.5	10

Tests number 1388 and 1389 are two dynamic tests with the out-of-position six year old child. All of the results were well within the injury criteria.

Static tests I and II are tests with the out-of-position child which meet the injury criteria, however, the child did slide over the front seat on Static I. The seat was changed to a bench type seat for Static II and the child remained in the front seat. A dynamic test (1390) with the six year old child seated normally was conducted for information and the chest loadings did not meet the injury criteria.

Runs 1392 and 1393 were dynamic tests with the 5th percentile female and 95th percentile male, respectively. All of the results on these tests passed the injury criteria except for the femur load on the 95th. These excessive loads were caused by the 95th percentile male dummy contacting the bottom of the inflation system at the end of ridedown.

VEHICLE TESTING

A series of six full scale vehicle tests was conducted during Task III of the program. The tests employed unmodified 1974 full-size Ford sedans For the passenger position, the refined dual bag system developed under Task II was utilized. For the driver position, the driver air bag restraint system developed under NHTSA Contract DOT-HS-113-2-441 was employed*. The test matrix for the vehicle tests was as follows

1 Flat Barrier Impact (Perpendicular) (5 tests)

V_o = 30 mph (1)

V_o = 40 mph (1)

V_o = 45 mph (3)

2 Flat Barrier Impact (30 degree oblique) (1 test)

V_o = 40 mph

The test reports of each individual test are bound together and form Volume II of the Final Report.

A summary of the passenger results are shown on Table 9. The passenger restraint system physical measurements are tabulated in Table 10

* D Friedman and K Friedman, "Advanced Air Bag Restraints for Standard Size Car Driver," Final Rpt. DOT-HS-113-2-441, February 1974

TABLE 9

TASK III

VEHICLE TESTS

PASSENGER RESULTS

TEST NO.	1 30.2 MPH BARRIER	2 40.8 MPH BARRIER	3 45.5 MPH BARRIER	4 45.2 MPH BARRIER	5 44.6 MPH BARRIER	6 40.3 MPH 30^{0} ∠ RT. OBLIQUE
HEAD RESULTANT (G'S)	36	135	200	66	56	35
HSI	174	656	745	769	470	154
HIC	121	432	477	638	414	122
CHEST RESULTANT (G'S)	33	43	51	54	57	41
AP	24	39	50	52	56	36
SI	28	15	34	24	14	16
RL	10	14	10	8	9	10
CSI	117	300	365	513	511	200
FEMUR LOADS (LBS)						
LEFT	750	1300	1700	1500	1250	1200
RIGHT	800	1100	1250	1600	900	1050
REMARKS	GOOD TEST	DUMMY SUBMARINED & RODE THROUGH BAG	WINDSHIELD RELEASED	DUMMY SUBMARINED	GOOD TEST	GOOD TEST

