April 1984
Final Report

DOT HS-806 685

TL
242
.F5827

U.S Department
of Transportation
National Highway
Traffic Safety
Administration

CRASH SURVIVABILITY ANALYSIS COMPUTER STUDY

Michael Fitzpatrick

Fitzpatrick Engineering
Route 5, Box 495A
Warsaw, IN 46580

Contract No. DTRS57-84-P-80707

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

TL
242
.F5827

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS-806 685		

4. Title and Subtitle	5. Report Date
Crash Survivability Analysis Computer Study	April 25, 1984
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s)	
Michael Fitzpatrick	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Fitzpatrick Engineering Route 5, Box 495A Warsaw, IN 46580	11. Contract or Grant No. P.O. DTRS57-84-P-80707
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	January-April 1984
National Highway Traffic Safety Administration 400 7th Street, S.W. Washington, DC 20590	14. Sponsoring Agency Code NRD-12
15. Supplementary Notes	

DEPARTMENT OF TRANSPORTATION
APR 02 1985
LIBRARY

16. Abstract

This report documents the findings of a four month study in which a "Crash Survivability Envelope" was derived for three basic vehicle sizes.

The computer programs used in this study are enhanced versions of two programs previously written by Fitzpatrick Engineering for NHTSA. The programs are DRACR for the driver and PAC for the right front passenger. The enhancements made to the programs were primarily the addition of a three-point belt restraint system to each program.

Survivability limits for various occupant sizes, crash modes, and vehicle sizes are presented for both the driver and front seat passenger when restrained by a seat belt and air bag and by an air bag only.

17. Key Words	18. Distribution Statement
Air Bag, Seat Belt, Gas generator, Occupant survivability, Injury Severity.	Document is available to the U.S. 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	127	$19,800

TABLE OF CONTENTS

1.0 INTRODUCTION

This report is written to document the findings of a four month study in which a "Crash Survivability Envelope" was derived for three basic vehicle sizes. Before going any further it would be helpful to define the term "Crash Survivability Envelope". To find the Crash Survivability Envelope means to find the allowable velocity change a given vehicle may undergo for a given accident mode and with a given restraint system without exceeding either the occupant injury criteria or vehicle crush limit for the particular occupant size being studied.

Thus, using computer techniques, we propose to determine the maximum crash velocity a given vehicle may undergo in a given accident mode for a certain restraint system and still receive injury measures on the vehicle occupant which are less than the criteria limits.

The computer programs used in this study are enhanced versions of two programs previously written by Fitzpatrick Engineering for NHTSA. The programs are DRACR for the driver and PAC for the right front passenger. The enhancements made to the programs were primarily the addition of a three-point belt restraint system to each program. This part of the total project was largely accomplished and funded by in house work and two small commercial projects.

The two enhanced versions of the programs are now known as BDRACR and BPAC with the "B" prefix signifying that "belts" may now also be simulated with the models. With these additions the programs are now able to model the interaction of the vehicle occupant with an airbag and/or belt restraint system. All the previous

capability of the models exist plus the fact that the restraint system analyzed may be either a belt system alone, an airbag system alone or a combination of the two systems.

1.1 Study Parameters

The parameters varied in the study were:

a. The vehicle size - "large, compact and small".

b. The vehicle station - driver or passenger.

c. The occupant size - 5th percentile female through 95th percentile male.

d. The crash mode - frontal, frontal offset, and thirty degree oblique.

e. The restraint system - airbag alone or airbag in combination with a three point belt system.

f. The crash velocity.

Since there were so many possible combinations of the variables which were studied, approximately 300 computer runs were necessary to complete the analysis. Fitzpatrick Engineering used our in house computer for all of these simulations. In the past an analysis using the PAC and DRACR programs made use of the General Electric Time Sharing System at an approximate cost to NHTSA of $30 to $35 per run. Thus a significant cost savings to NHTSA was realized through our transporting these programs to our own computer. It should be noted that the labor involved in this transportation was borne entirely by Fitzpatrick Engineering and

was accomplished before this contract was awarded.

In any program such as this one where such an ambitious scope of computer simulations are contemplated and where the process being simulated is as complex as an automobile crash, certain simplifying assumptions must be made. The assumptions made in this analysis are described below.

1.2 Assumptions

1.2.1 Approach

First of all, one must decide in a study such as this whether one is going to define a "laboratory" restraint system and theortically attainable vehicle crash environment or define an "off-the-shelf" type restraint system operating in a currently produced vehicle. That is, are we going for the theortical maximum performance possible for an airbag/belt type restraint system or are we going to simulate a system which could be mass produced today with components which are readily available?

In this study we opted for the latter approach. We did this because our experience has shown that manufacturer resistance to any system which violates established procedure or the geometrical or performance constraints of a given vehicle too severely will result in the analysis ending up being merely an academic exercise with no possibility of further development. We therefore have conducted an analysis which has produced results which we believe are attainable with the restraint system components, compartment interior dimensions and vehicle structural performance currently available.

On the other hand, we also wanted the study to reflect performance

improvements in areas where such improvements could be realized with minimal changes to existing practices or vehicle or restraint system design. Where this was possible such improvements have been made.

1.2.2 Gas Generators

In order to prevent the number of computer runs from becoming even higher, we simply chose an off-the-shelf gas generator for the simulations. The chosen gas generator for the driver is the latest Thiokol design which consists of an aluminum inflator loaded with approximately 95 gm of propellant. The gas generator chosen for the passenger consists of two Talley "driver type" generators firing in parallel.

For these choices we simply used past experience to select the gas generators. In our view, some of the currently popular gas generators are too lightly loaded to perform optimally in a crash. The current emphasis seems to be on just meeting the injury criteria at 30 mph rather than designing "all out" for minimum injury. Also, it seems that most current systems are designed to be used in conjunction with a three-point belt and use a rather under-inflated airbag to protect the driver. The emphasis seems to be on merely providing cosmetic protection rather than maximizing the inherent effectiveness of the airbag to minimize other injury as well. While the desirability of cosmetic protection is laudable, it is our view that by going just a step further in the design process, one has the opportunity to achieve injury measures which are even lower. We feel that the chosen generators will provide this opportunity.

This increased propellent capacity also makes it possible to design a right front passenger system which uses a pair of the less expensive driver type inflators (in this case mfg'd by Talley) for the purpose of achieving the required protective levels

for the passenger.

1.2.3 Vehicle Definition.

One has really two choices in his approach to defining the vehicle in an analysis such as this. One way is to simply pick three specific vehicles such that each represents a particular weight class and then use the detailed characteristics of each vehicle as input for the computer study. While this straight forward approach may be simple, the problem with getting involved with the specifics of three actual vehicles is that there may be "personality quirks" which each vehicle may have in a specific area which is not typical of the class as a whole. If this happens, one may end up with a study which focuses on the individual characteristics of the chosen vehicles rather than on the broad trends of a given vehicle class.

For example, if one of the three vehicles has a column which does not stroke easily or a crash pulse which is abnormally harsh, the Crash Survivability Envelope may be unduly restrictive since it has been colored by a personality quirk rather than by a generic attribute of the vehicle class.

A second problem with using three specific vehicles is that we were unable to obtain crash pulses for the three different accident modes at even one velocity. In actuality, we require crash pulses for the three accident modes at several velocities for three separate, currently produced vehicles.

Therefore, for this study we have chosen to simulate three generic classes of vehicle rather than specific vehicles per se.

Some detailed characteristics of a specific vehicle have been used in some instances where the values were thought to be fairly typical. However in other areas a type of "class average" was used.

The areas in which a specific vehicle parameter was used are primarily in the area of internal measurements. The areas where class average values and past experience were used were in the area of crash pulse determination. Finally, in certain areas of restraint system design where the overall vehicle design would not suffer from some creative analysis, we have sought to optimize the system for a given vehicle class. An example of this last area would be the steering wheel and column force-stroke relationship and the airbag design.

Table 1, which shows the type of input values required for for the BDRACR and BPAC computer models, also shows how each of these input values were derived - actual measurement, class average, iteration for superior performance or just typical values based upon past experience. In those cases where actual measurements were used, the full size car was the Ford LTD, the compact car was the Chevrolet Citation, and the small car was the sub-compact Chevette.

1.2.4 Occupant Survivability.

In general, for each vehicle size, crash mode, restraint type, occupant size and occupant location the "highest allowable" vehicle change in velocity was sought. By "highest allowable" we mean the highest crash velocity the system defined by the foregoing parameters may undergo before one or more of the following criteria is met or exceeded.

TABLE 1 - INPUT PARAMETER DESCRIPTION

Variable Description	How Obtained
Vehicle impact velocity	Iteration variable.
Head angle	Class average for occupant size.
Torso angle	Class average for occupant size.
Body segement weights	Class average for occupant size.
Body segment lengths	Class average for occupant size.
Column force vs stroke	Iteration for superior performance.
Seat friction force	Class average for occupant size.
Neck rotational resistance	Class average for occupant size.
Crash pulse g's	Class average for vehicle size and crash mode. (based upon computer algorithm)
Knee restraint force vs crush	Iteration for superior performance.
Wheel torque vs rotation	Typical values.
Column torque vs rotation	Typical Values.
Anchor point locations	Actual measurements.
Pelvic girdle force vs def'l	Estimate.
Gas generator flow profile	Actual - Thiokol 95 gm aluminum inflator.
Steering wheel force vs crush	Iteration for superior performance.
Sternal force vs displacement	Typical values.
Chest force vs displacement	Typical values.
Steering wheel angle	Actual measurement.
Steering wheel weight	Typical values.
Horizontal ref. distance to steering wheel pivot	Actual measurement.
Vertical ref. distance to steering wheel pivot	Actual measurement.
Head/neck damping coefficient	Previous studies.
Wheel moment of inertia	Typical value.
St. column angle	Actual measurement.
St. column coeff. of friction	Typical value for generic column.
Column dimensions	Typical values.

Column weight (stroking part)	Typical value.
Chest width	Class average for occupant size.
Femur length	Class average for occupant size.
Initial femur angle	Typical values.
Initial tibia angle	Typical values.
Distance from wheel pivot to wheel rim.	Iteration for superior performance.
Chest damping coefficient	Actual measurement.
Horiz. H-pt dimension	Actual measurement for occ. size.
Vertical H-pt dimension	Actual measurement for occ. size.
Seat friction coefficient	Typical value.
Initial distance of knee from knee restraint (horiz.)	Typical value.
X-coord. of top of windshield	Actual measurements.
Y-coord. of top of windshield	Actual measurements.
Windshield angle	Actual measurements.
Gas temperature	Computed.
Airbag dimensions	Iteration for superior performance.
Steering wheel dimensions	Typical values.
Belt forces vs stretch	Actual meas. for 7% elong. mat'l.
Seat bottom force vs def'l	Typical values.
Airbag fabric weight	Typical values.

a. HIC > 1000.

b. Pk. Resultant Chest G's > 60 g.

c. Pk. Femur Load > 1750 lb. for 5th percentile female,
> 2250 lb. for 50th percentile male,
> 2750 lb. for 95th percentile male.

d. Head Contact with the Windshield or A-Pillar.

e. Exceeding the Available Crush for the Vehicle.

Full Size Car:	47.6 in.	(80% of bumper to F/W distance)
Compact Car:	41.5 in.	(77.5% of bumper to F/W distance)
Subcompact Car:	35.6 in.	(75% of bumper to F/W distance)

2.0 Driver Study

2.1 Obtaining the BDRACR Input

Before discussing the results in detail, a word is in order about how the various crash pulses were determined. Since we were unable to locate crash pulses for the three vehicle sizes for each of the three crash modes at a common velocity it was necessary to derive an algorithm which would generate the desired pulses. The way this was done is as follows.

The first step was to locate a particular vehicle which had been crashed in all three crash modes - frontal, frontal offset and frontal oblique at several crash velocities. The only vehicle with which we had prior experience for these conditions was the 1976 Volvo for which we had developed air cushions several years ago on another NHTSA contract. We studied the crash pulses from these crashes and formed a few general rules which we applied to formulating a general algorithm for this study. These rules were then modified as required as more and more cars were studied. The rules which we finally settled on are given below and seem to be generally valid for highly filtered data where local "spikes" have been removed:

1. If the crash velocity is held constant, the peak g-level is approximately the same for the frontal and frontal oblique conditions, and approximately 85% of this peak for the peak g's for the frontal offset condition.

2. For a given crash mode the crash pulse duration is largely invariant with the crash velocity for the velocities of interest. Further, the crash pulse duration for the frontal and frontal oblique crash modes are approximately the same.

3. The frontal and frontal offset modes may be approximated by a haversine type curve with good accuracy. The frontal oblique mode however, is best approximated with a triangular type pulse which rises to its peak value at a time of approximately six-tenths of the total pulse duration.

4. The pulse durations considered typical of a wide range of cars and used in this study are:

   Full Size Car: 115 msec. frontal and oblique, 135 msec offset.

   Compact Car: 100 msec. frontal and oblique, 118 msec offset.

   Subcompact Car: 90 msec. frontal and oblique, 106 msec offset.

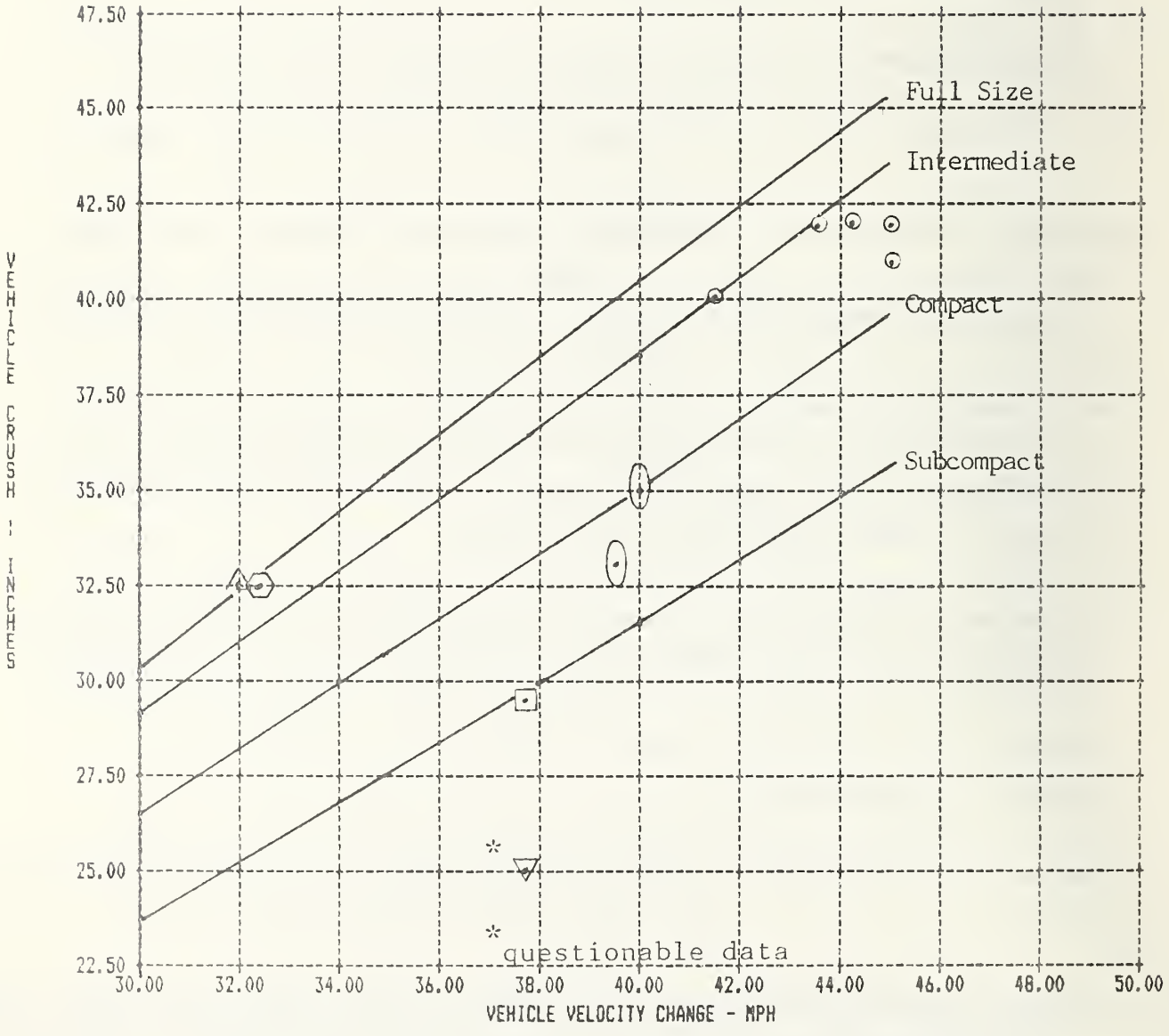
   The period of very low g's when the only the bumper was deforming was subtracted from the total pulse duration to yield those durations shown above.

These general rules were used in formulating the crash pulses for this study. Figure 1 shows these results for the frontal impact mode plotted as vehicle crush versus impact velocity. Several actual test results are also plotted on the curves for comparision purposes.

Appendix A contains a listing of the actual crash pulses used in the study.

Tables 2 and 3 and Figures 2 through 11 show additional input used in the BDRACR computer simulations while Figure 12 shows a typical BDRACR input file. Appendix B contains definitions of the Figure 12 input values.

*VEHICLE CRUSH VS VELOCITY CHANGE - FRONTAL IMPACT



*Curves based upon computer algorithm which gives crash pulse for full size, intermediate, compact and subcompact car frontal, offset and 30° oblique impact.

Legend
- ⊙ Volvo
- △ Ford LTD
- ⬡ Dodge Diplomat
- ⊡ Chevette
- ▽ Omni
- (·) Citation

Figure 1.

"BDRACR" INPUT DATA

Vehicle	a	b	V Area	θ_c	Rim Dia.	X1Z	Y1Z	Xr	Yr	θ_{ws}
Full Size	12.	7.0	1.20	21.5	15.0	22.8	25.0	21.8	42.5	34.0
Intermediate	12.	6.5	1.38	23.3	15.0	21.6	25.3	20.4	42.5	32.0
Subcompact	12.	6.0	1.50	25.0	15.0	20.5	25.5	19.0	42.5	35.5

Driver - F.S.	X2Z	Y2Z	θ_T	θ_H
5th	29.3	13.4	-12.	3.
50th	30.0	12.9	-16.	1.
95th	31.8	12.4	-20.	0.

Driver - Int.	X2Z	Y2Z	θ_T	θ_H
5th	28.3	13.4	-12.	3.
50th	29.0	12.9	-16.	1.
95th	30.8	12.4	-20.	0.

Driver - Sub.	X2Z	Y2Z	θ_T	θ_H
5th	27.3	13.4	-12.	3.
50th	28.0	12.9	-16.	1.
95th	29.7	12.4	-20.	0.

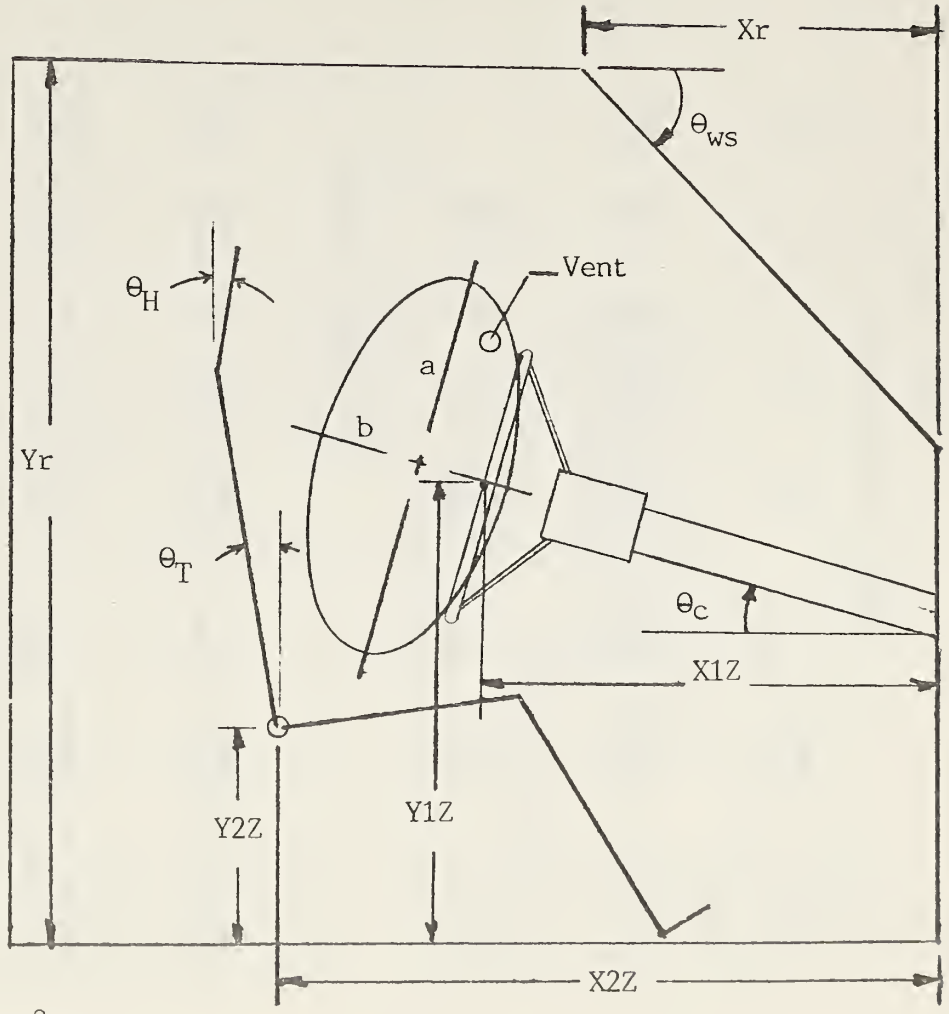


Table 2.

SENSING TIMES USED FOR COMPUTER INPUT

Full Size Car

Frontal

Delta V - Mph:	30	35	40	45	50
Sensing Time - Msec:	19	17	15	12	10

Offset

Delta V - Mph:	30	35	40	45	50
Sensing Time - Msec:	23	21	19	16	13

30 Degree Oblique

Delta V - Mph:	30	35	40	45
Sensing Time - Msec:	25	23	21	18

Compact Size Car

Frontal

Delta V - Mph:	30	35	40	45	50
Sensing Time - Msec:	16.5	15	13	10	8

Offset

Delta V - Mph:	30	35	40	45	50
Sensing Time - Msec:	21	19	17	14	11

30 Degree Oblique

Delta V - Mph:	30	35	40	45	50
Sensing Time - Msec:	22	20.5	18.5	15.5	12.5

Subcompact Size Car

Frontal

Delta V - Mph:	25	30	35	40	45
Sensing Time - Msec:	15	14	13	11	8

Offset

Delta V - Mph:	30	35	40	45	50
Sensing Time - Msec:	19	17	15	12	9

30 Degree Oblique

Delta V - Mph:	25	30	35	40	45	50
Sensing Time - Msec:	20	19	18	16	13	10

Table 3.