TABLE 10

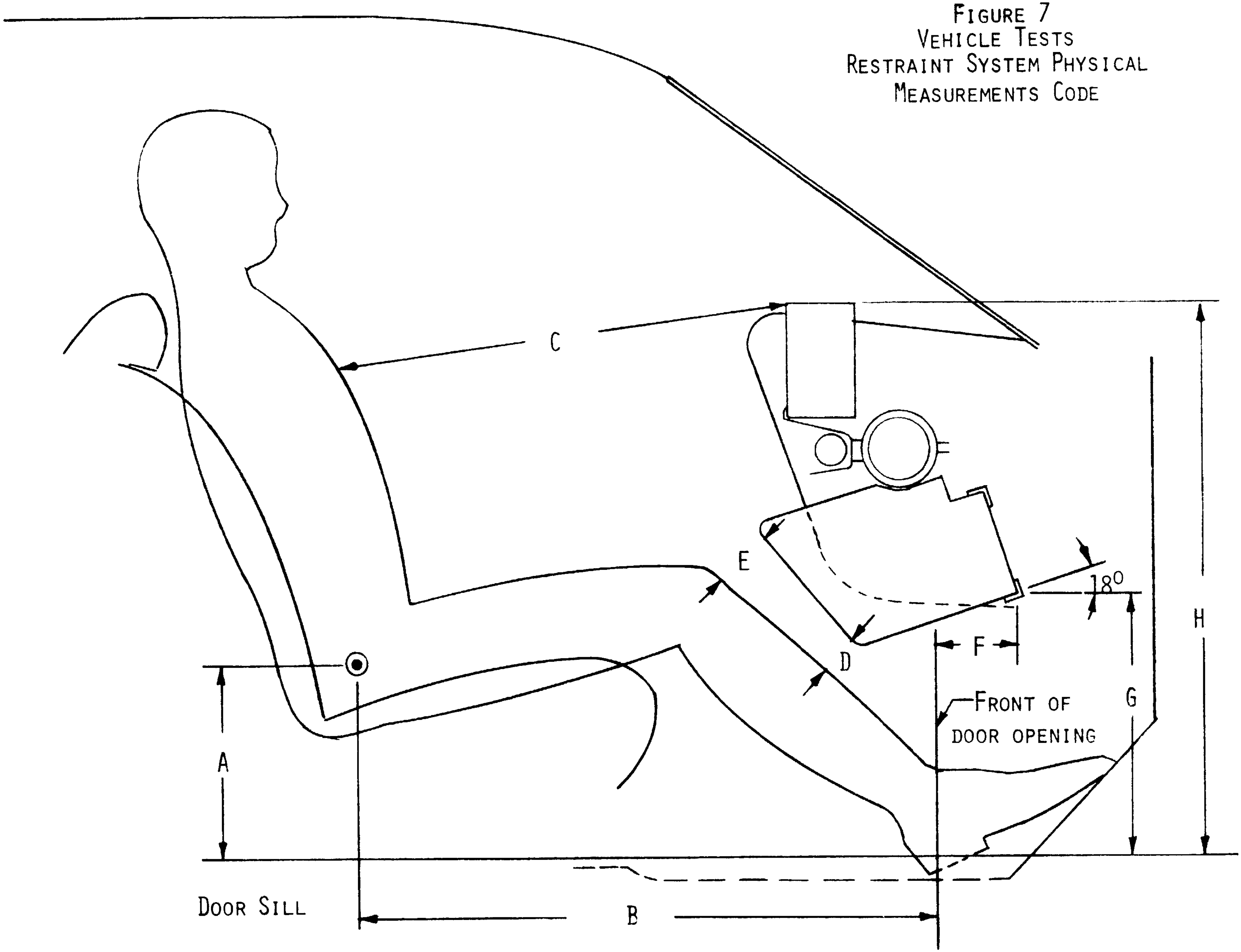
VEHICLE TESTS

RESTRAINT SYSTEM PHYSICAL MEASUREMENTS

	Test No.					
Dimension*	1	2	3	4	5	6
A	7	9	9	9	8	9
B	28 3/4	28 1/4	29 1/4	30 1/4	30 1/4	30
C	24	24	24	24	23 1/2	23 1/2
D	3	2	2	3.5	2	2
E	4	3	2.5	4	2 1/2	2 1/2
F	5 1/4	4 1/4	3 1/4	3 1/4	3 1/2	3 1/4
G	13 1/2	13 1/2	13 3/4	14	13 3/4	14
H	29 1/2	29 1/4	29 1/2	30	29 1/2	29 3/4

* Dimensions in inches. Refer to Figure 7 for letter code.

FIGURE 7
VEHICLE TESTS
RESTRAINT SYSTEM PHYSICAL
MEASUREMENTS CODE



The first vehicle test was conducted at 30 mph and the results indicated good survivability. The loads in the SI direction of the chest were slightly high and foam was placed under the seat for the second test to increase the resistance to downward motion. No other changes were made in the system. The second test was conducted at 40 mph and the dummy submarined and rode through the bag. However, the results were still well within the survivability requirements.

The third vehicle test was conducted at 45 mph and a change in the bag venting was made in an attempt to prevent the dummy from riding through the bag. The vent hole in the upper bag was removed and the knee restraint was moved one inch towards the passenger. The windshield released on this test. This failure removed the reaction surface (the windshield) for the passenger bag and allowed the dummy to contact the dash area at the end of ridedown. Although the results met the injury criteria, it was not considered a good test since the windshield released.