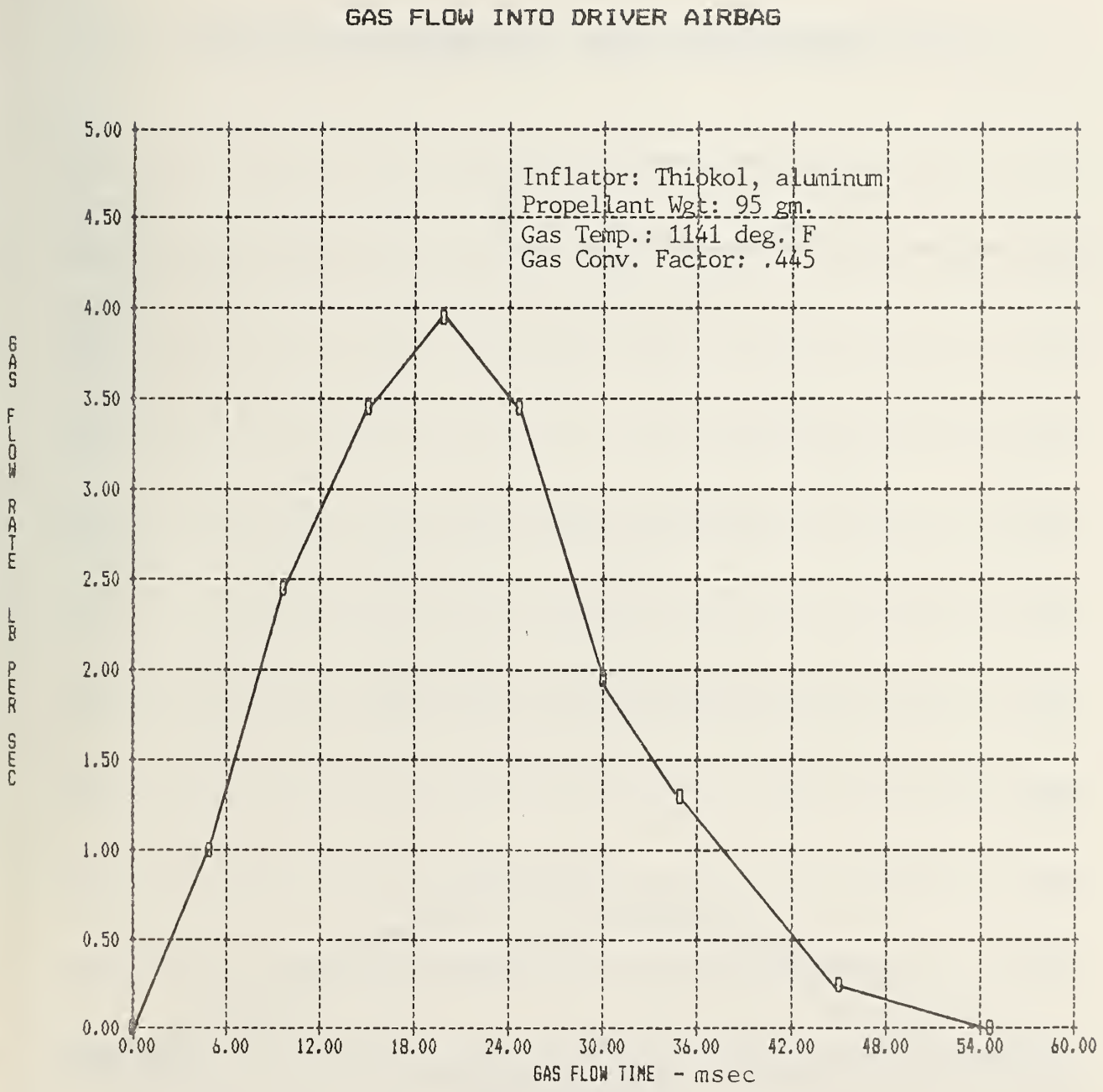

GAS FLOW INTO DRIVER AIRBAG
Inflator: Thiokol, aluminum
Propellant Wgt: 95 gm.
Gas Temp.: 1141 deg. F
Gas Conv. Factor: .445
GAS FLOW RATE LB PER SEC
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
6.00
12.00
18.00
24.00
30.00
36.00
42.00
48.00
54.00
60.00
GAS FLOW TIME - msec

Figure 2.

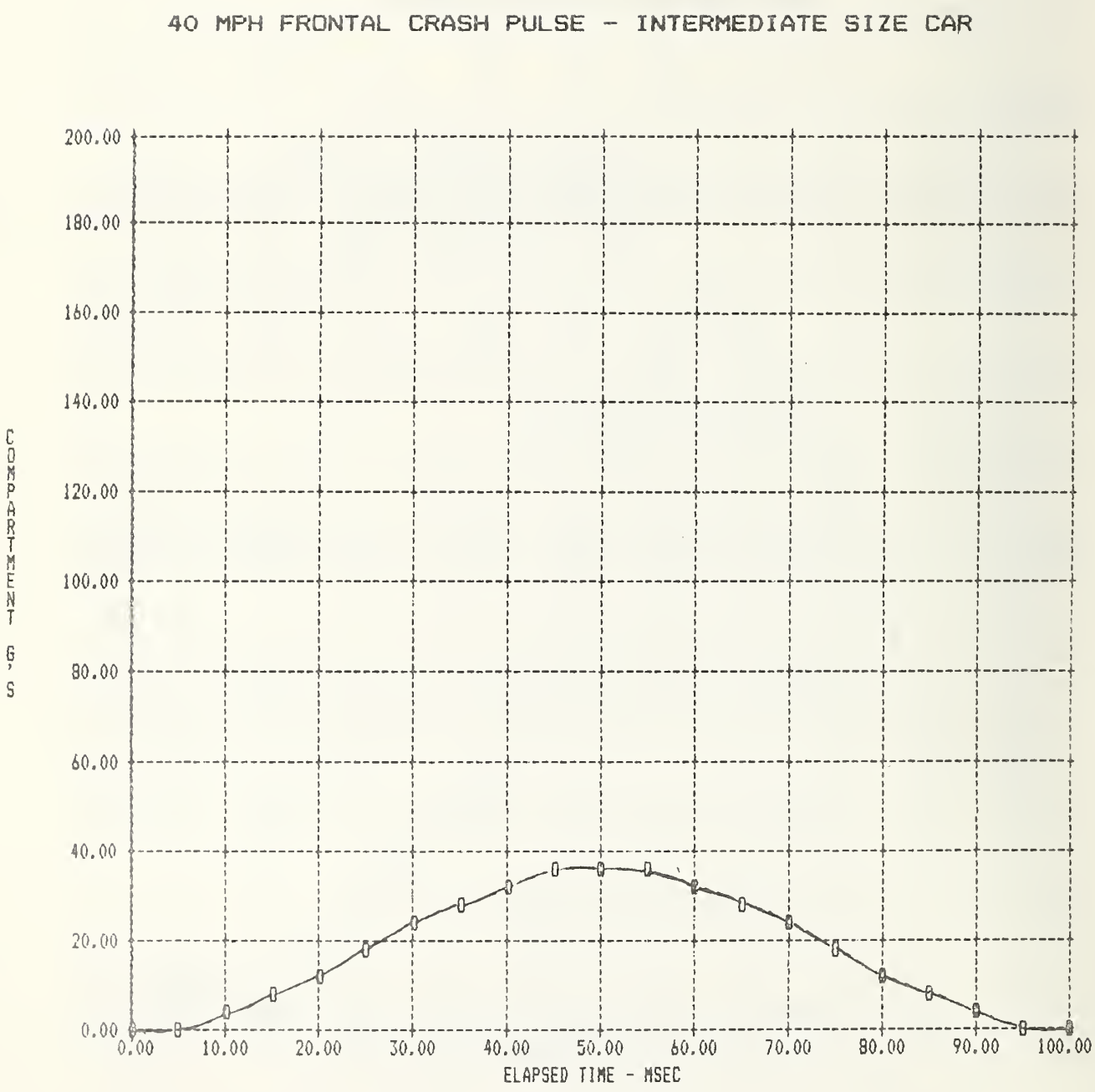


Figure 3. - Sample Crash Pulse - Frontal

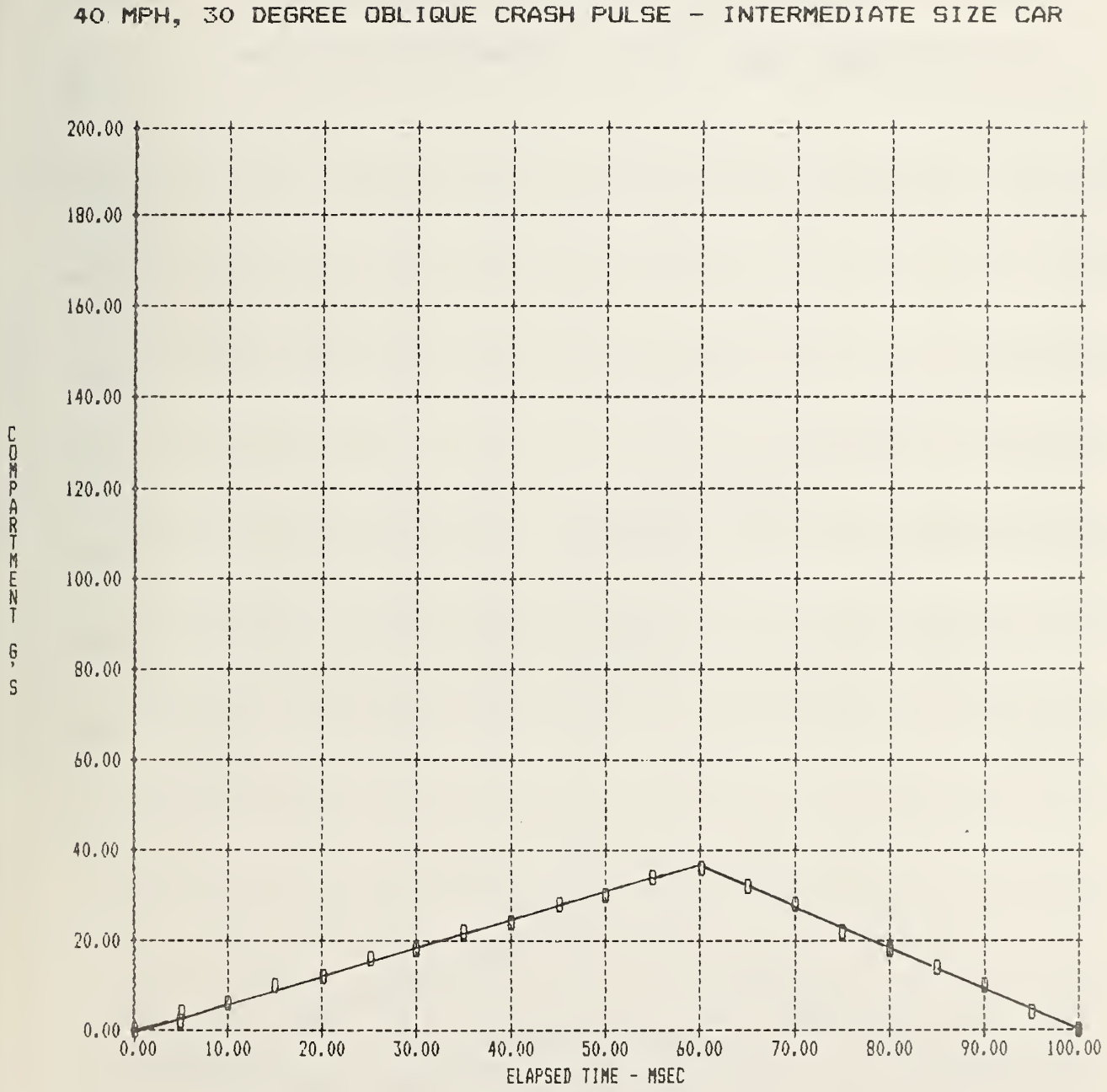


Figure 4. - Sample Crash Pulse - 30 Degree Oblique

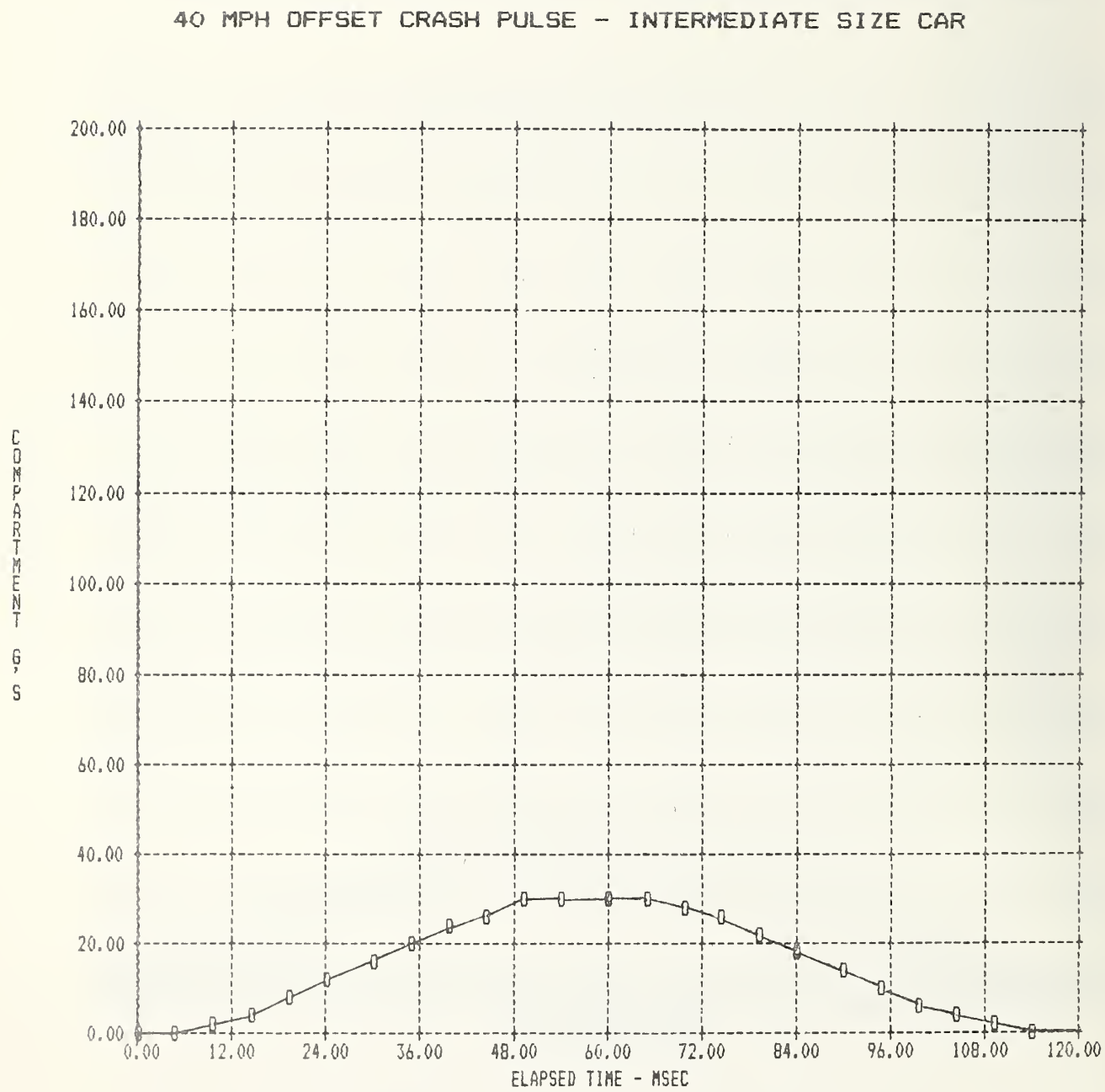


Figure 5 - Sample Crash Pulse - One-half Offset

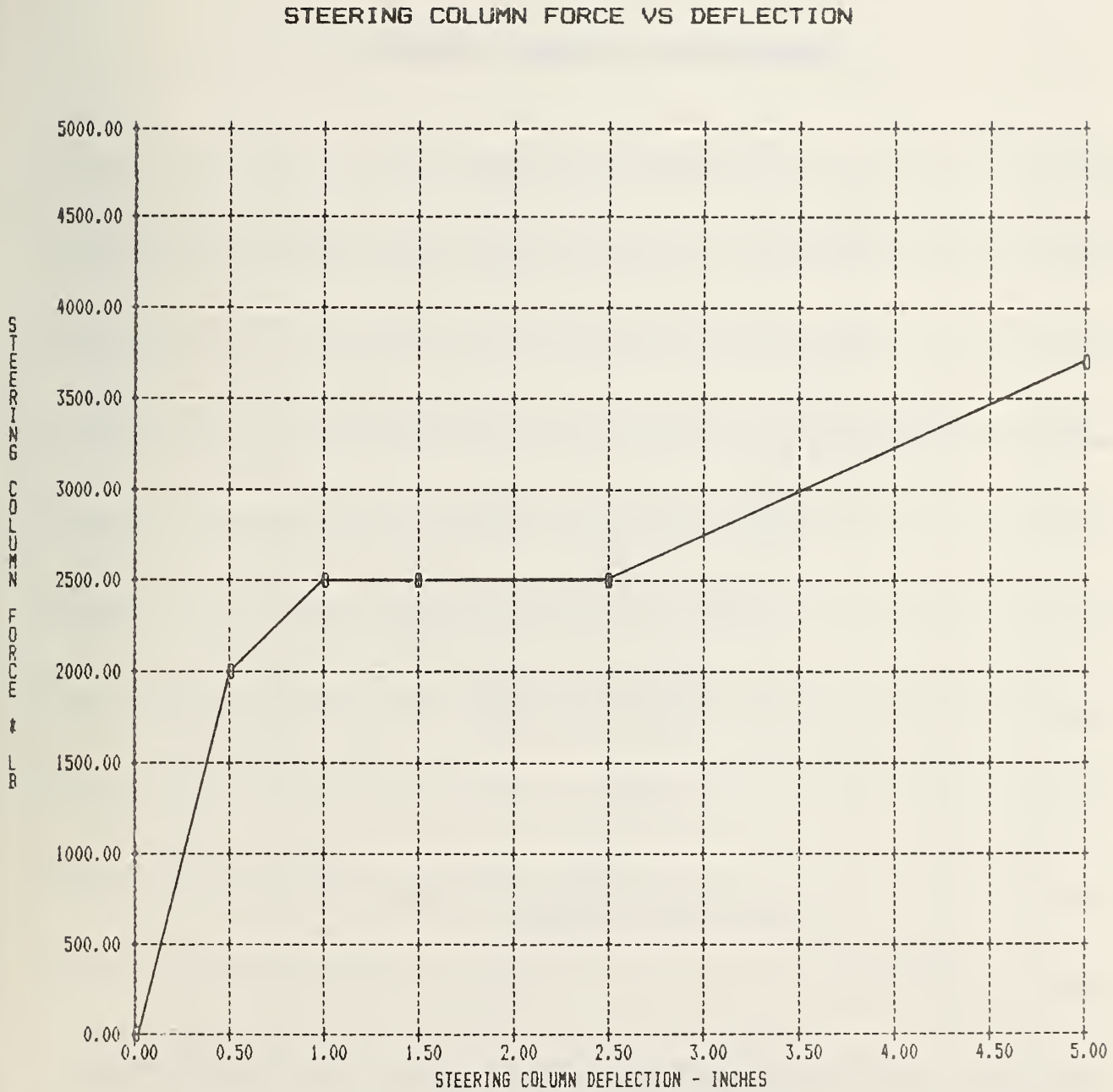

STEERING COLUMN FORCE VS DEFLECTION
STEERING COLUMN FORCE - LB
5000.00
4500.00
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
STEERING COLUMN DEFLECTION - INCHES

Figure 6.

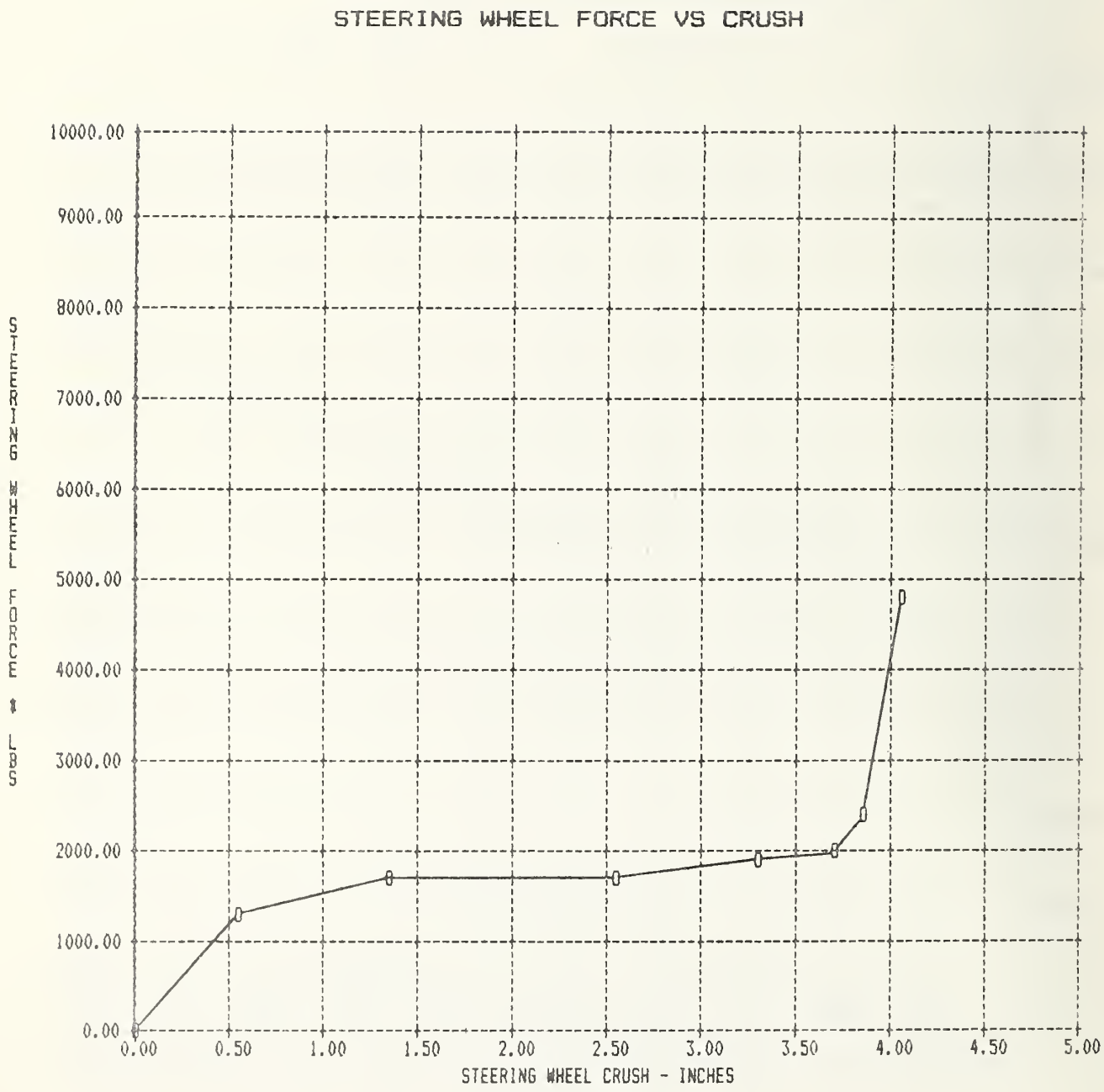

STEERING WHEEL FORCE VS CRUSH
STEERING WHEEL FORCE - LBS
10000.00
9000.00
8000.00
7000.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
STEERING WHEEL CRUSH - INCHES

Figure 7.