Since the second and third vehicle tests were marginal with respect to dummy penetration of the bag, it was felt that a series of sled tests was necessary to tune the system for the longer crash pulse (125 ms.) being evidenced in the car crashes as compared to the 100 ms. sled pulse under which the system was developed. Figure 8 compares the 1974 Ford crash pulse with the sled pulses tested

DECELERATION PROFILES

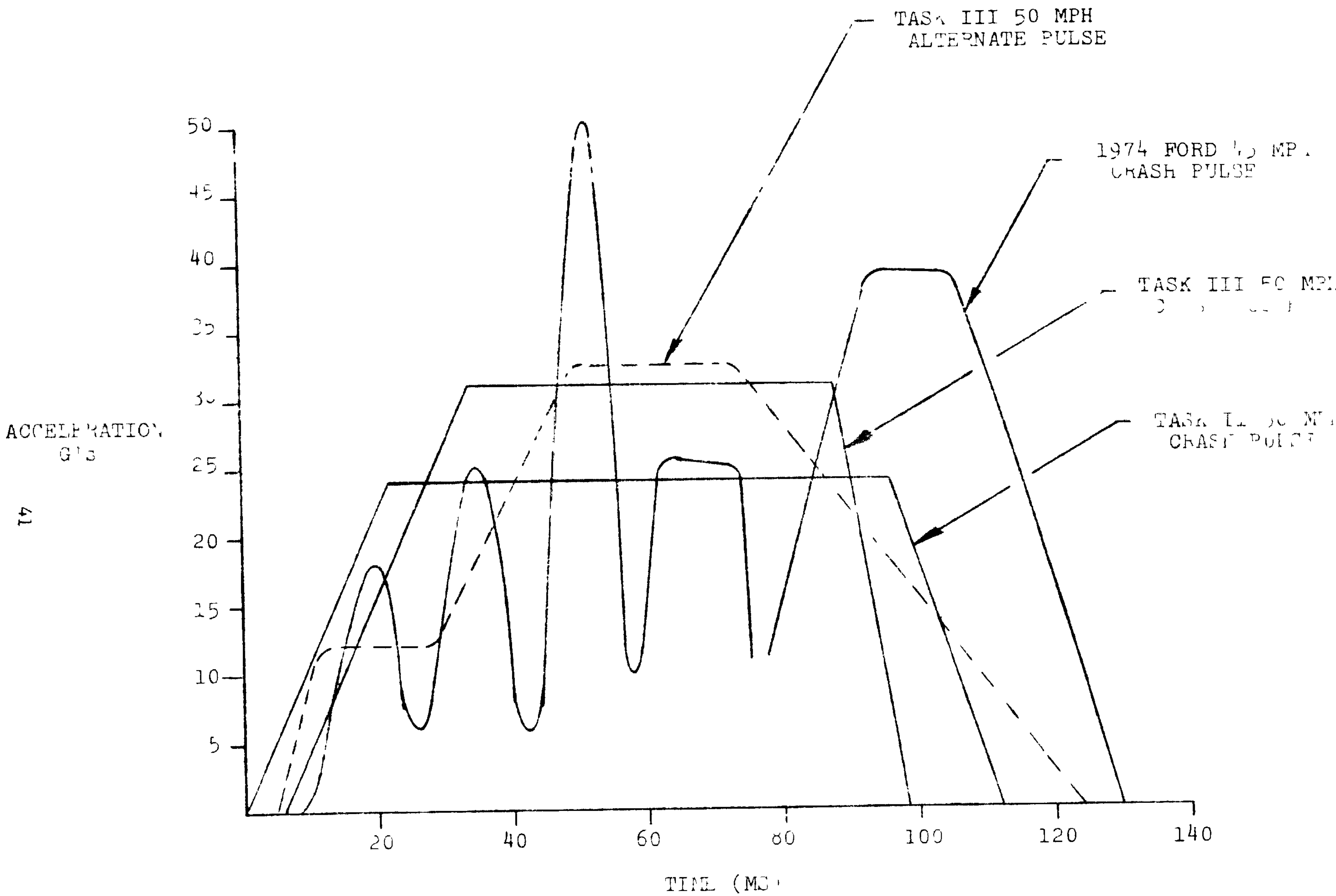


Figure 8

during the program. The Task III alternate pulse was utilized for tuning the system on the sled for the last three vehicle tests. During the final sled test series the restraint system was only changed in the area of bag venting.

The fourth vehicle test was conducted at 45 mph with the modified bag venting restraint system. Although the results met the injury criteria, the dummy did slide off the front of the seat. The knee bolster was modified (thickness increased one inch) prior to the next car crash to prevent the submarining. The fifth test was also conducted at 45 mph into a flat barrier. The results indicated good survivability, and it was considered a very good test (See Table 9).

The sixth and final vehicle test was conducted at 40 mph into a 30° angled right oblique flat barrier. The results of this test also indicated a very high degree of survivability.

ALL-PYROTECHNIC SYSTEM DEVELOPMENT

Because of the recent emphasis placed on system weight, system reliability, and cost/benefit considerations, Olin proposed to convert the lower bag augmented inflator of the dual bag system to a solid propellant inflator. The NHTSA agreed that development work in this area was within the scope of the program provided it could be conducted within the monetary limitations of the contract.

An all-pyrotechnic reloadable inflator is shown in detail in Drawing 4777128. To optimize weight and volume of the inflator, a coaxial arrangement of propellant chamber inside the coolant chamber-diffuser was incorporated into the design. Olin's SF-26 propellant, which was developed for use in a wheel mounted driver inflator, was used for this development program. The inflator uses small hollow beads with a slit or perforation through the spherical wall to cool and filter the gas.

A total of eleven development tests were conducted with the pure pyrotechnic inflator. These tests are summarized in Table 11. All of the tests were conducted with a single 5.6 $ft.^3$ bag. During the testing the propellant/coolant ratio and orifice control were varied to obtain the desired inflation data. The final test,