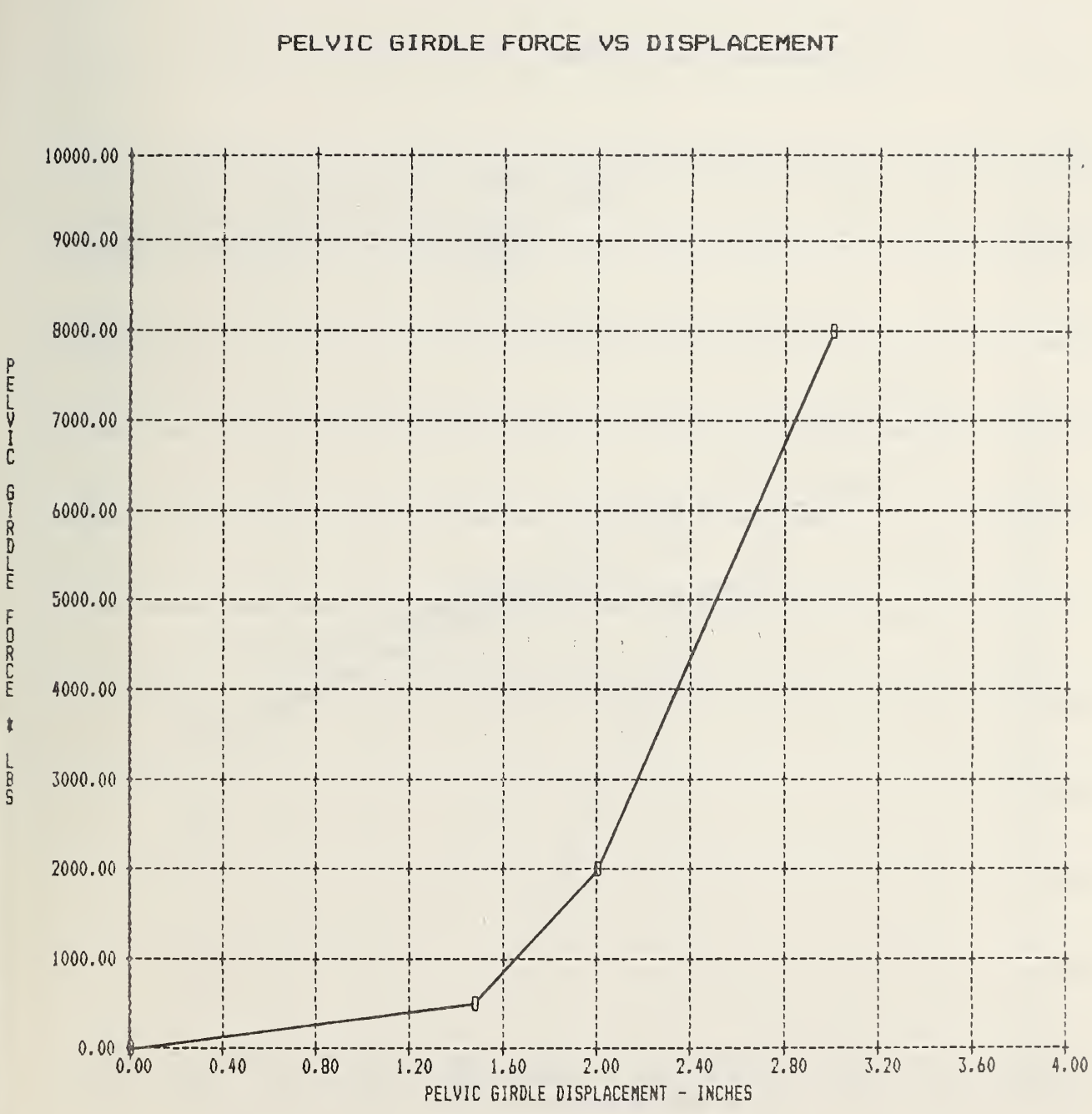

PELVIC GIRDLE FORCE VS DISPLACEMENT
PELVIC GIRDLE FORCE * LBS
10000.00
9000.00
8000.00
7000.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
0.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80
3.20
3.60
4.00
PELVIC GIRDLE DISPLACEMENT - INCHES

Figure 8.

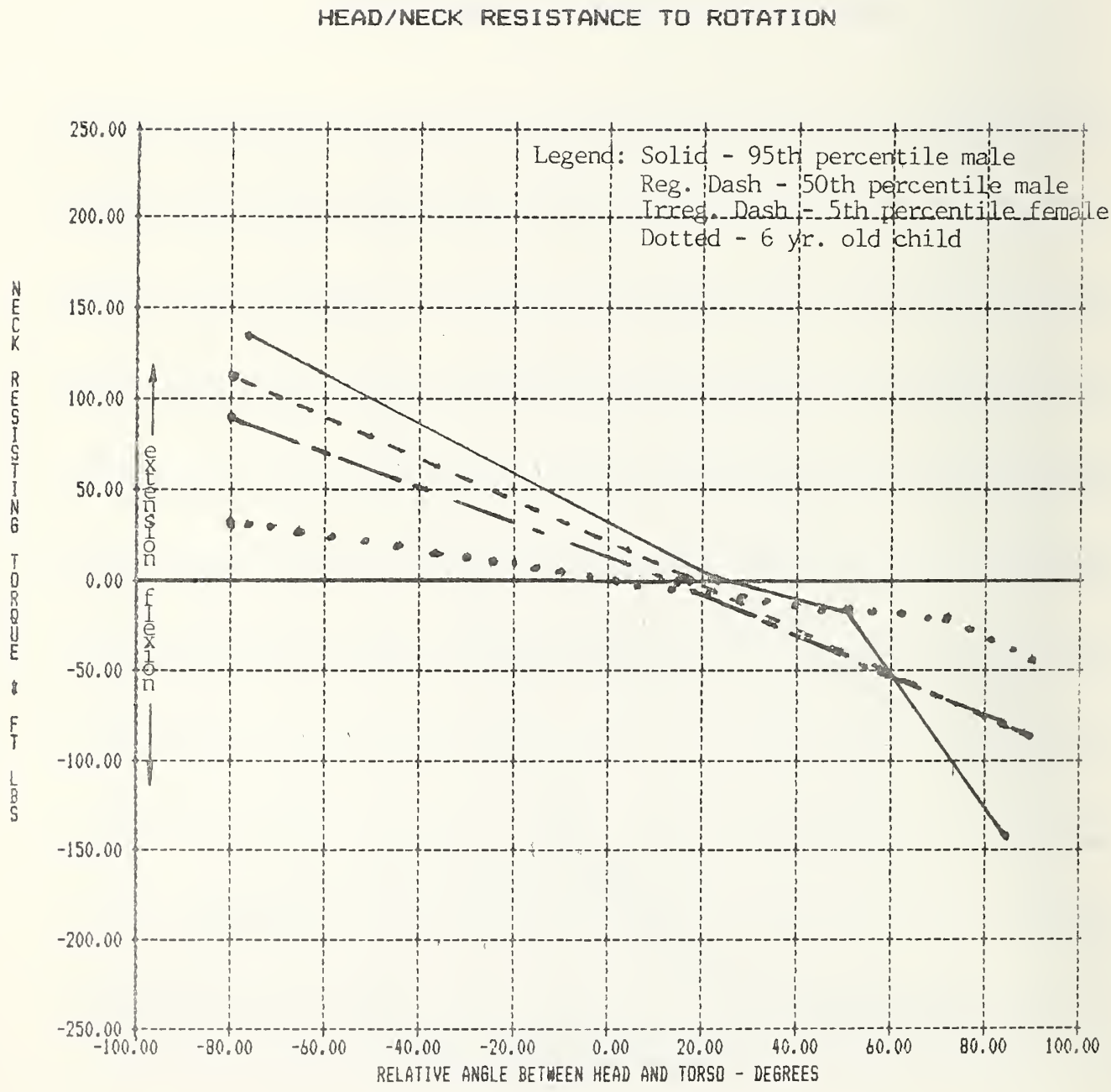

HEAD/NECK RESISTANCE TO ROTATION
Legend: Solid - 95th percentile male
Reg. Dash - 50th percentile male
Irreg. Dash - 5th percentile female
Dotted - 6 yr. old child
NECK RESISTING TORQUE # FT LBS
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
extension
flexion
-100.00
-80.00
-60.00
-40.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
RELATIVE ANGLE BETWEEN HEAD AND TORSO - DEGREES

Figure 9.

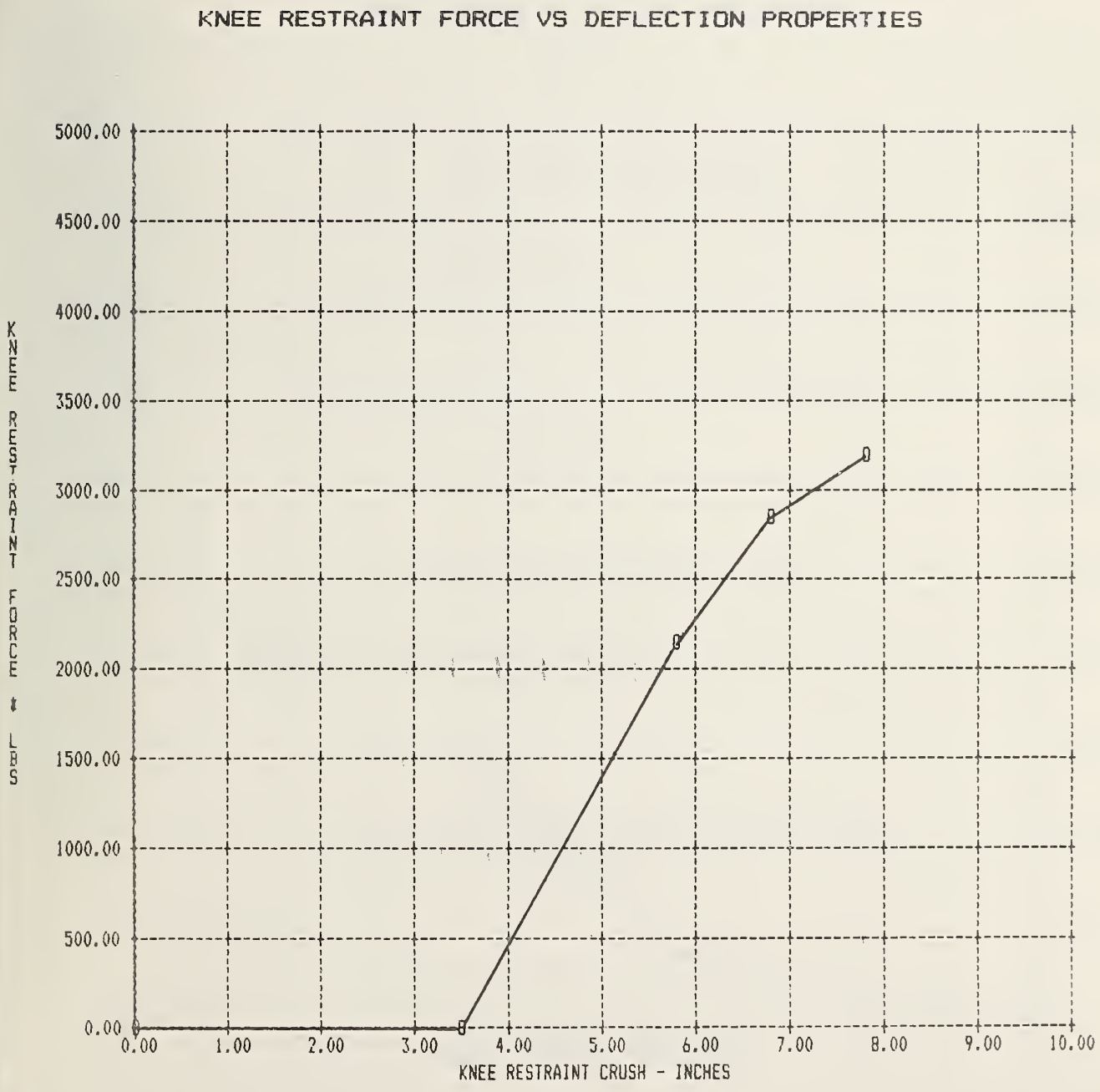

KNEE RESTRAINT FORCE VS DEFLECTION PROPERTIES
5000.00
4500.00
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
KNEE RESTRAINT FORCE - LBS
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
KNEE RESTRAINT CRUSH - INCHES

Figure 10.

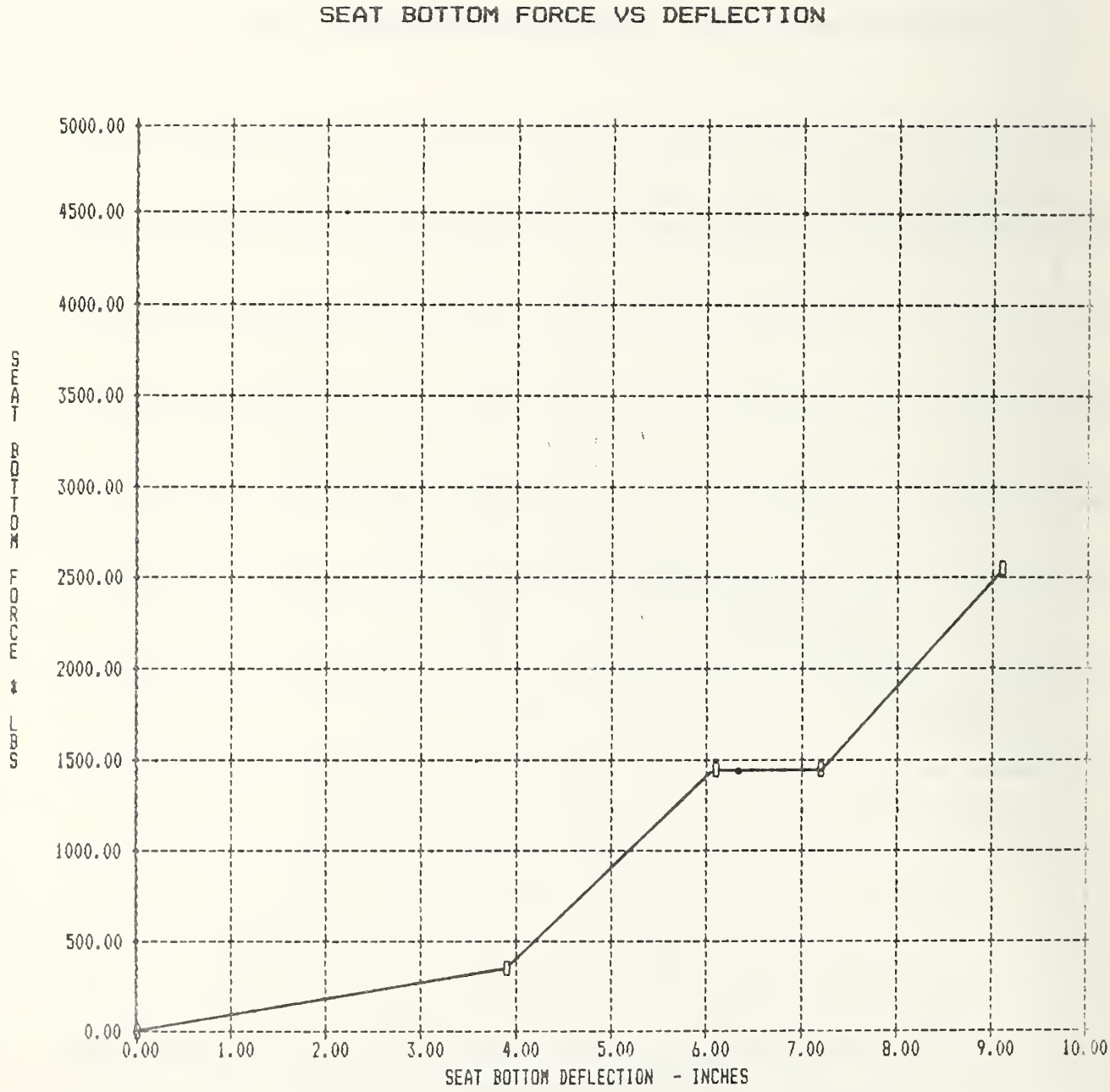

SEAT BOTTOM FORCE VS DEFLECTION
SEAT BOTTOM FORCE - LBS
5000.00
4500.00
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
SEAT BOTTOM DEFLECTION - INCHES

Figure 11.

SAMPLE BDRACR INPUT FILE

INTERMEDIATE CAR, 40 MPH FRONTAL IMPACT, 50TH PERCENTILE MALE DRIVER

```
40.,1.,-16.
71.04,62.9,12.54,14.0,20.5,4.53,29.75
7.0,6.3,9.5,16.3,5.75,6.,14.5,4.5,6.75,6.,13.
3,5,25,3,12,7,9,5,5,3,3,3,3,5
6,6,2500.,1827.,1050.,1930.
0.,13.,18.,23.,28.,33.,38.,43.,48.,58.,68.,120.
0.,0.,.99,2.47,3.45,3.94,3.45,1.97,1.28,.25,0.,0.
-10.,0.,0.5,1.0,1.5,2.5,5.
0.,0.,2000.,2500.,2500.,2500.,3700.
14.7,-14.7,1601.,662.,1.4,1.4,1.4,0.0
23.3,2.5,5.72,4.5,18.7,3.25,0.3,360.
0.20,0.3,68.,37.,5.,1200.
20.38,42.5,32.,25.75
0.7,0.7,1.38,12.0,6.5,21.63,25.25
23.3,0.,4.3,14.6,8.9,12.6,7.4,
14.3,8.,55.7,.125,.001,.005,.005,.01
2.5,7.50,29.00,12.88,17.9,6.1,0.5,0.5
-10.,0.0,4.76
0.,0.,2500.
-10.,0.0,2.59
0.,0.,2500.
-10.,0.,1.5,2.,3.
0.,0.,500.,2000.,8000.
-10.,0.,.2,.4,.6,.8
0.,0.,30.,72.,175.,350.
-10.,0.,1.
70.6,70.6,70.6
-80.,17.,90.
117.,0.,-87.
0.0,5.0,10.0,15.0,20.0,25.0,30.0,35.0,40.0,45.0,50.0,55.0,60.0,65.0,70.0
,75.0,80.0,85.0,90.0,95.0,100.0,105.0,110.0,115.0,250.0
0.0,0.9,3.5,7.5,12.5,18.1,23.7,28.8,32.8,35.4,36.3,35.4,32.8,28.8,23.7,1
8.1,12.5,7.5,3.5,0.9,0.0,0.0,0.0,0.0,0.0,0.0
-10.,3.5,5.86,6.84,7.8
0.,0.,2140.,2837.,3200
-10.,0.,.59,1.38,2.56,3.35,3.74,3.86,4.09
0.,0.,1278.,1710.,1740.,1893.,2048.,2356.,4820.
-10.,0.,10.,24.,30.
0.,0.,5000.,6000.,10000.
-10.,0.,10.,24.,30.
0.,0.,5000.,6000.,10000.
-10.,0.,10.
0.,0.,4000.
-10.,0.,10.
0.,0.,4000.
-10.,0.,3.93,6.1,7.28,9.13
0.,0.,337.,1461.,1461.,2540.
```

Figure 12.

2.2 Driver Study Results

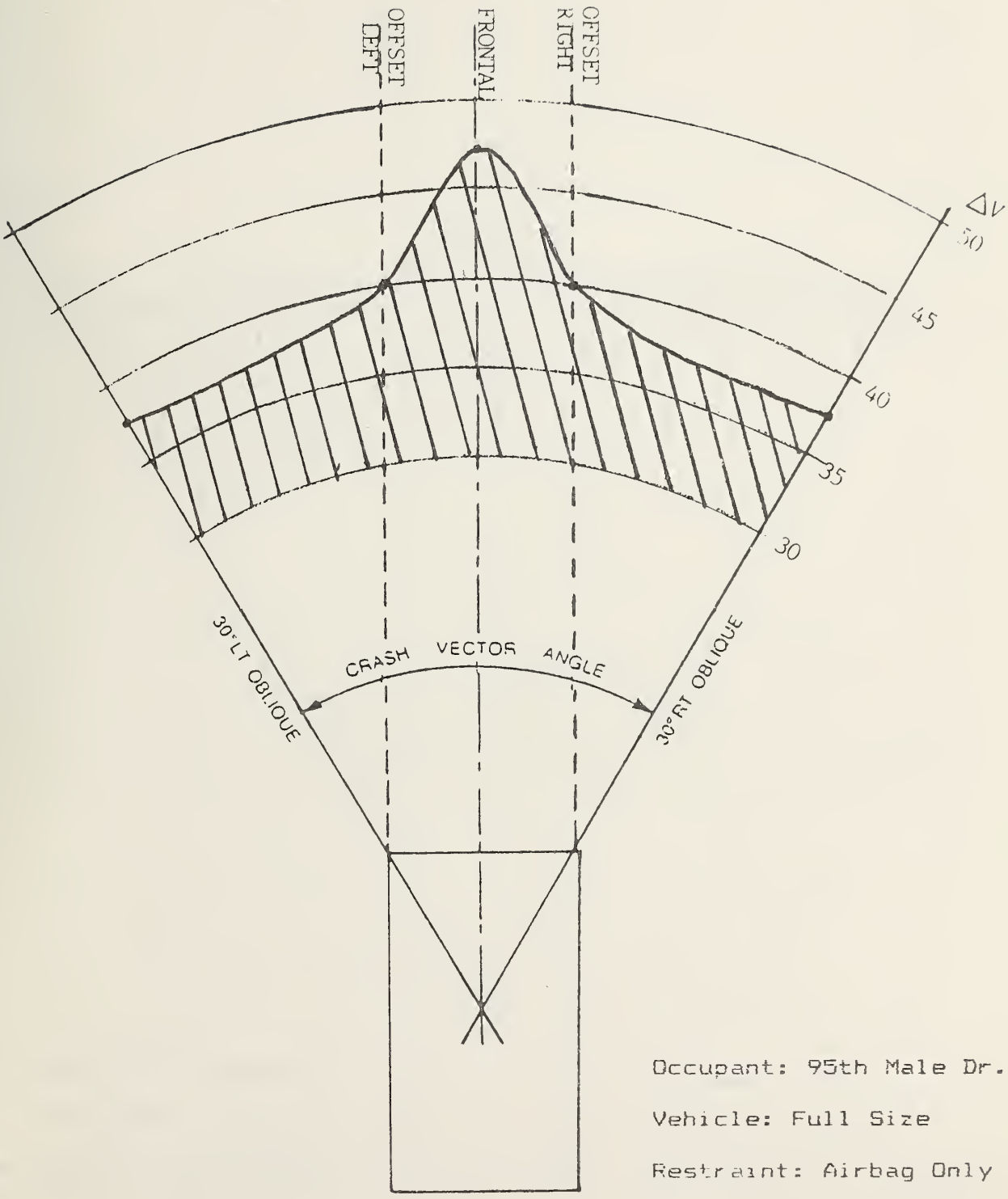
A total of 204 BDRACR computer runs were made in conducting the driver analysis. The results of these runs are shown by the Figures 13 through 30 on the following pages. For each of the three driver sizes studied (5th female, 50th male and 95th male), three separate accident modes were analyzed for two separate restraint conditions (airbag only and three point belt plus airbag). A sufficent number of runs were made at each condition to determine the velocity at which the "Crash Survivability Limit" is reached. As previously described,this velocity limit is reached when any one of the conditions defined in Section 1.2.4 is met or exceeded.

2.3 Conclusions

From the Figures, several things are readily apparent and several conclusions may be drawn. These conclusions are listed below:

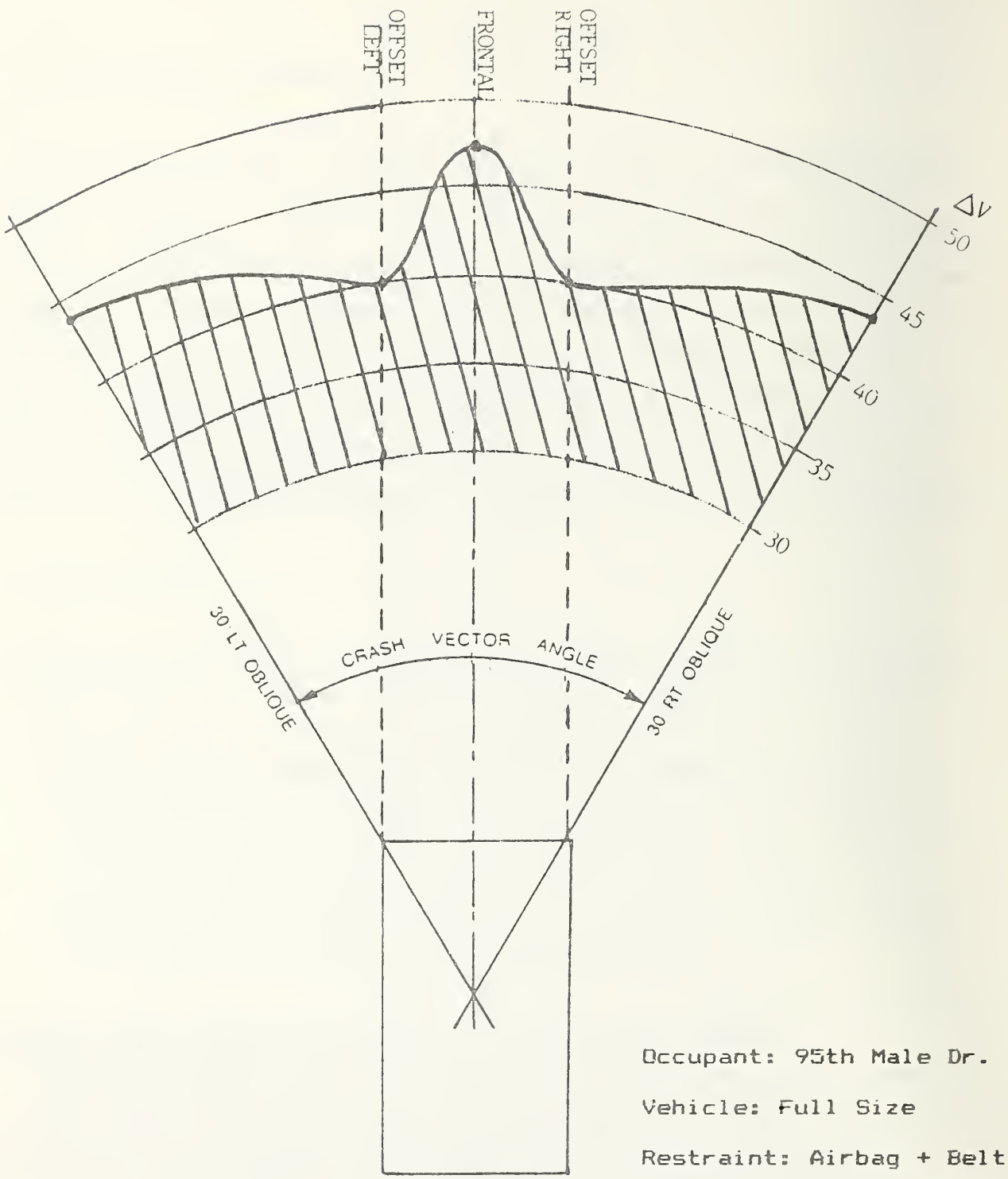
1. As one would intuitively expect, the Crash Survivability Limit generally is highest for the full size car which has a relatively "soft" crash pulse and slightly larger interior dimensions within which to bring the driver to rest, and lowest for the subcompact car which has a relatively "hard" crash pulse and a more confining interior.

2. The 50th percentile male has the greatest overall "Survivability Margin" as measured by the total area under the curves in Figures 25 and 26. The 50th percentile male is then followed by the 95th percentile male and then the 5th percentile female. The 95th percentile male has generally lower overall g-levels than the 50th percentile male; however he is also more prone to striking the windshield,header and



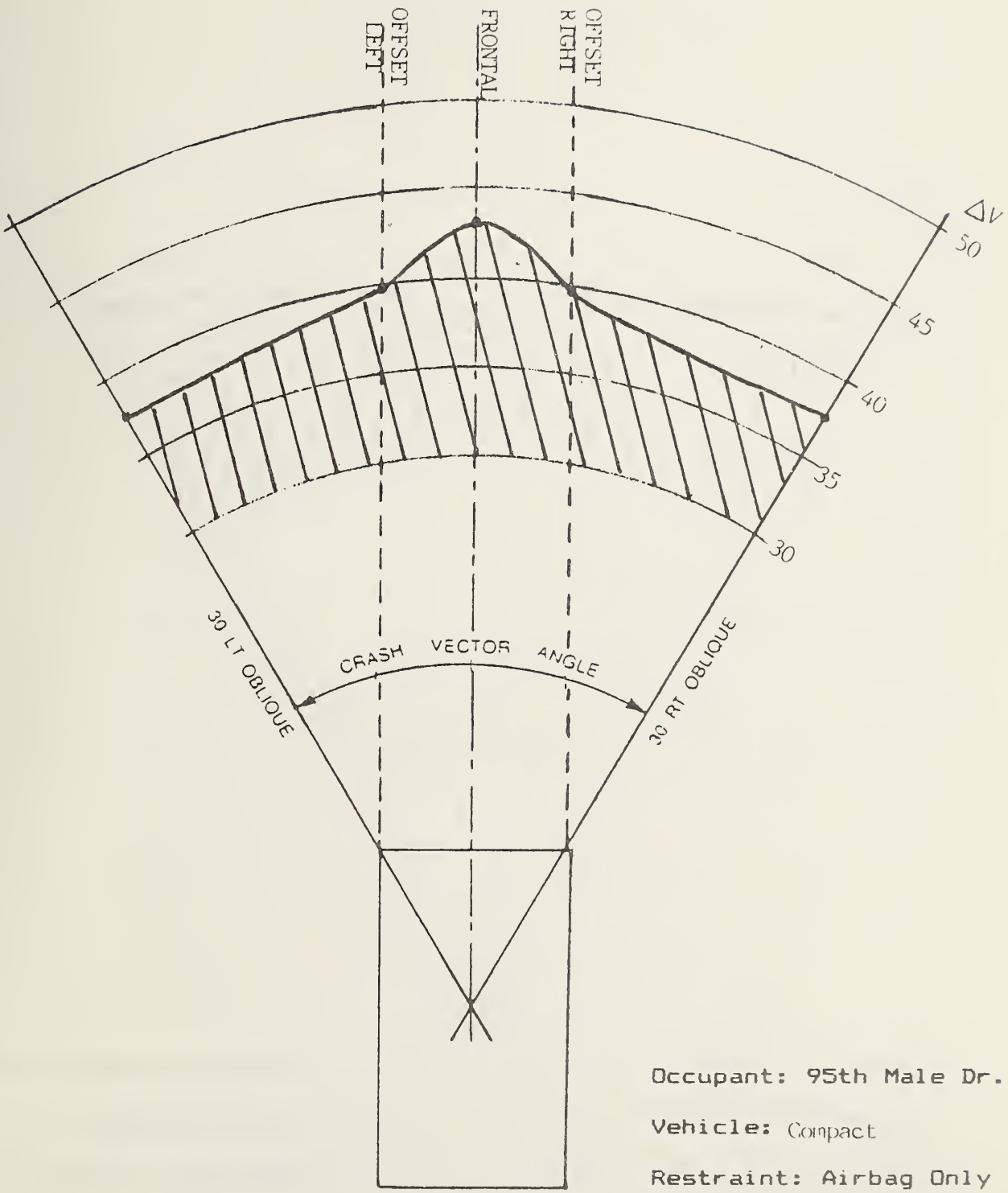
CRASH SURVIVABILITY ENVELOPE

Figure 13.



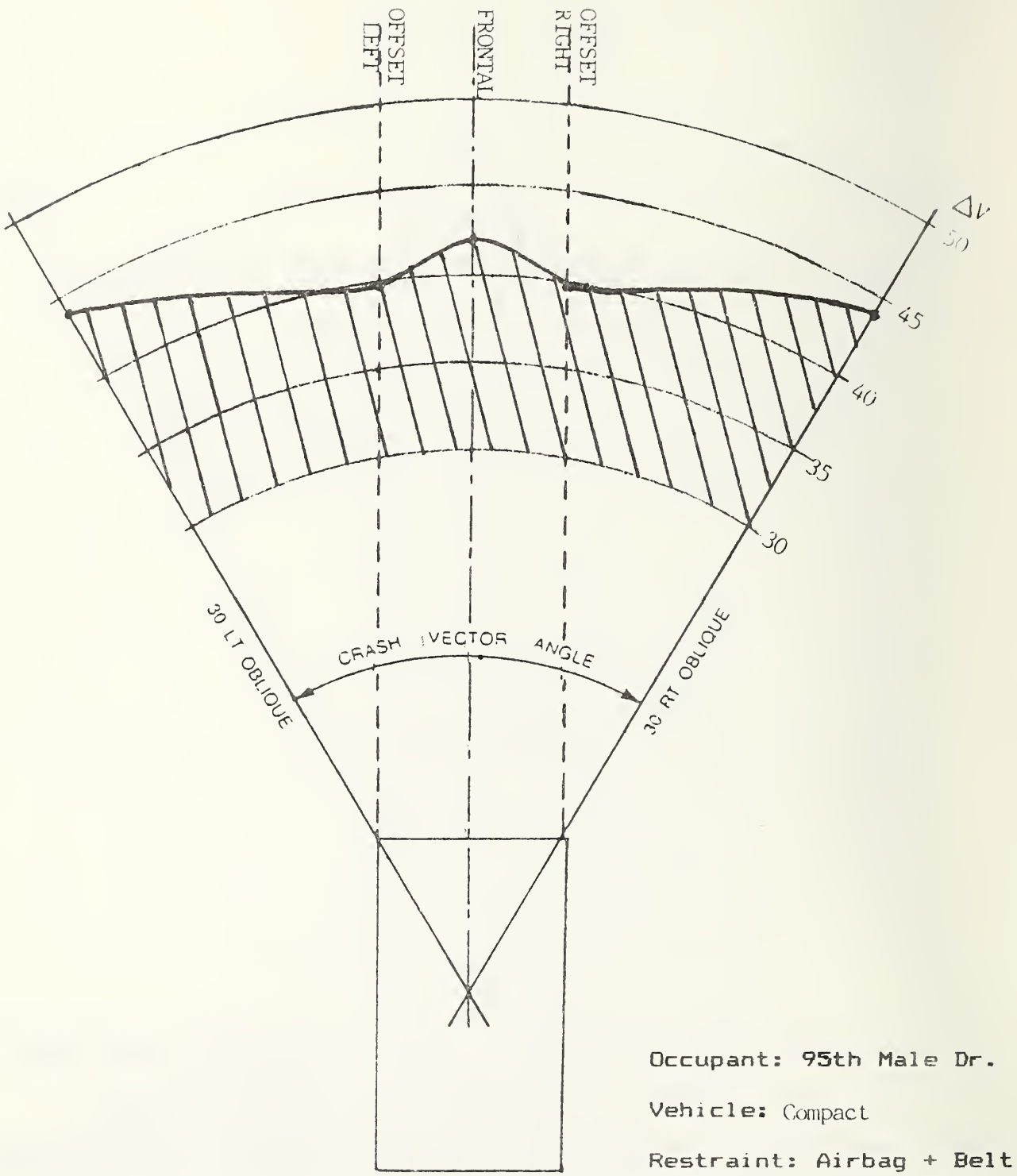
CRASH SURVIVABILITY ENVELOPE

Figure 14.



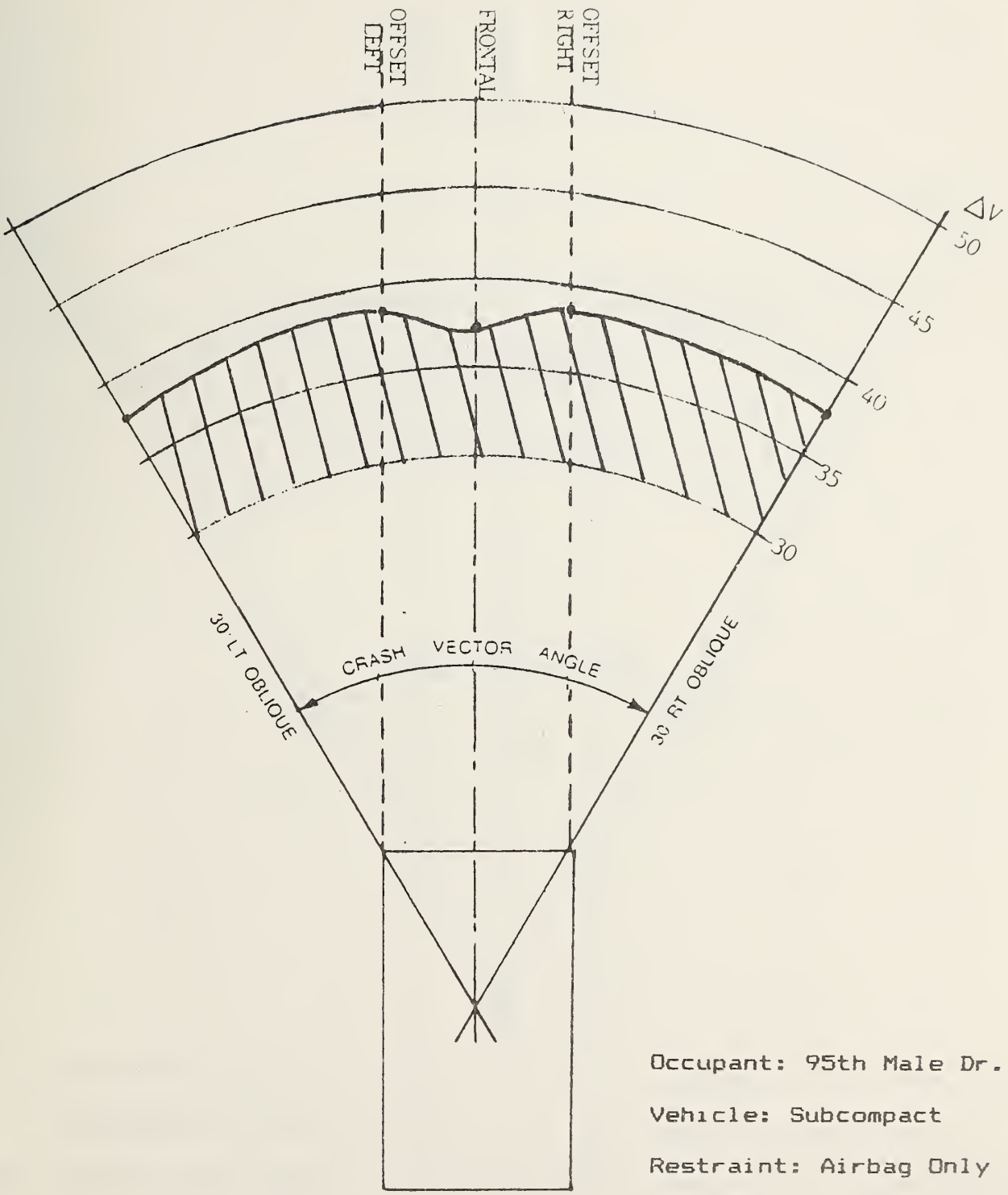
CRASH SURVIVABILITY ENVELOPE

Figure 15.



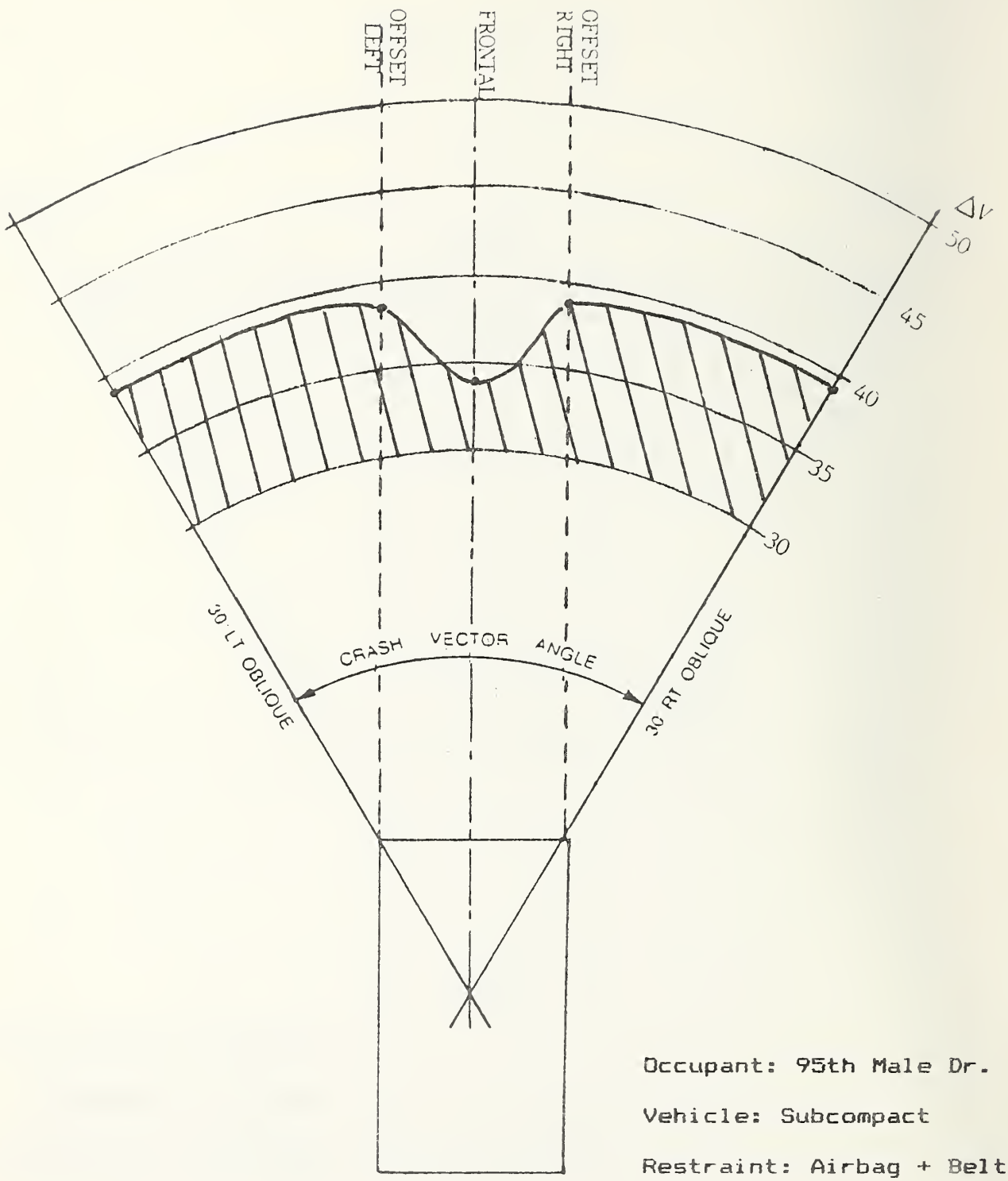
CRASH SURVIVABILITY ENVELOPE

Figure 16.



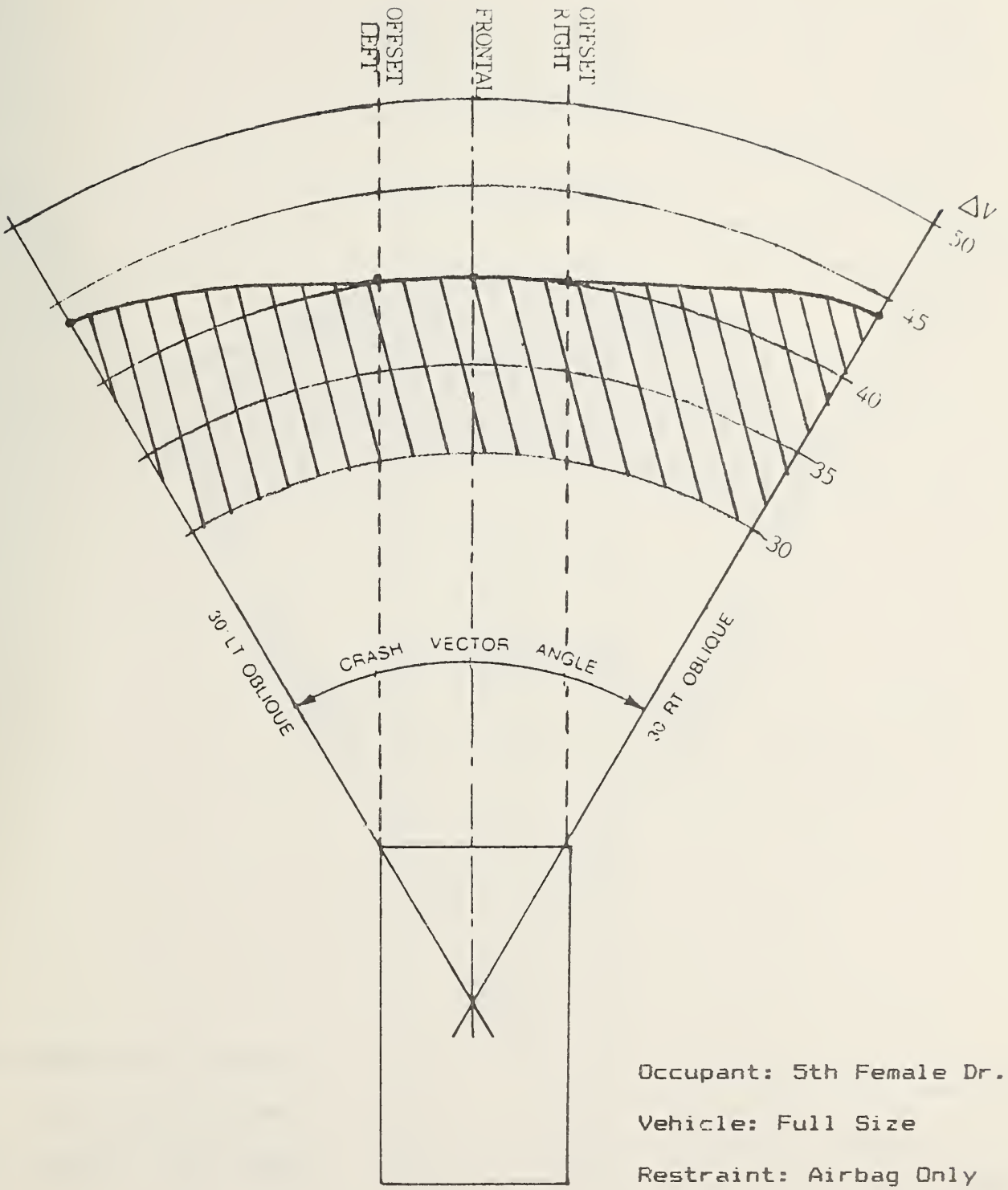
CRASH SURVIVABILITY ENVELOPE

Figure 17.