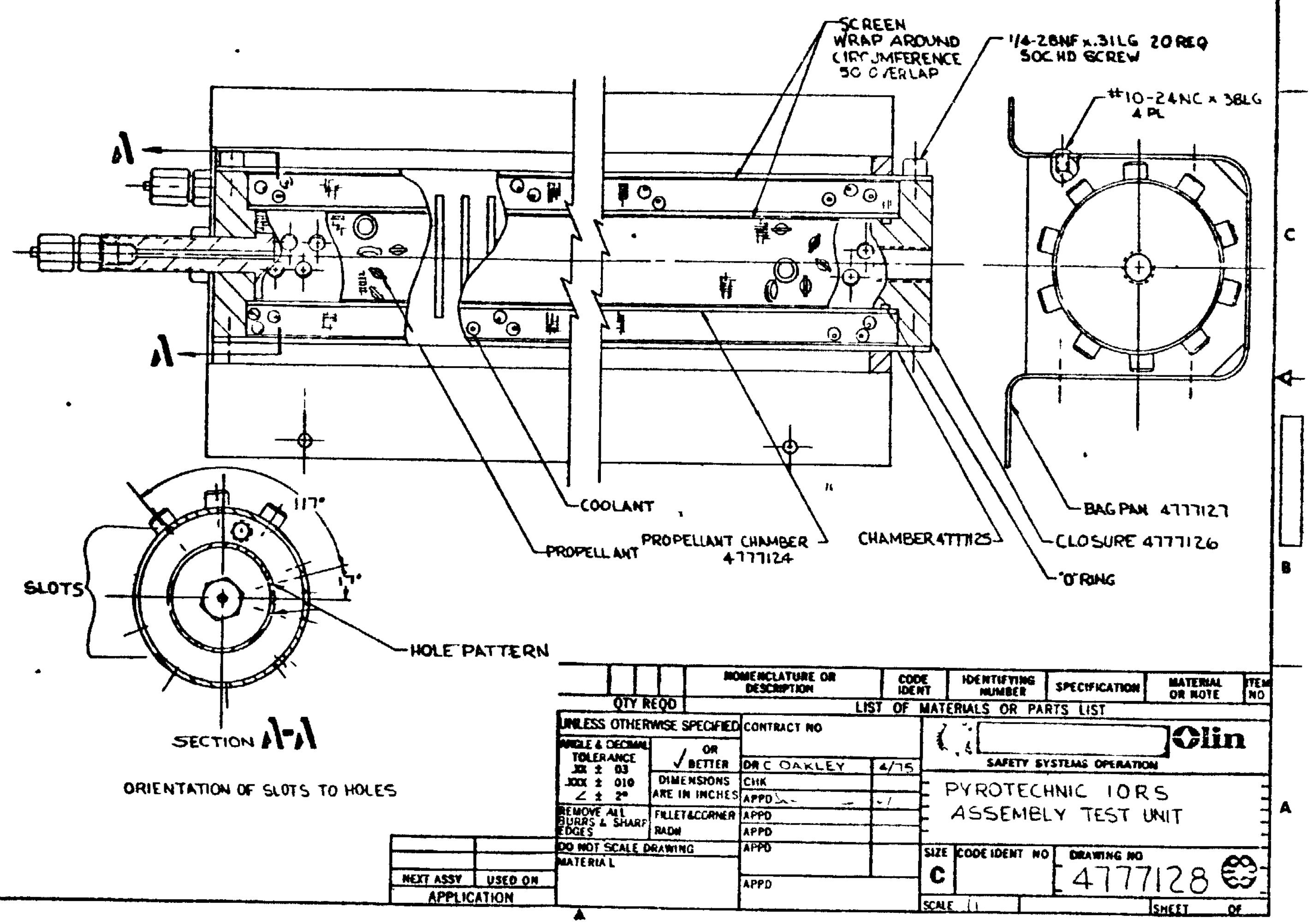

SCREEN
WRAP AROUND
CIRCUMFERENCE
50 OVERLAP
1/4-28NF x.31LG 20 REQ
SOC HD SCREW
#10-24NC x 38LG
4 PL
COOLANT
PROPELLANT
PROPELLANT CHAMBER
4777124
CHAMBER 4777125
BAG PAN 4777127
CLOSURE 4777126
"O" RING
SLOTS
HOLE PATTERN
117°
SECTION A-A
ORIENTATION OF SLOTS TO HOLES
QTY REQD
NOMENCLATURE OR DESCRIPTION
CODE IDENT
IDENTIFYING NUMBER
SPECIFICATION
MATERIAL OR NOTE
ITEM NO
LIST OF MATERIALS OR PARTS LIST
UNLESS OTHERWISE SPECIFIED
ANGLE & DECIMAL TOLERANCE
.XX ± .03
.XXX ± .010
∠ ± 2°
OR BETTER
DIMENSIONS ARE IN INCHES
REMOVE ALL BURRS & SHARP EDGES
FILLET & CORNER RADII
DO NOT SCALE DRAWING
MATERIAL
CONTRACT NO
DR C OAKLEY 4/75
CHK
APPD
APPD
APPD
APPD
APPD
NEXT ASSY
USED ON
APPLICATION
Olin
SAFETY SYSTEMS OPERATION
PYROTECHNIC IORS
ASSEMBLY TEST UNIT
SIZE C
CODE IDENT NO
DRAWING NO
4777128
SCALE
SHEET
OF