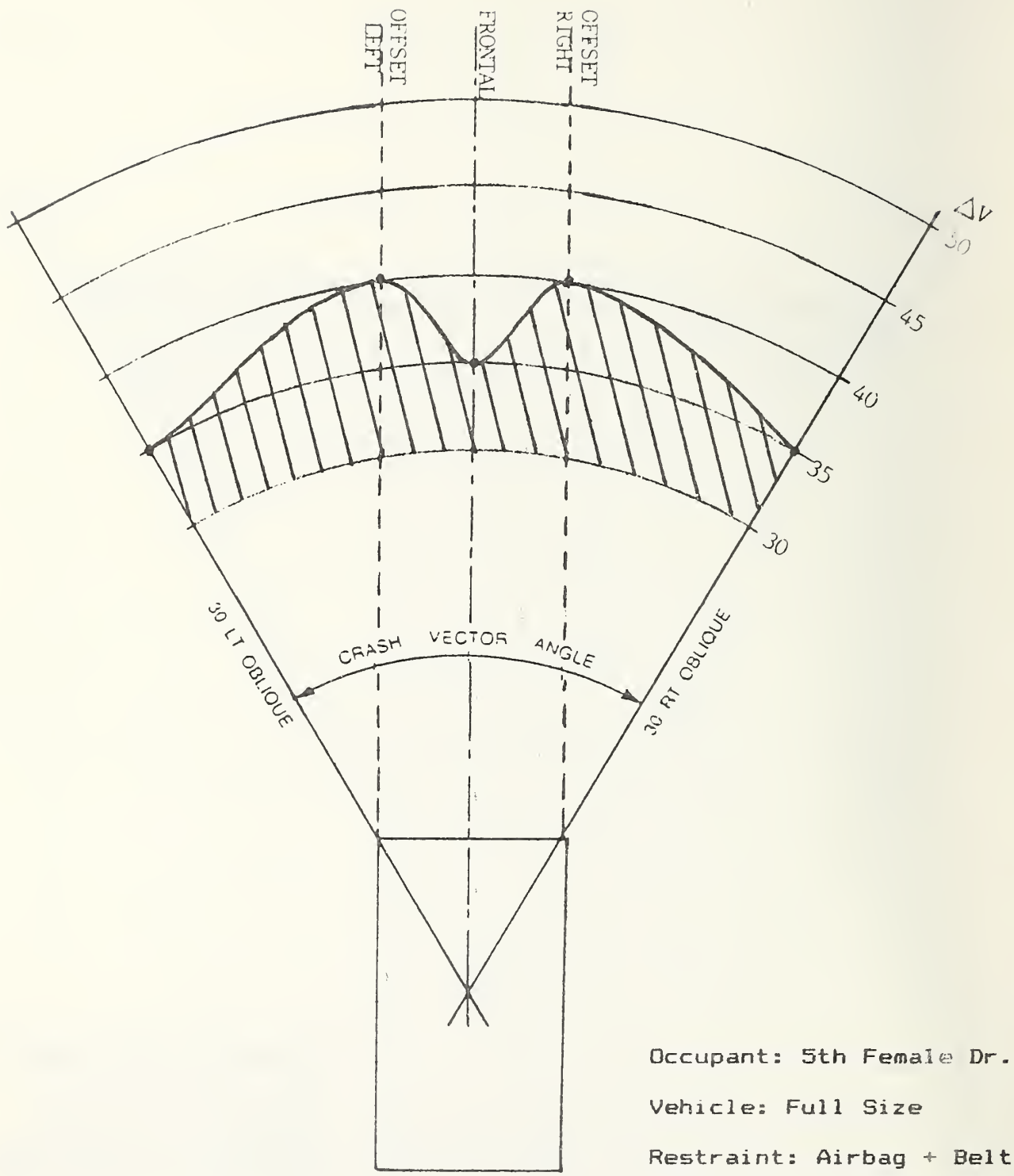
CRASH SURVIVABILITY ENVELOPE

Figure 18.



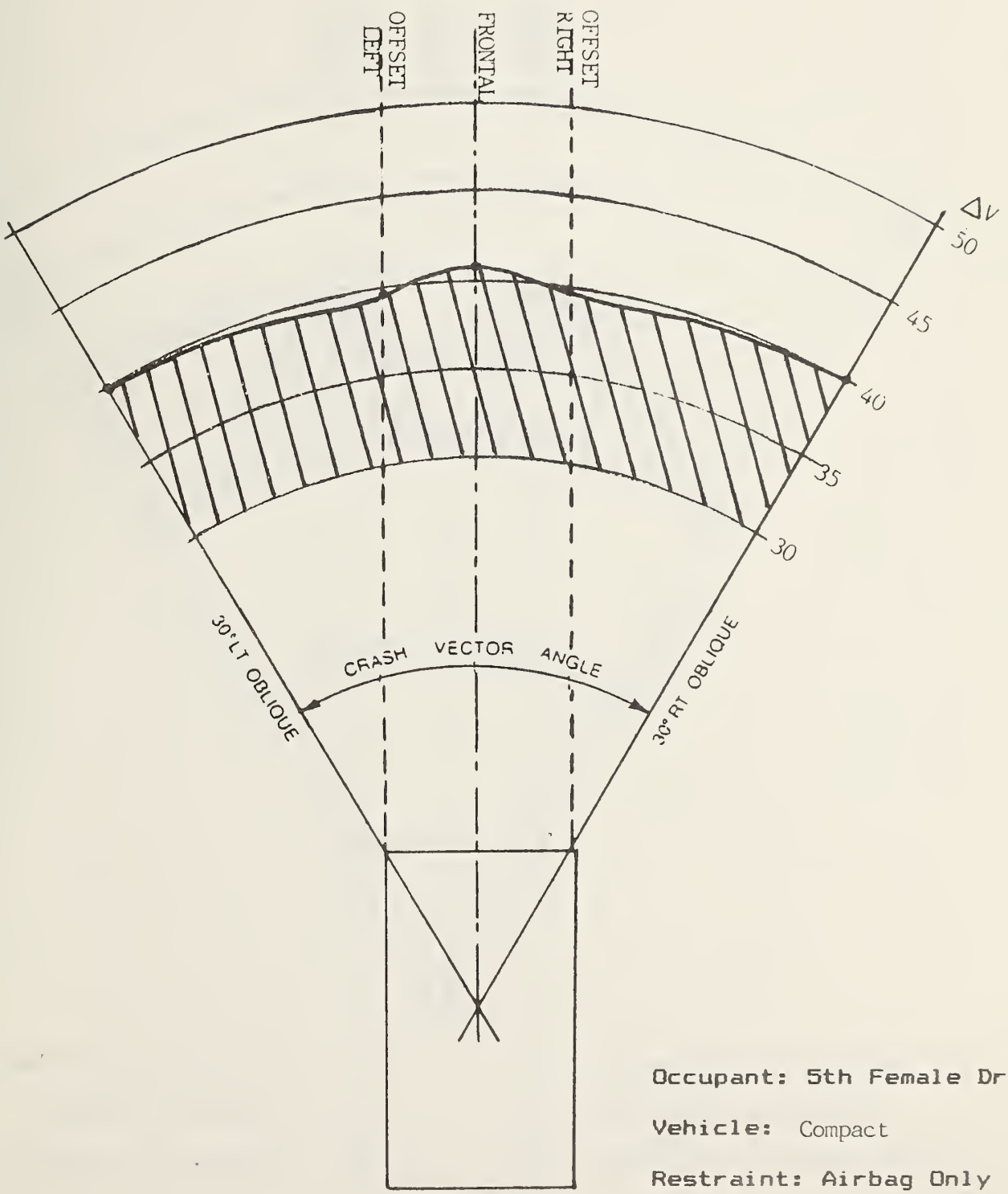
CRASH SURVIVABILITY ENVELOPE

Figure 19.



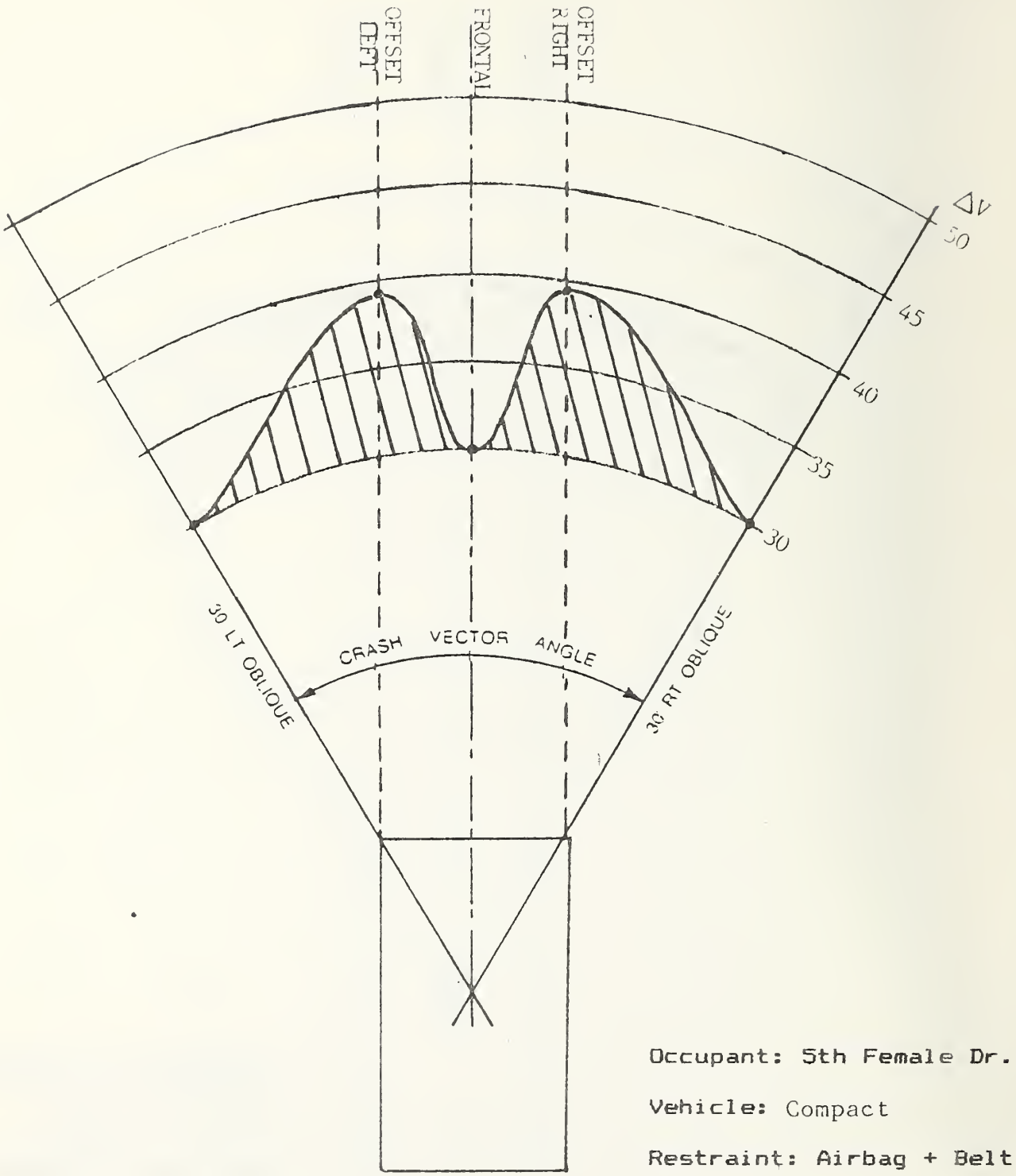
CRASH SURVIVABILITY ENVELOPE

Figure 20.



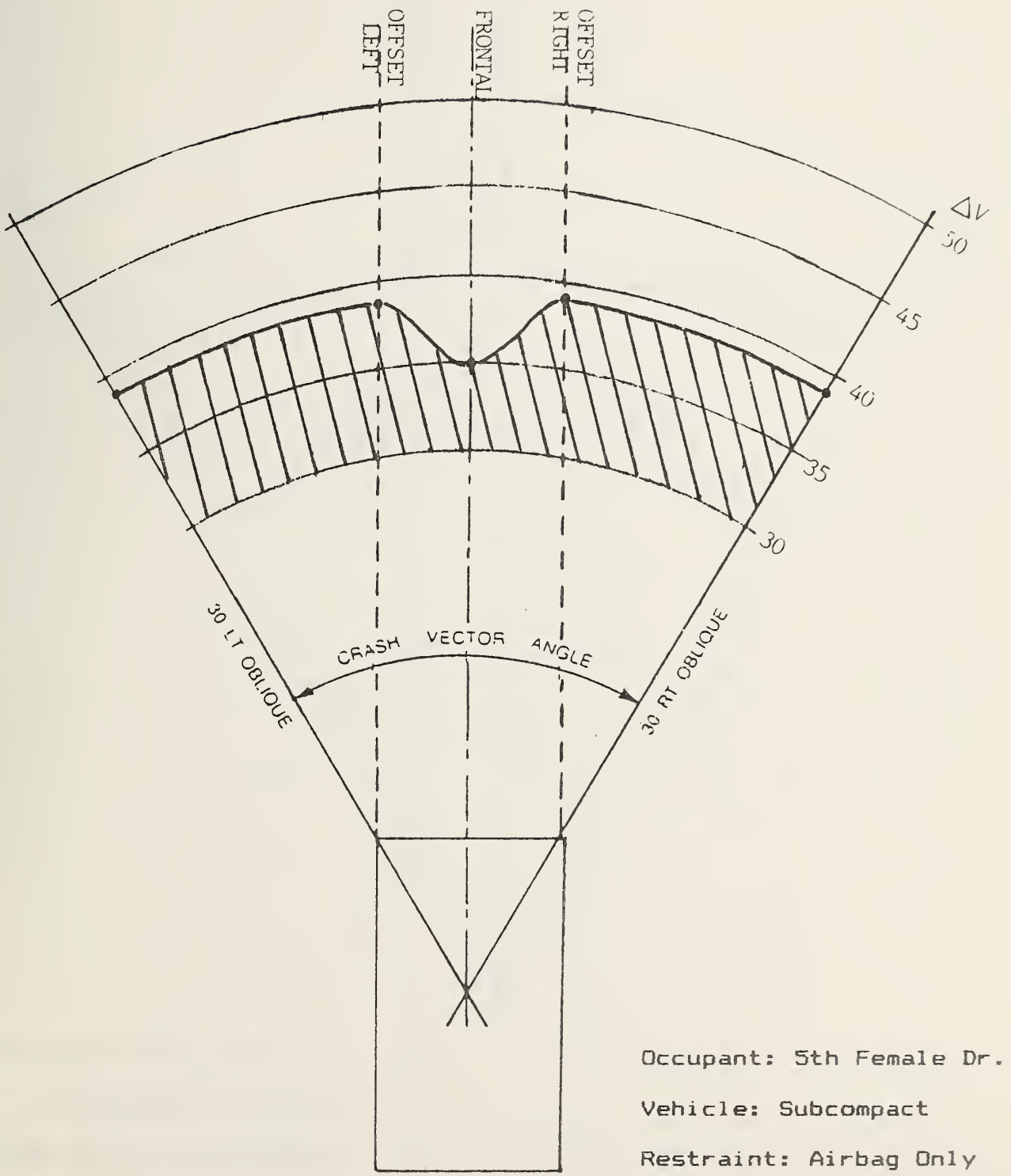
CRASH SURVIVABILITY ENVELOPE

Figure 21.



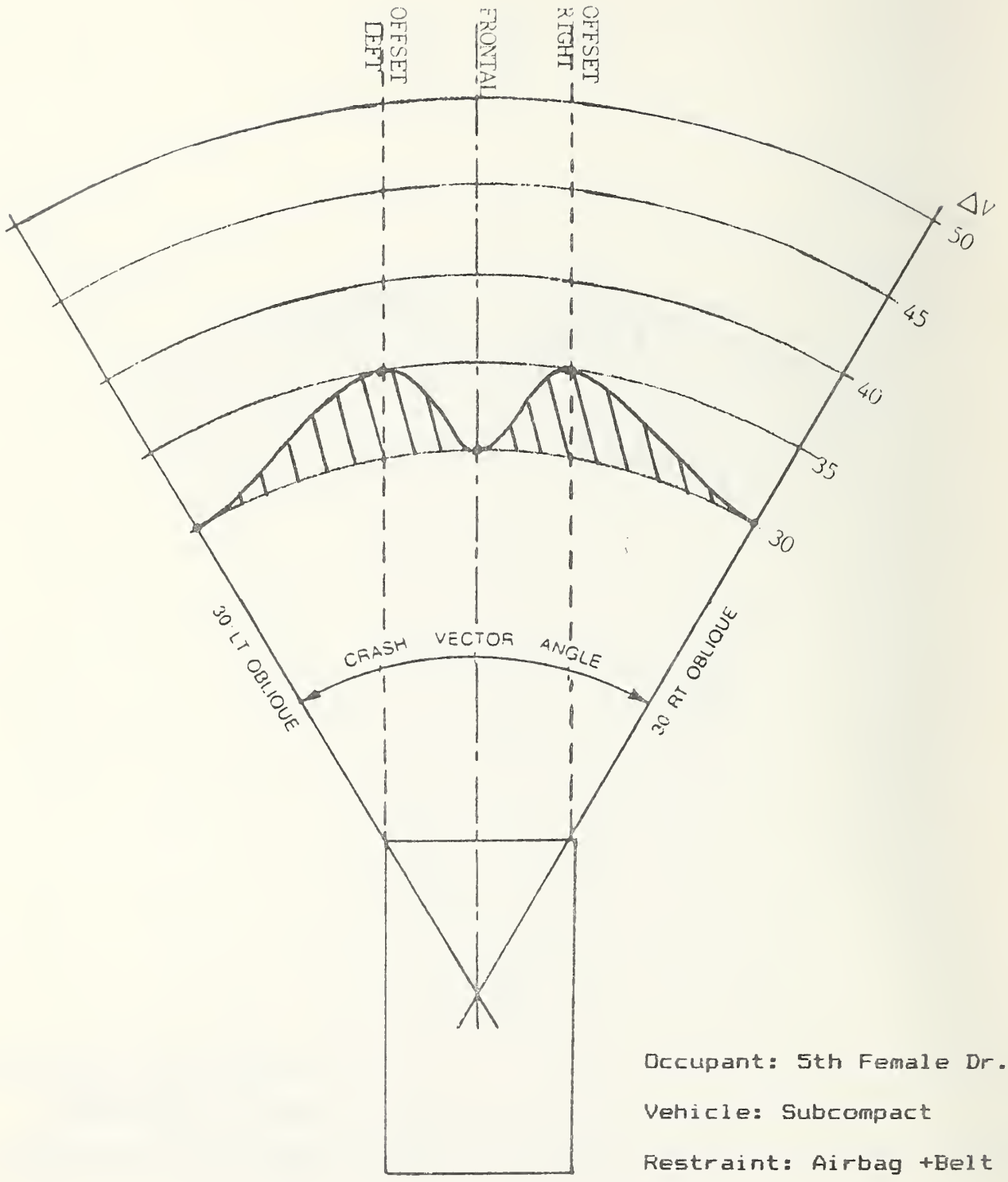
CRASH SURVIVABILITY ENVELOPE

Figure 22.



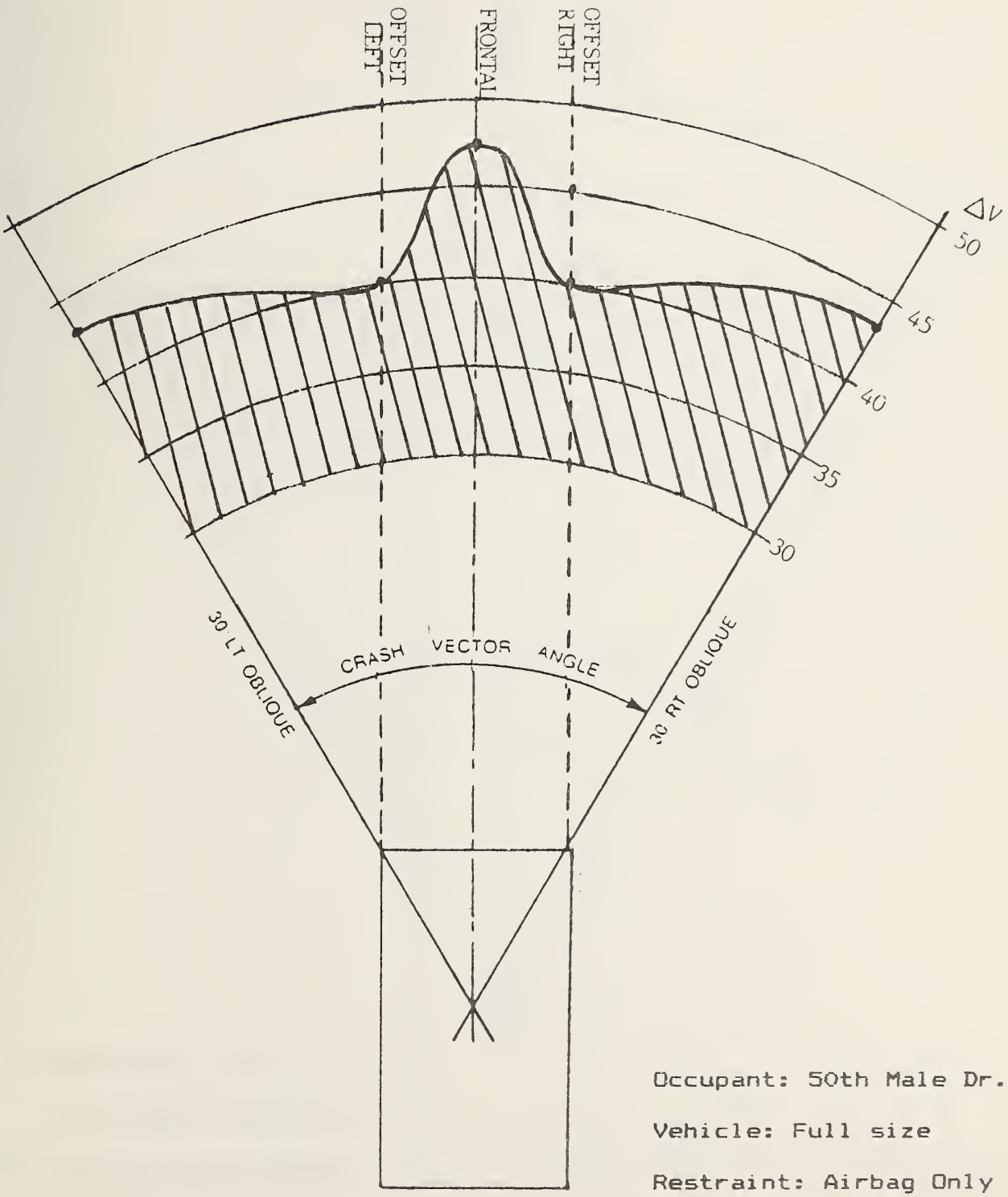
CRASH SURVIVABILITY ENVELOPE

Figure 23.



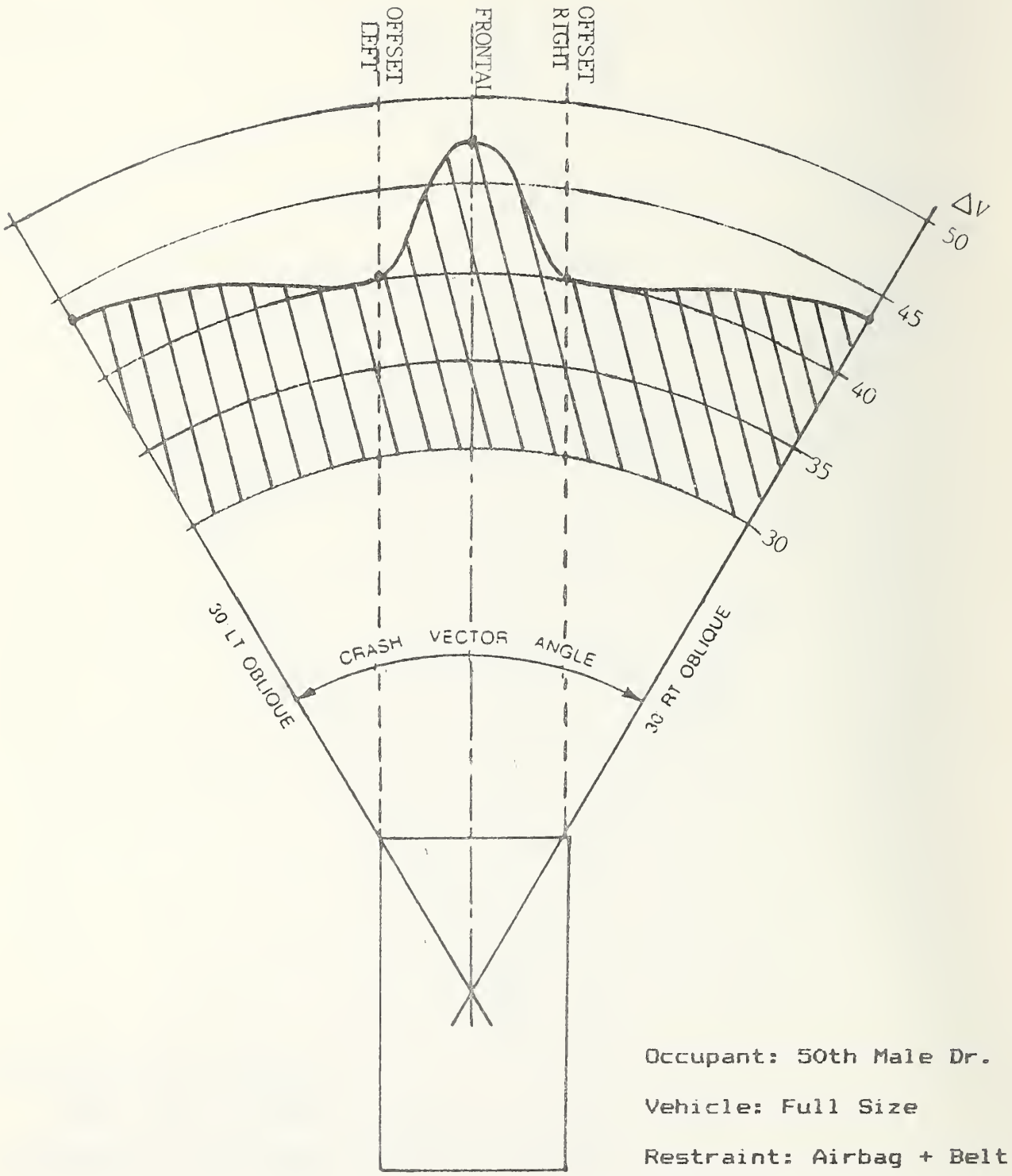
CRASH SURVIVABILITY ENVELOPE

Figure 24.



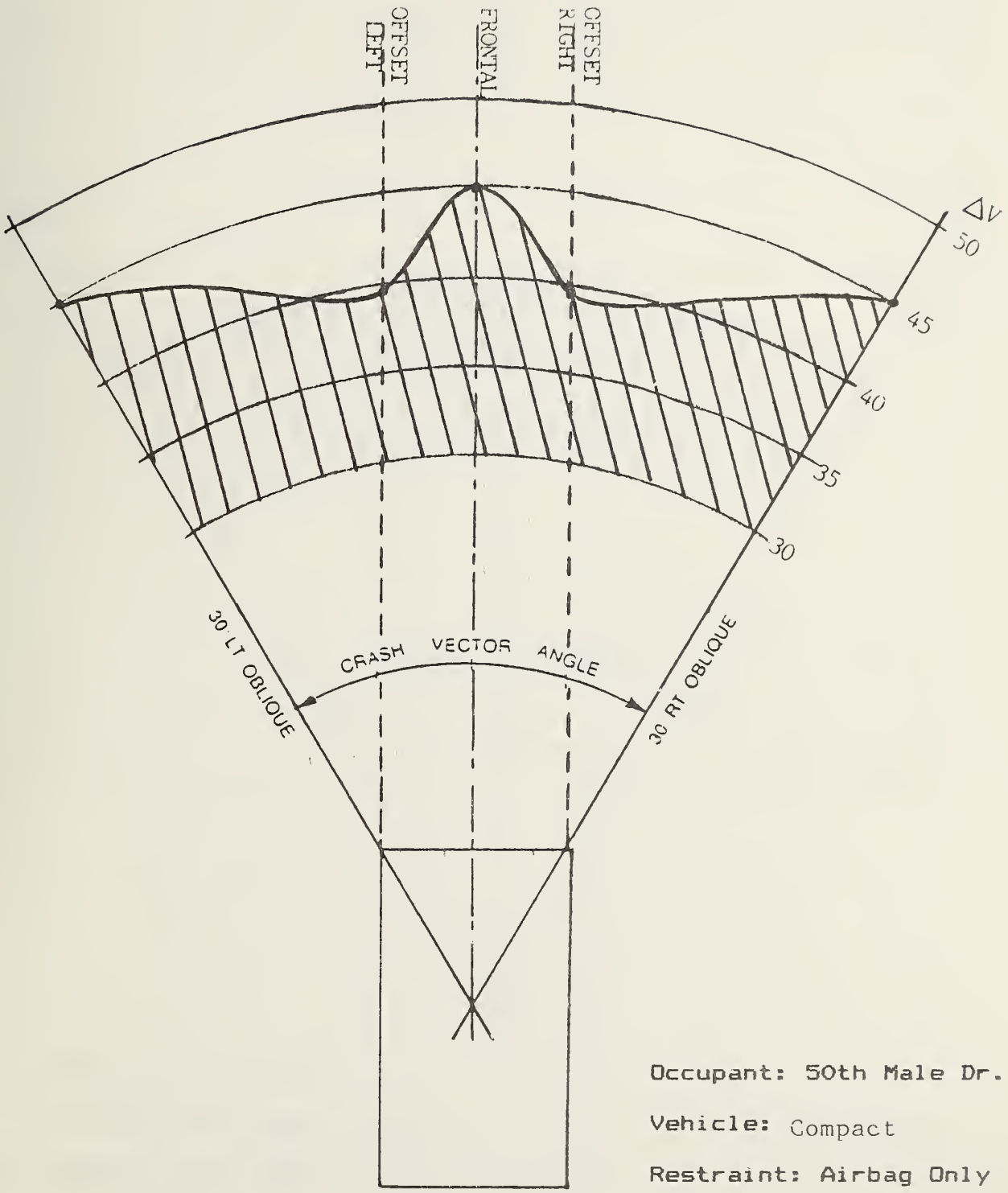
CRASH SURVIVABILITY ENVELOPE

Figure 25.



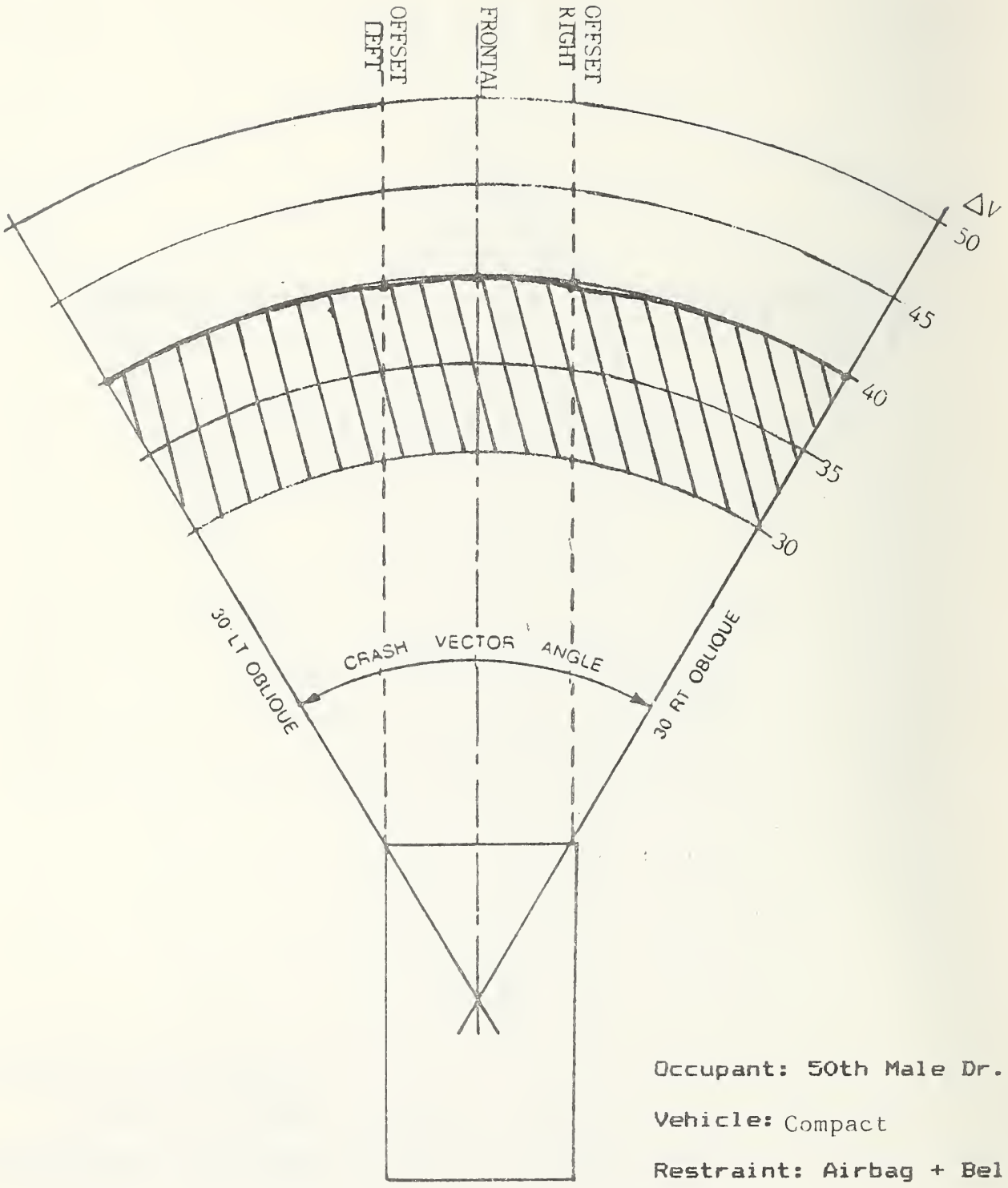
CRASH SURVIVABILITY ENVELOPE

Figure 15.



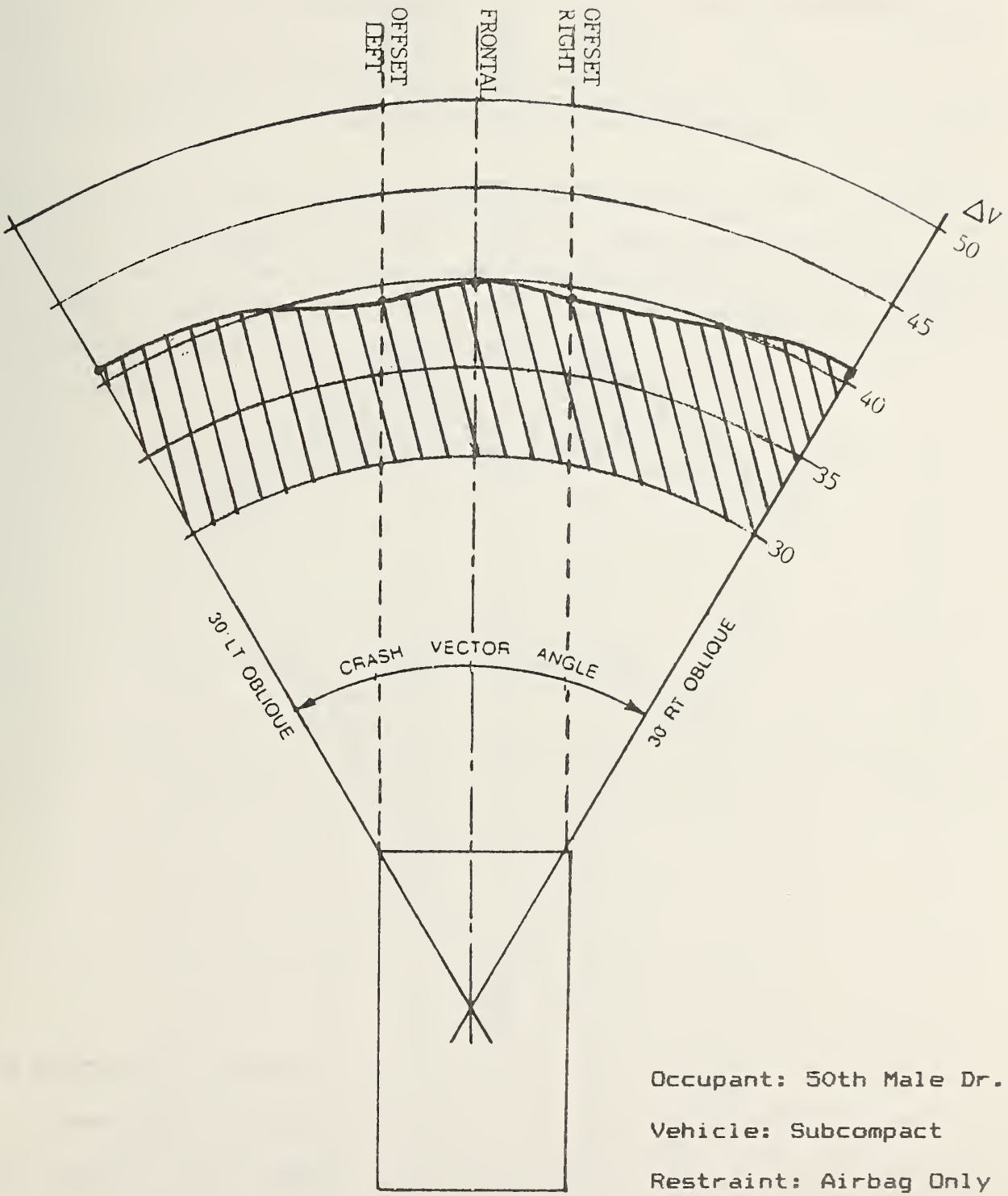
CRASH SURVIVABILITY ENVELOPE

Figure 27.



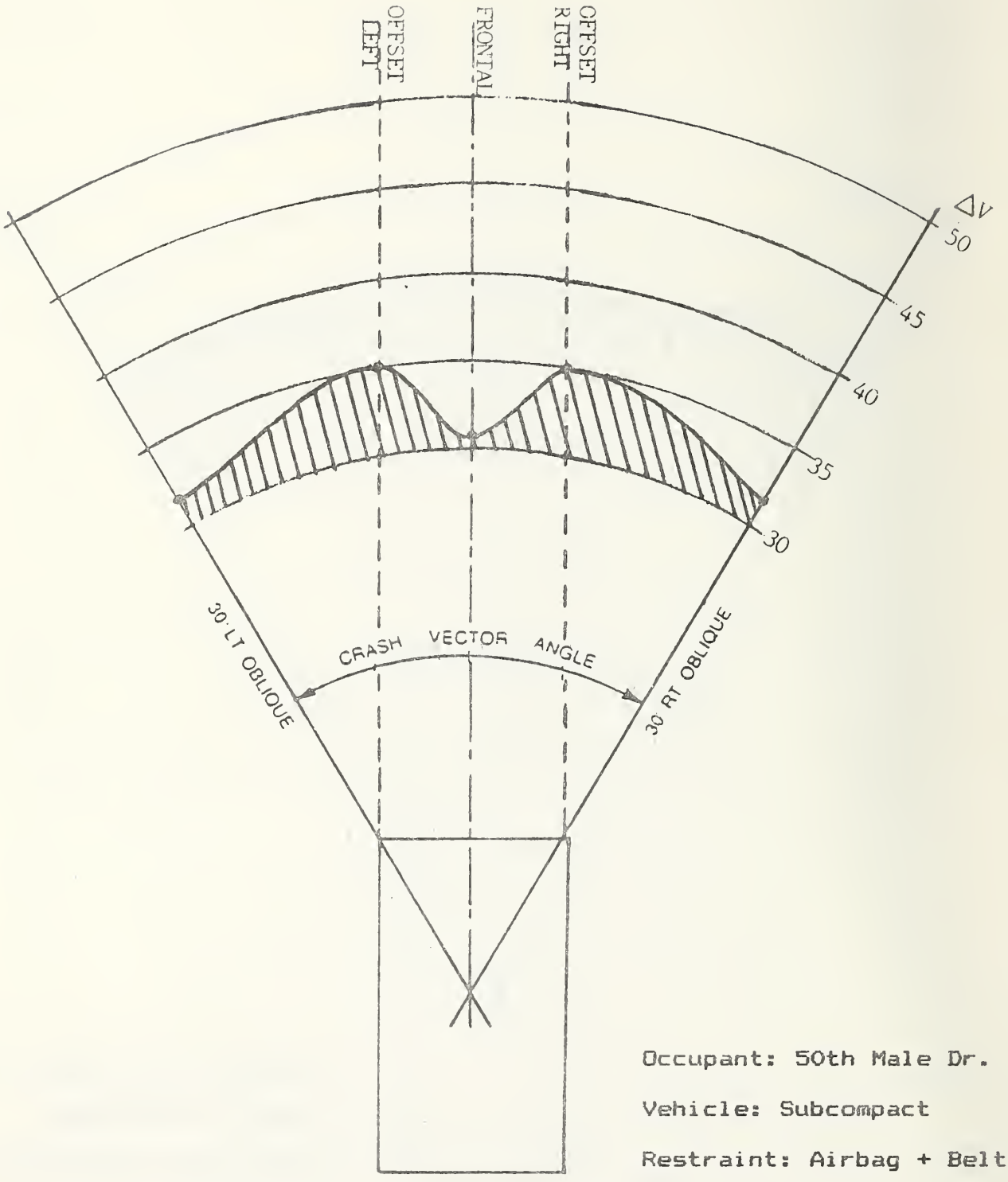
CRASH SURVIVABILITY ENVELOPE

Figure 28.



CRASH SURVIVABILITY ENVELOPE

Figure 29.



CRASH SURVIVABILITY ENVELOPE

Figure 30

A-pillar which limits his survivability margin somewhat.

The 5th percentile female has the highest g-levels and, therefore, injury measures due to her comparatively low mass.

Using the Survivability Margin curves as a criteria, the following ranking of Survivability Margin may be made; i.e. the closer an item is to the top of the list the greater the velocity at which the crash may occur without exceeding the criteria limits specified in Section 1.2.4.

Rank	Crash Mode	Vehicle	MPH	Driver	Restraint	Criteria
1	Frontal	Full Size	47.5	95th	Airbag	Crush
	Frontal	Full Size	47.5	95th	Belt&Bag	Crush
	Frontal	Full Size	47.5	50th	Airbag	Crush
	Frontal	Full Size	47.5	50th	Belt&Bag	Crush
2	Frontal	Compact	45.0	50th	Airbag	Femur
	Oblique	Compact	45.0	50th	Airbag	Femur
3	Oblique	Compact	44.2	95th	Belt&Bag	Crush
4	Oblique	Full Size	43.4	95th	Belt&Bag	Crush
	Oblique	Full Size	43.4	50th	Airbag	Crush
	Oblique	Full Size	43.4	50th	Belt&Bag	Crush
	Oblique	Full Size	43.4	5th	Airbag	Crush
5	Frontal	Compact	43.0	95th	Airbag	W/S Imp.
6	Frontal	Compact	42.2	95th	Belt&Bag	HIC
7	Frontal	Compact	41.0	5th	Airbag	Femur
	Oblique	Subcompact	41.0	50th	Airbag	Femur
8	Frontal	Compact	40.5	50th	Belt&Bag	Chest
	Oblique	Compact	40.5	50th	Belt&Bag	Chest
9	Offset	Full Size	40.1	95th	Airbag	Crush
	Offset	Full Size	40.1	95th	Belt&Bag	Crush
	Offset	Full Size	40.1	50th	Airbag	Crush
	Offset	Full Size	40.1	50th	Belt&Bag	Crush
	Offset	Full Size	40.1	5th	Airbag	Crush
	Offset	Full Size	40.1	5th	Belt&Bag	Crush

10	Oblique	Compact	40.0	5th	Airbag	Chest
	Frontal	Full Size	40.0	5th	Airbag	Femur
11	Offset	Compact	39.9	95th	Airbag	Crush
	Offset	Compact	39.9	95th	Belt&Bag	Crush
	Offset	Compact	39.9	50th	Airbag	Crush
	Offset	Compact	39.9	50th	Belt&Bag	Crush
	Offset	Compact	39.9	5th	Airbag	Crush
12	Frontal	Subcompact	39.8	50th	Airbag	HIC
13	Offset	Compact	39.5	5th	Belt&Bag	Chest
14	Offset	Subcompact	39.0	95th	Airbag	Crush
	Offset	Subcompact	39.0	95th	Belt&Bag	Crush
	Offset	Subcompact	39.0	50th	Airbag	Crush
	Offset	Subcompact	39.0	5th	Airbag	Crush
15	Oblique	Subcompact	38.7	95th	Belt&Bag	Chest
16	Oblique	Subcompact	38.5	5th	Airbag	Chest
17	Oblique	Full Size	37.5	95th	Airbag	A/P Imp.
	Oblique	Compact	37.5	95th	Airbag	A/P Imp.
	Oblique	Subcompact	37.5	95th	Airbag	A/P Imp.
	Frontal	Subcompact	37.5	95th	Airbag	W/S Imp.
18	Offset	Subcompact	35.0	50th	Belt&Bag	Chest
	Frontal	Full Size	35.0	5th	Belt&Bag	Chest
	Frontal	Subcompact	35.0	5th	Airbag	Femur
	Offset	Subcompact	35.0	5th	Belt&Bag	Chest
	Oblique	Full Size	35.0	5th	Belt&Bag	Chest

19	Frontal	Subcompact	34.0	95th	Belt&Bag	Chest
20	Oblique	Subcompact	32.0	50th	Belt&Bag	Chest
21	Frontal	Subcompact	31.0	50th	Belt&Bag	Chest
22	Frontal	Compact	30.0	5th	Belt&Bag	Chest
	Oblique	Compact	30.0	5th	Belt&Bag	Chest
	Frontal	Subcompact	30.0	5th	Belt&Bag	Chest
	Oblique	Subcompact	30.0	5th	Belt&Bag	Chest

3. The frontal offset crash pulse is the "softest" of the three accident modes and has, therefore, the lowest associated injury measures. Because of this, the vehicle will often reach its crush limit before the injury measures climb to values which exceed the criteria limits. The offset mode, then is often "vehicle crush critical" meaning that the greatest danger to the driver is the effect of intruding structure rather than normally applied restraint system loads.

4. The 7% webbing elongation at 2500 lb which was used in the study (which is typical of the webbing properties used in current belt systems) is generally too "stiff" for the 5th percentile female when used in conjunction with the airbag. We recommend that further simulations be conducted at various webbing stiffnesses to determine the optimum webbing force-deflection properties for this new restraint condition where airbags and belts are used to simultaneously restrain vehicle occupants. The desirability of "force-limiting" the webbing should also be investigated at this time.

This completes the analysis for the driver restraint system. The right front passenger restraint system will be discussed next.

3.0 Right Front Passenger Study

3.1 Obtaining the BPAC Input

Section 2.1 contains information describing the input for the driver model, BDRACR. Much of this information is also common to the BPAC model as well. Additional information peculiar to the BPAC model not previously given is shown in Figures 31 through 33. Figure 34 shows a typical BPAC input file while Table 4 shows vehicle data required to run BPAC. The sensing times and vehicle crash pulse data used in the right front passenger simulations are the same as used in the driver portion of the study.

3.2 Passenger Study Results

A total of 129 BPAC computer runs were made in conducting the right front passenger portion of the analysis. The results of these runs (with the exception of the six year old child runs which were only in the frontal mode) are shown by Figures 35 through 52 on the following pages.

For three of the passenger sizes studied (95th percentile male, 50th percentile male, and 5th percentile female), three separate accident modes were analyzed in each of three vehicle sizes for two separate restaint conditions. These two restraint conditions were the airbag system only and the airbag plus belt system.