TABLE 11

STATIC DEVELOPMENT TESTING

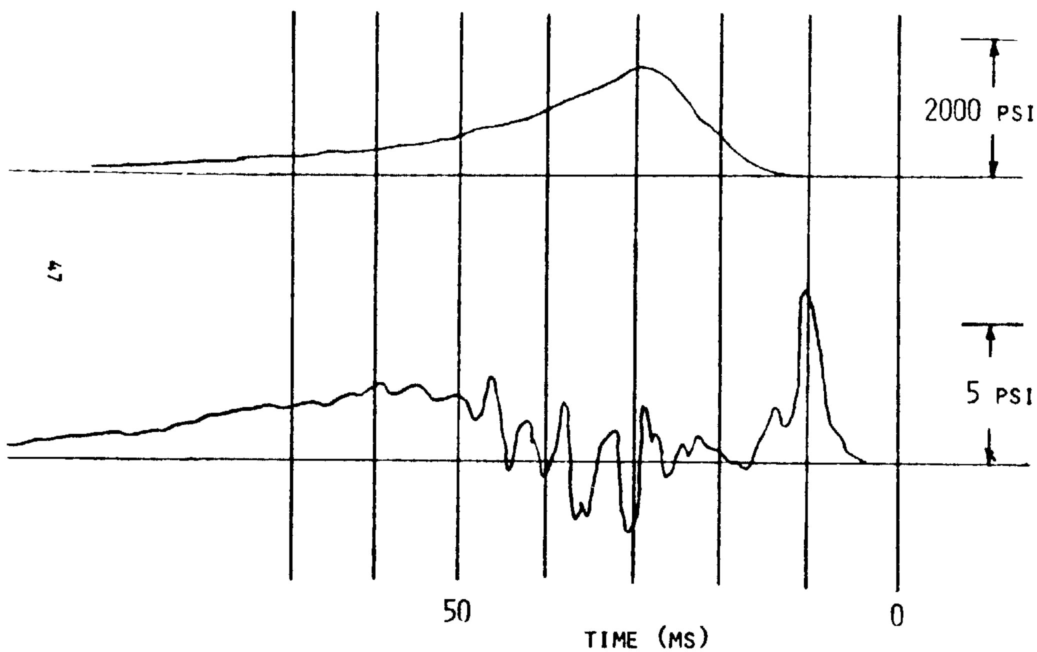
ALL-PYROTECHNIC SYSTEM (4777128)

TEST NO	PROPELLANT	COOLANT	BAG	ORIFICE	CONTROL	PROPELLANT CHBR. PRESS (psi)	DIFFUSER PRESSURE (psi)	BAG PRESSURE (psig)	REMARKS
3427 A	175 gms SP-26 15 gms IB-43	1300 gms. SS Hollow Beads	5.6 ft.^{3}	66 ea. holes	.25 dia.	-	-	-	
3428 A	250 gms SP-26 15 gms IB-43	"	"	52 ea holes	25 dia.	500	50	-	Bag Ruptured
3429	200 gms SP-26 15 gms IB-43	"	"	46 ea. holes	.25 dia.	500	50	0.5	
3430	225 gms SP-26 15 gms IB-43	" "	" "	66 ea. holes	.25 dia.	350	40	-	
3431	200 gms SP-26 15 gms IB-43	"	"	35 ea. holes	.25 dia.	1000	75	-	
3432	200 gms SP-26 15 gms IB-43	"	"	22 ea. holes	.25 dia.	1100	100	0.5	
3433	250 gms SP-26 15 gms IB-43	"	"	33 ea holes	.19 dia.	2000	75	-	Bolts Sheared thru Holes *in End of Diffuser*
3434	250 gms. SP-26 15 gms. 2A pellets	"	"	28 ea. holes	.25 dia.	650	75	-	Bag not fully inflated.
3435	275 gms. SP-26 15 gms 2A pellets	"	"	28 ea. holes	25 dia.	1300	105	-	Bag not fully inflated.
3436	300 gms SP-26 10 gms 2A pellets	850 gms. SS Hollow Beads	"	54 ea. holes	.203 dia	1000	185	0 psig @ 50 ms 1 psig @ 70 ms	Good Inflation.
3437	325 gms SP-26 15 gms. 2A pellets	700 gms SS Hollow Beads	"	"		1500	Not Rec	0 psig @ 36 ms 2.5 psig @ 55 ms	Very good inflation

test number 3437, (Figure 9) resulted in an inflation time of 36 milliseconds and a maximum bag pressure of 2.5 psig. This test provides sufficient data to indicate that a system of this design can be tailored to meet the requirements of a restraint system.

FIGURE 9

PYROTECHNIC INFLATION TEST



DATE 7/30/75

SHOT NO. 3437

PROPELLANT 325 GMS. SF-26, 15 GMS. 2A PELLETS

CHARGE NO. 9266

TEMPERATURE AMBIENT

BREECH 4777128, 700 GMS. SS BEADS

NOZZLE DATA 54 HOLES .203 DIA.

IGNITER OS-170G

5.6 $FT.^3$ BAG