The 6 year old child passenger was also analyzed but only in the frontal crash mode. In this case the child was studied for three separate conditions for each of the three vehicle sizes. These three modes were:

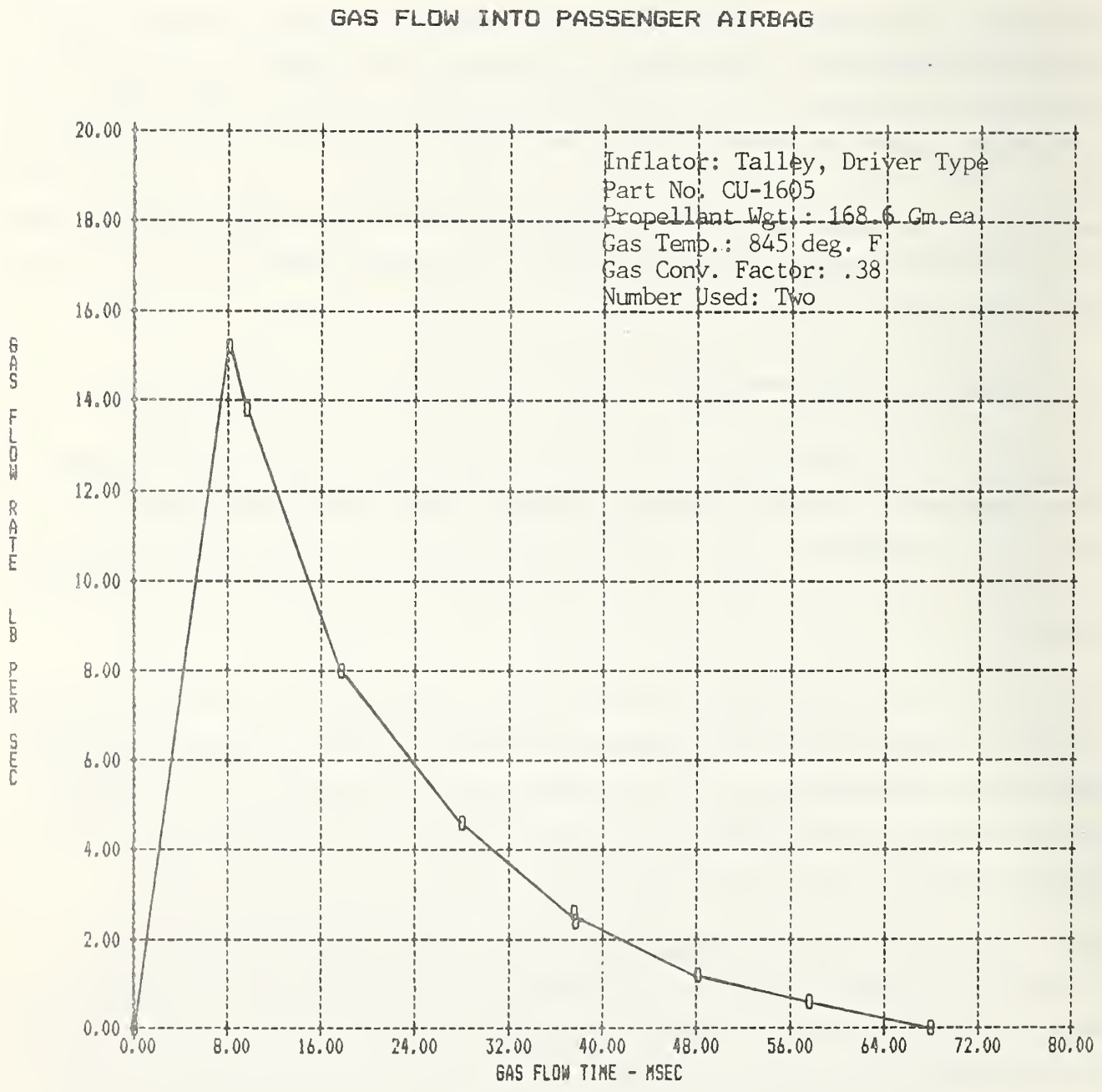

GAS FLOW INTO PASSENGER AIRBAG
Inflator: Talley, Driver Type
Part No. CU-1605
Propellant Wgt.: 168.6 Gm.ea
Gas Temp.: 845 deg. F
Gas Conv. Factor: .38
Number Used: Two
GAS FLOW RATE LB PER SEC
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
72.00
80.00
GAS FLOW TIME - MSEC

Figure 31.

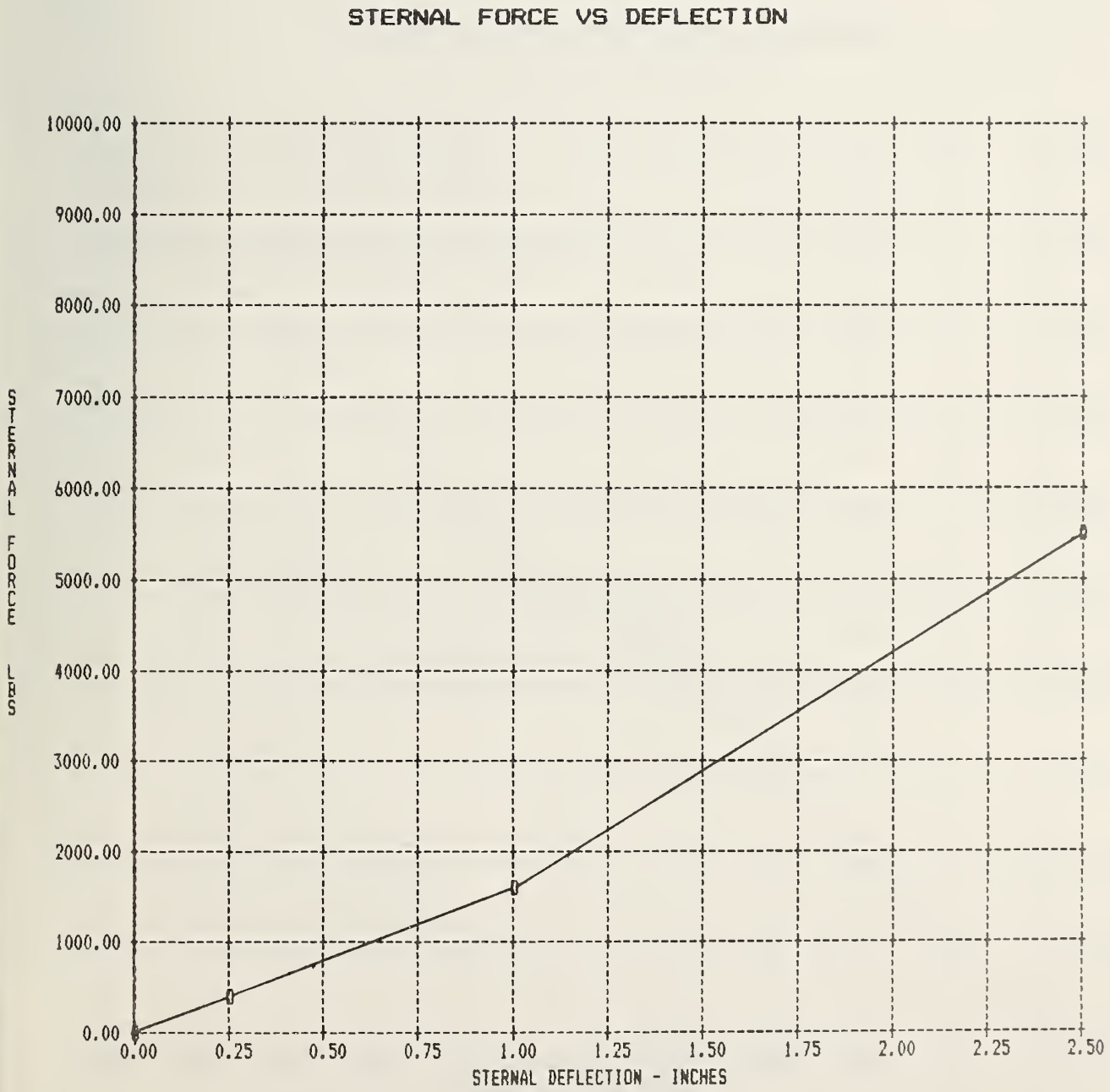

STERNAL FORCE VS DEFLECTION
10000.00
9000.00
8000.00
7000.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
STERNAL FORCE LBS
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
STERNAL DEFLECTION - INCHES

Figure 32.

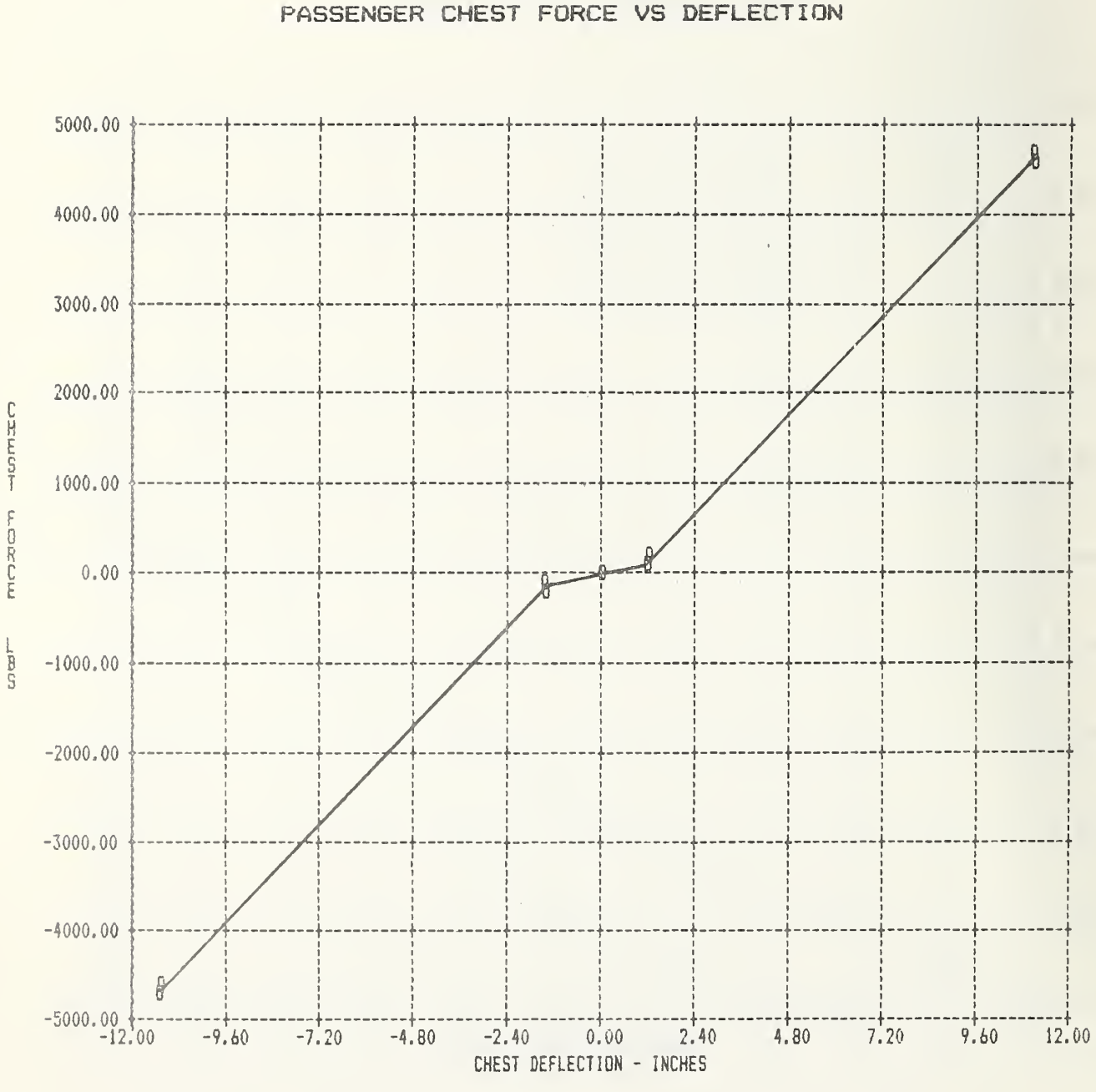

PASSENGER CHEST FORCE VS DEFLECTION
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
-1000.00
-2000.00
-3000.00
-4000.00
-5000.00
CHEST FORCE - LBS
-12.00
-9.60
-7.20
-4.80
-2.40
0.00
2.40
4.80
7.20
9.60
12.00
CHEST DEFLECTION - INCHES

Figure 33.

SAMPLE BPAC INPUT FILE

```
SUBCOMPACT CAR, 35 MPH FRONTAL IMPACT, 50TH PERCENTILE MALE PASSENGER

35.,1.,-16.
71.04,62.9,2.5,12.54,14.0,20.5,4.53,29.75
5.5,5.,8.25,16.3,4.75,6.,15.5,4.5,5.75,6.,13.5
3,5,23,3,11,6,2500.,1827.
5,5,3,3,5,6,1133.,2008.
13.,-100.,0.,8.,10.,18.,28.,38.,48.,58.,68.,100.
0.,0.,7.60,6.90,4.00,2.30,1.25,0.58,0.32,0.,0.
14.7,0.,1305.,662.,1.4,1.4,1.4,0.0
0.20,0.3,63.,35.5,5.,0.5,0.5
19.,42.5,38.5,24,13,360.,0.0
.7,.7,10.0,15.,2.,9.,15.35,26.5
10.,0.,8.4,0.0,3.,6.,4.,13.
6.1,5.,28.0,12.88,17.9,14.3,3.25,0.3
8.,55.7,.125,.001,.005,.005,.01
-10.,0.,1.
70.6,70.6,70.6
-80.,17.,90.
117.,0.,-87.
-10.,0.0,3.45
0.,0.,2500.
-10.,0.0,3.45
0.,0.,2500.
-10.,0.,1.5,2.,3.
0.,0.,500.,2000.,8000.
-10.,0.,.2,.4,.6,.8,
0.,0.,30.,72.,175.,350.
0.0,5.0,10.0,15.0,20.0,25.0,30.0,35.0,40.0,45.0,50.0,55.0,60.0,65.0,70.0,
75.0,80.0,85.0,90.0,95.0,100.0,105.0,250.0
0.0,1.1,4.1,8.8,14.6,20.7,26.4,31.1,34.2,35.3,34.2,31.1,26.4,20.7,14.6,8.
8,4.1,1.1,0.0,0.0,0.0,0.0,0.0
-10.,3.5,5.86,6.84,7.8
0.,0.,2140.,2837.,3200
-50.,0.,.25,1.,10.
0.,0.,400.,1600.,25000.
-11.25,-1.25,0.,1.25,11.25
-4650.,-150.,0.,150.,4650.
-10.,0.,3.93,6.1,7.28,9.13
0.,0.,337.,1461.,1461.,2540.
0.,90.,107.,1.5,8.,8.,45.,36.,5.
```

Figure 34.

"BPAC" VEHICLE DATA

Vehicle	a	b	V Area	X1	Y1
Full Size	15.0	9.0	10.0	17.4	26.5
Intermediate	15.0	9.0	10.0	16.4	26.5
Subcompact	15.0	9.0	10.0	15.4	26.5

Note: Xr, Yr, Θ_{WS}, and the passenger initial positions are the same as shown in Table 1.

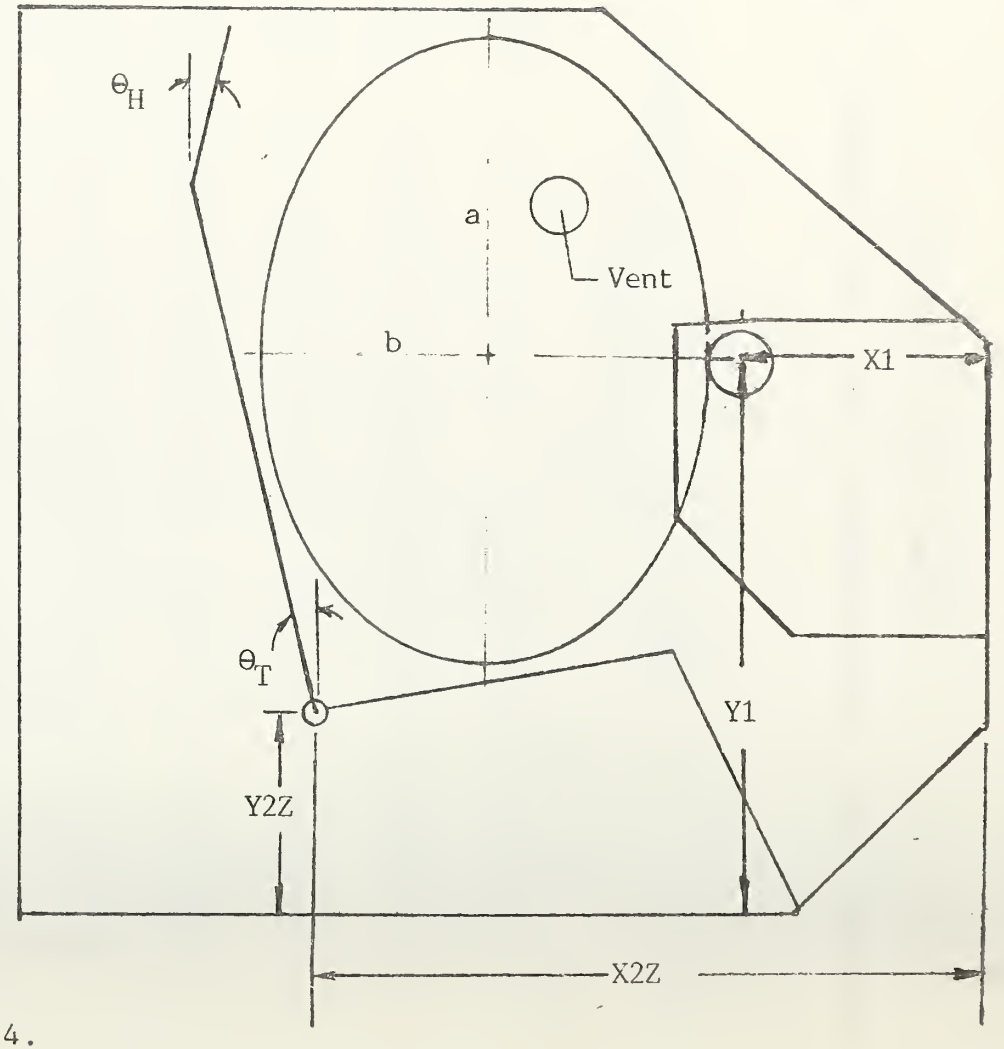
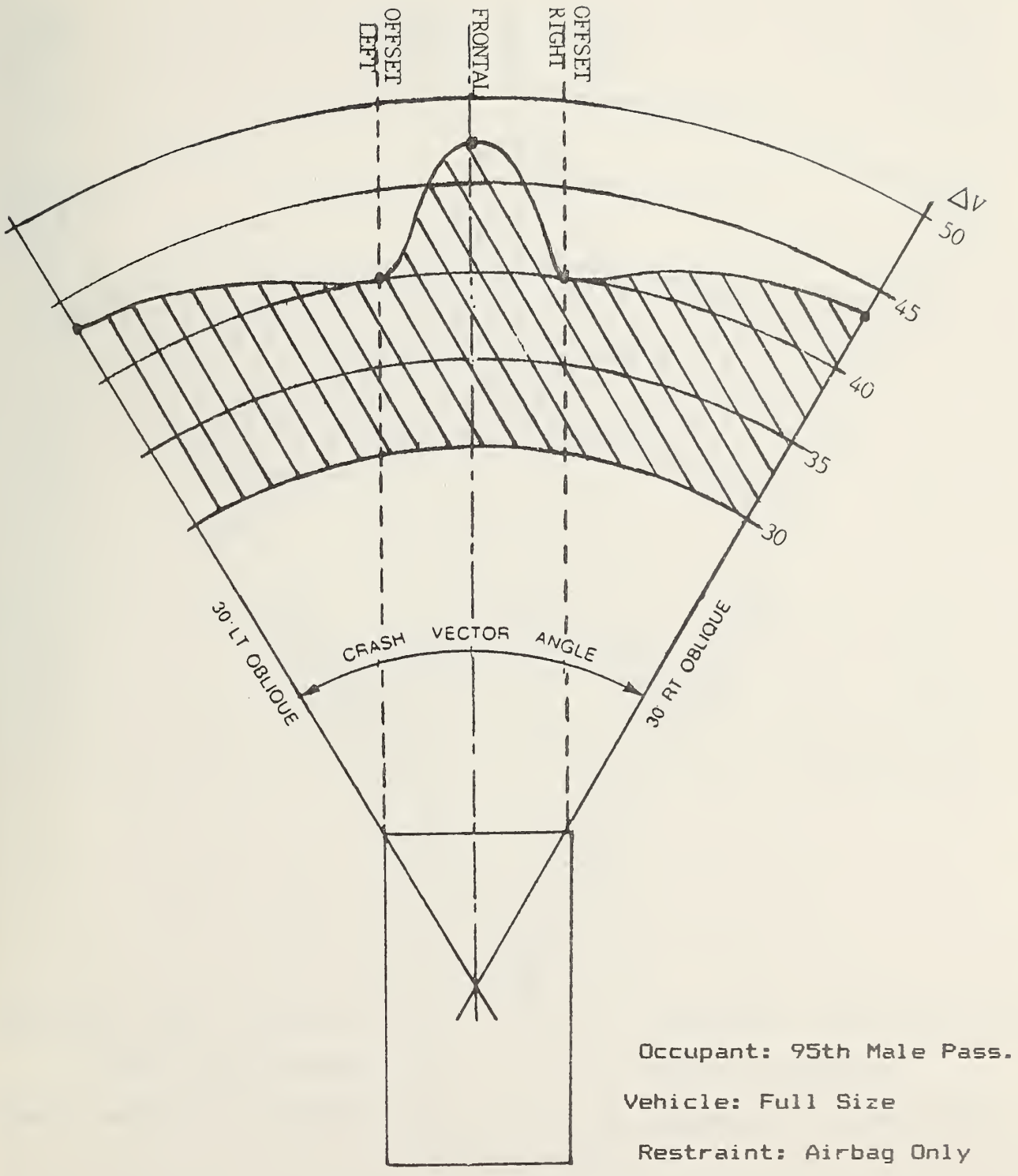
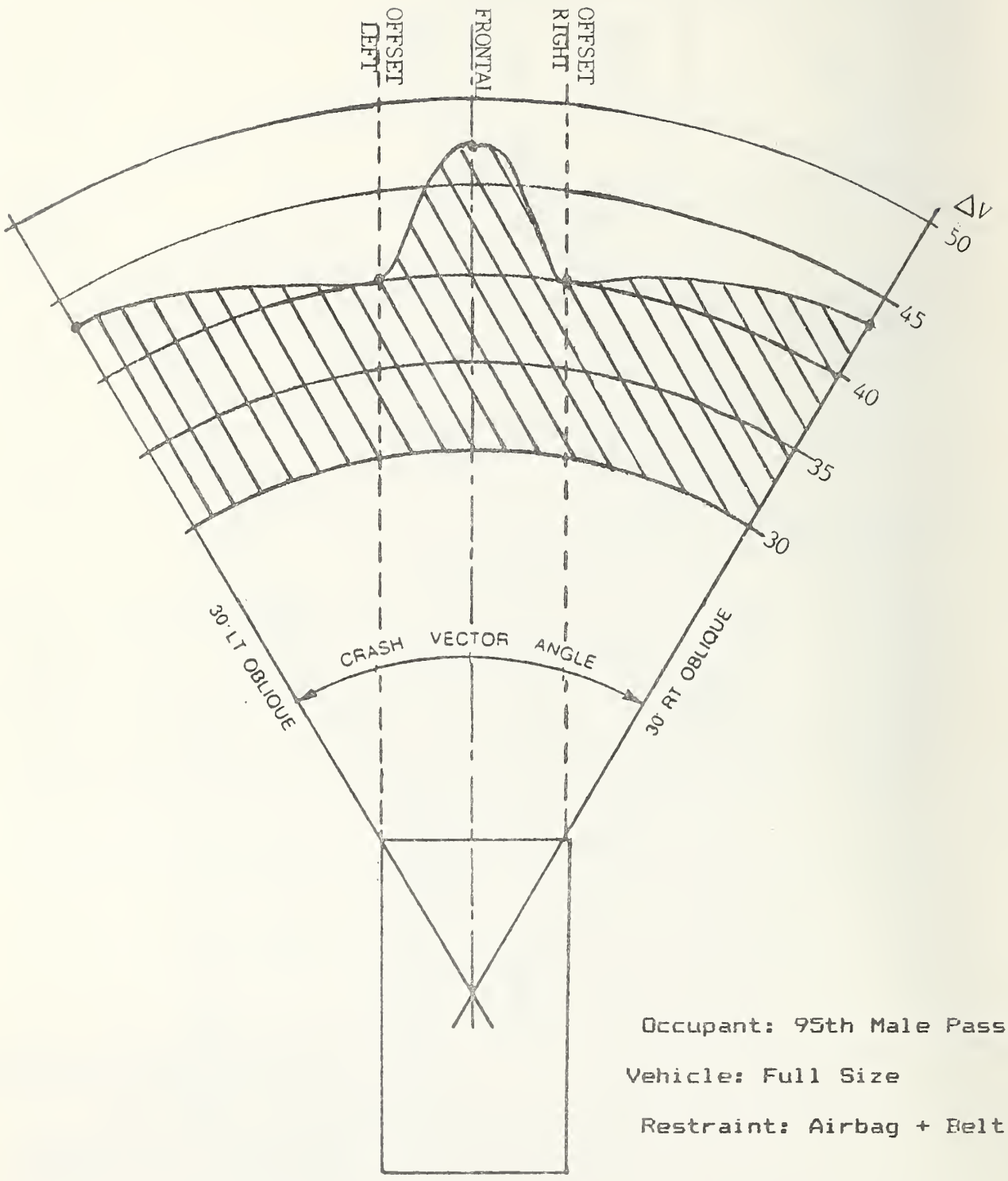


Table 4.



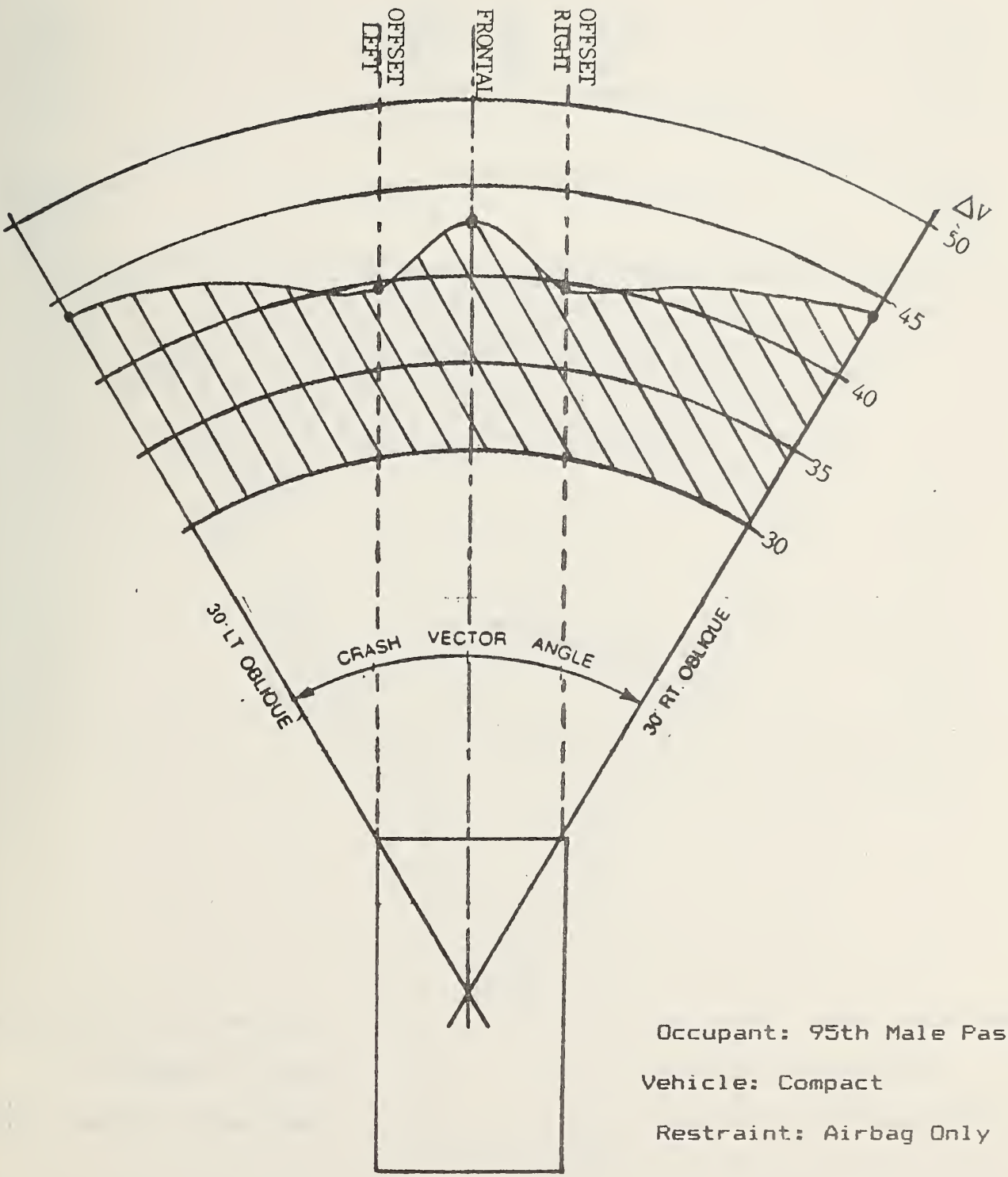
CRASH SURVIVABILITY ENVELOPE

Figure 35.



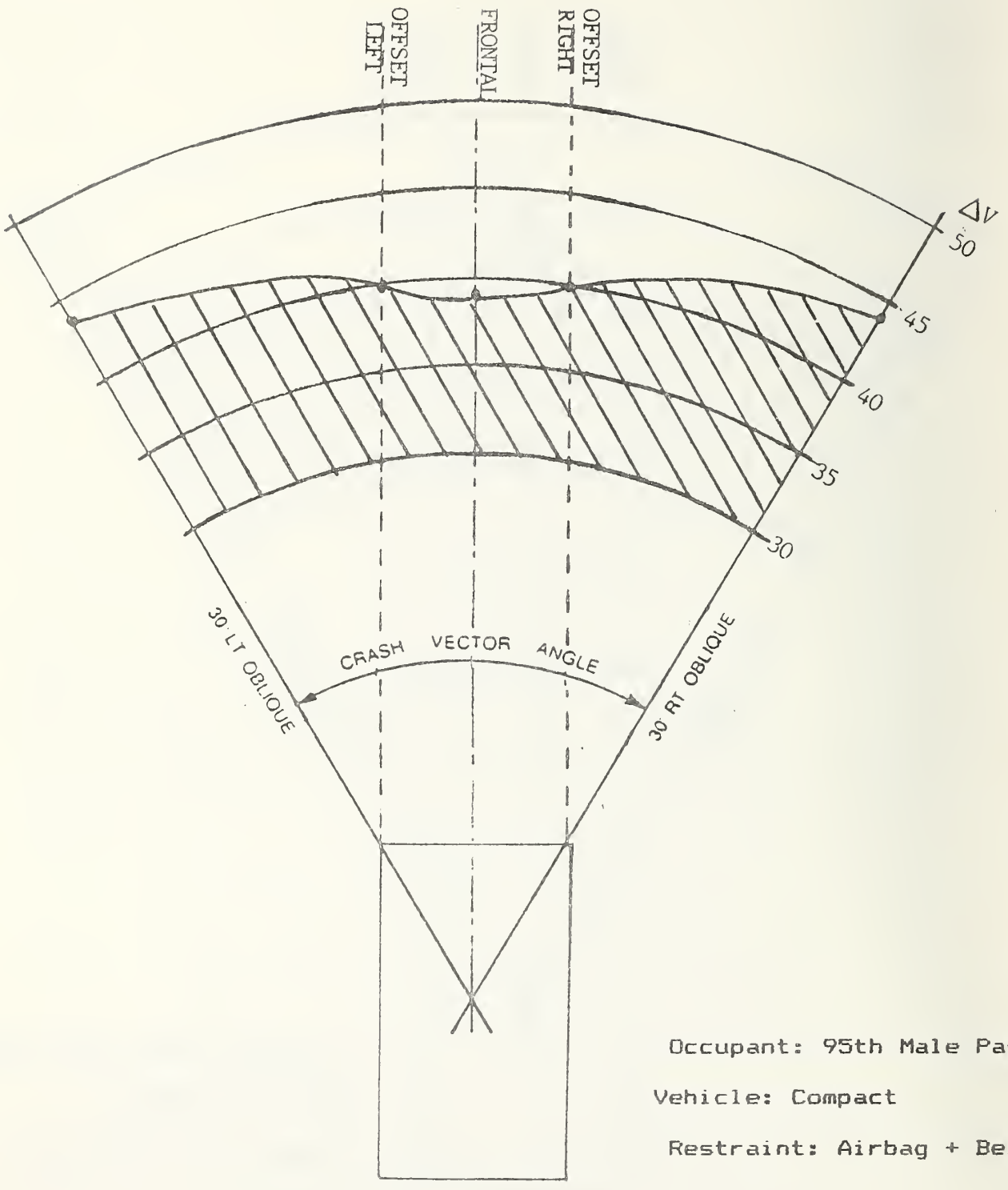
CRASH SURVIVABILITY ENVELOPE

Figure 36.



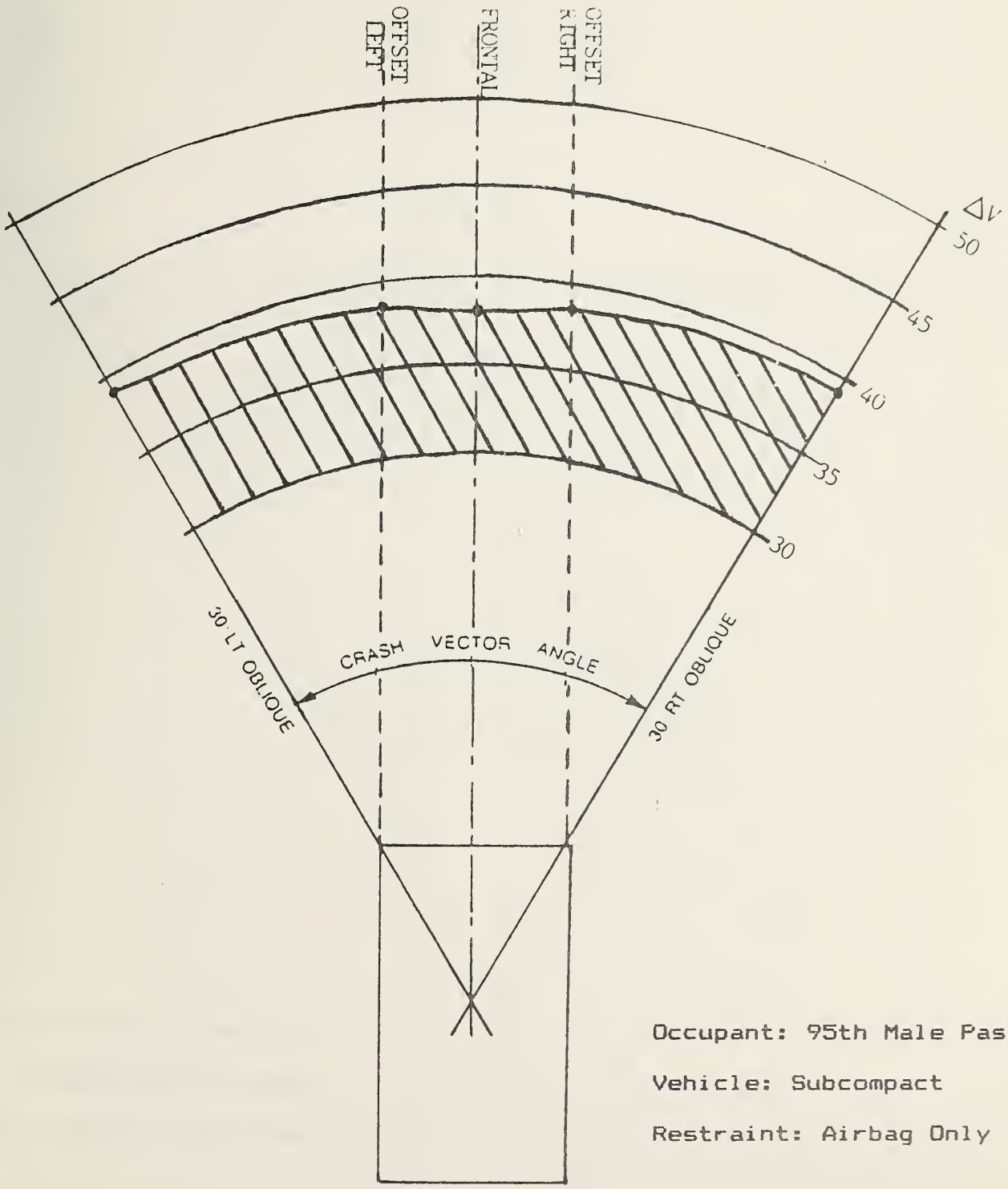
CRASH SURVIVABILITY ENVELOPE

Figure 37.



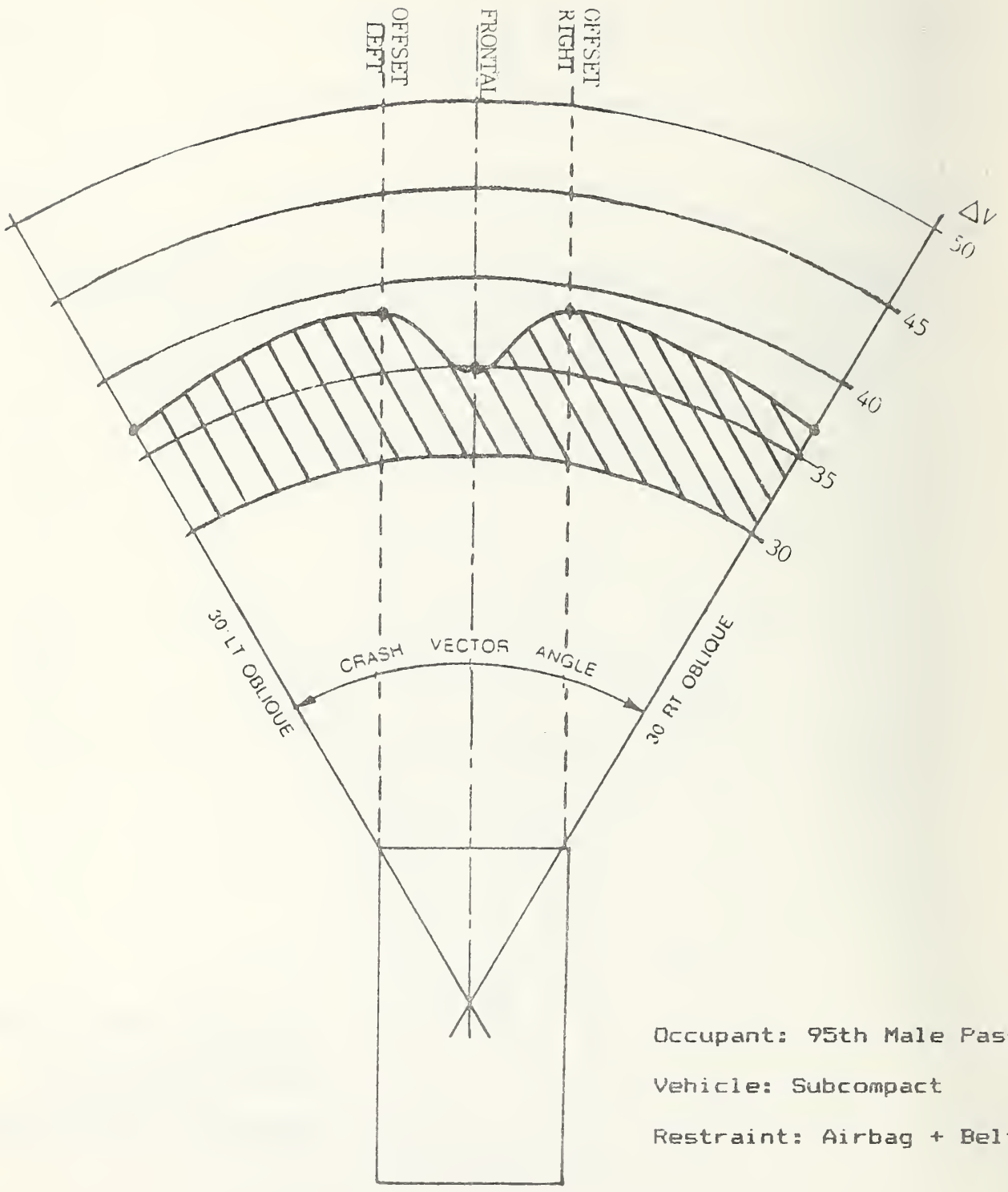
CRASH SURVIVABILITY ENVELOPE

Figure 38.



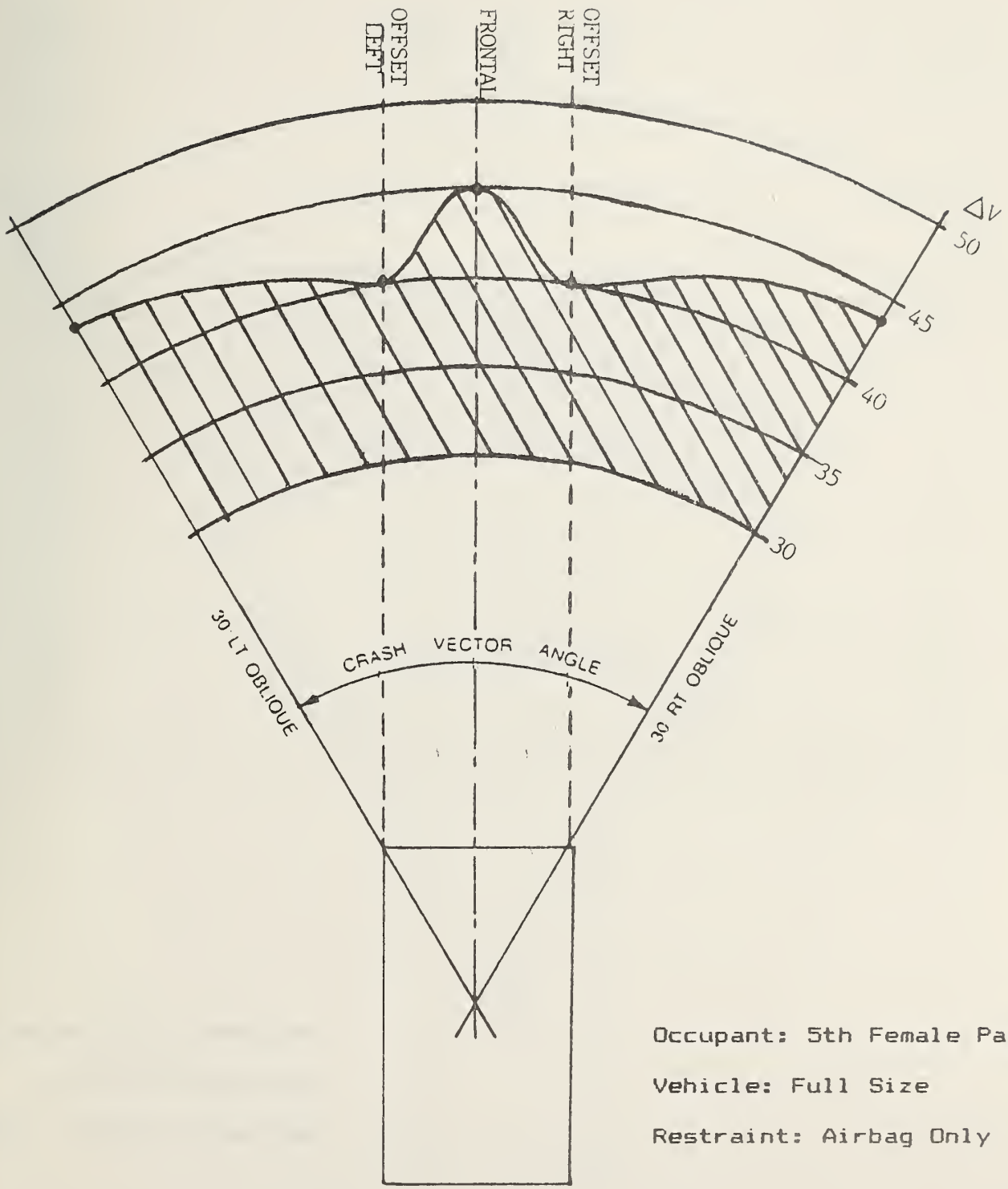
CRASH SURVIVABILITY ENVELOPE

Figure 39.



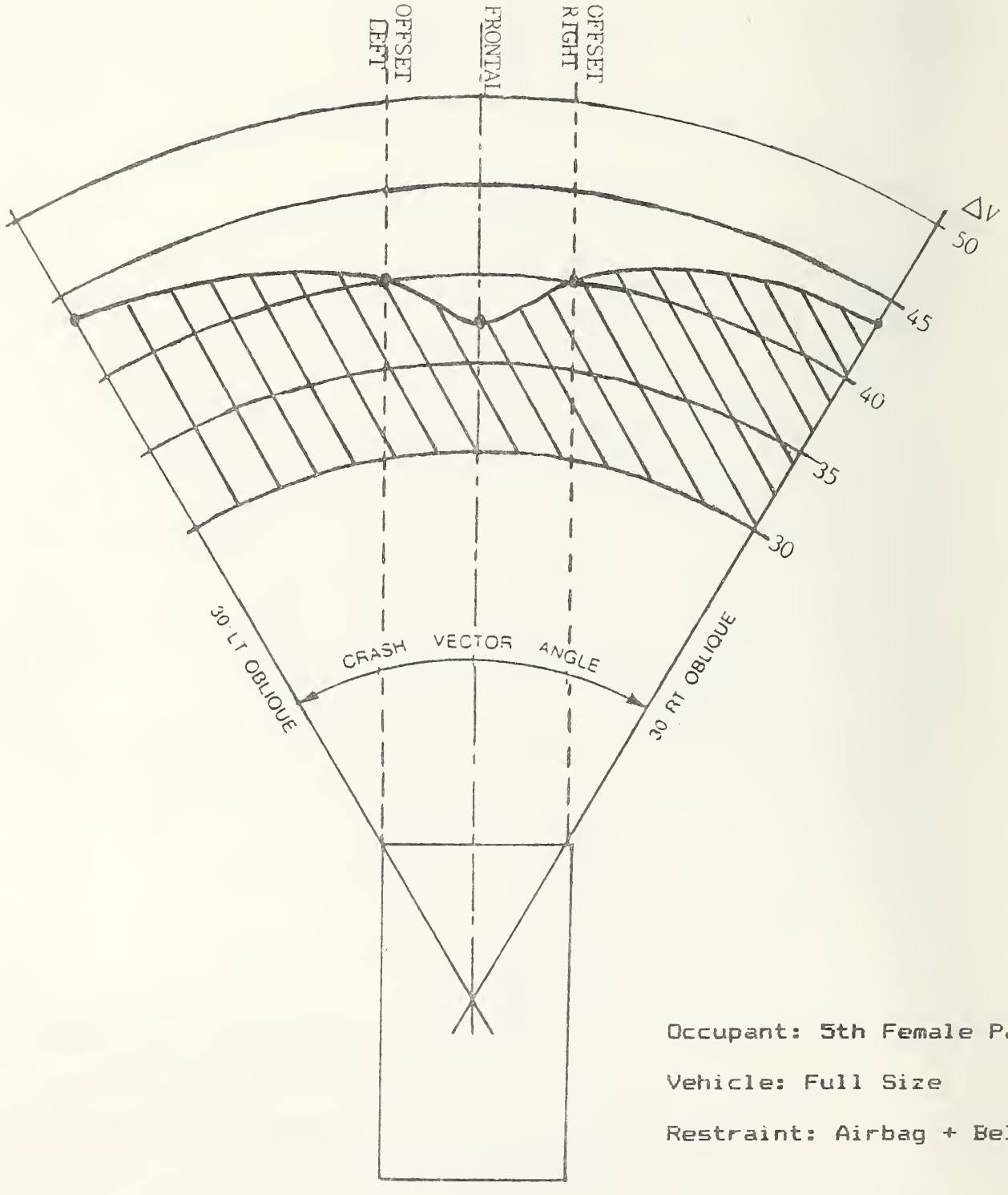
CRASH SURVIVABILITY ENVELOPE

Figure 40.



CRASH SURVIVABILITY ENVELOPE

Figure 41.



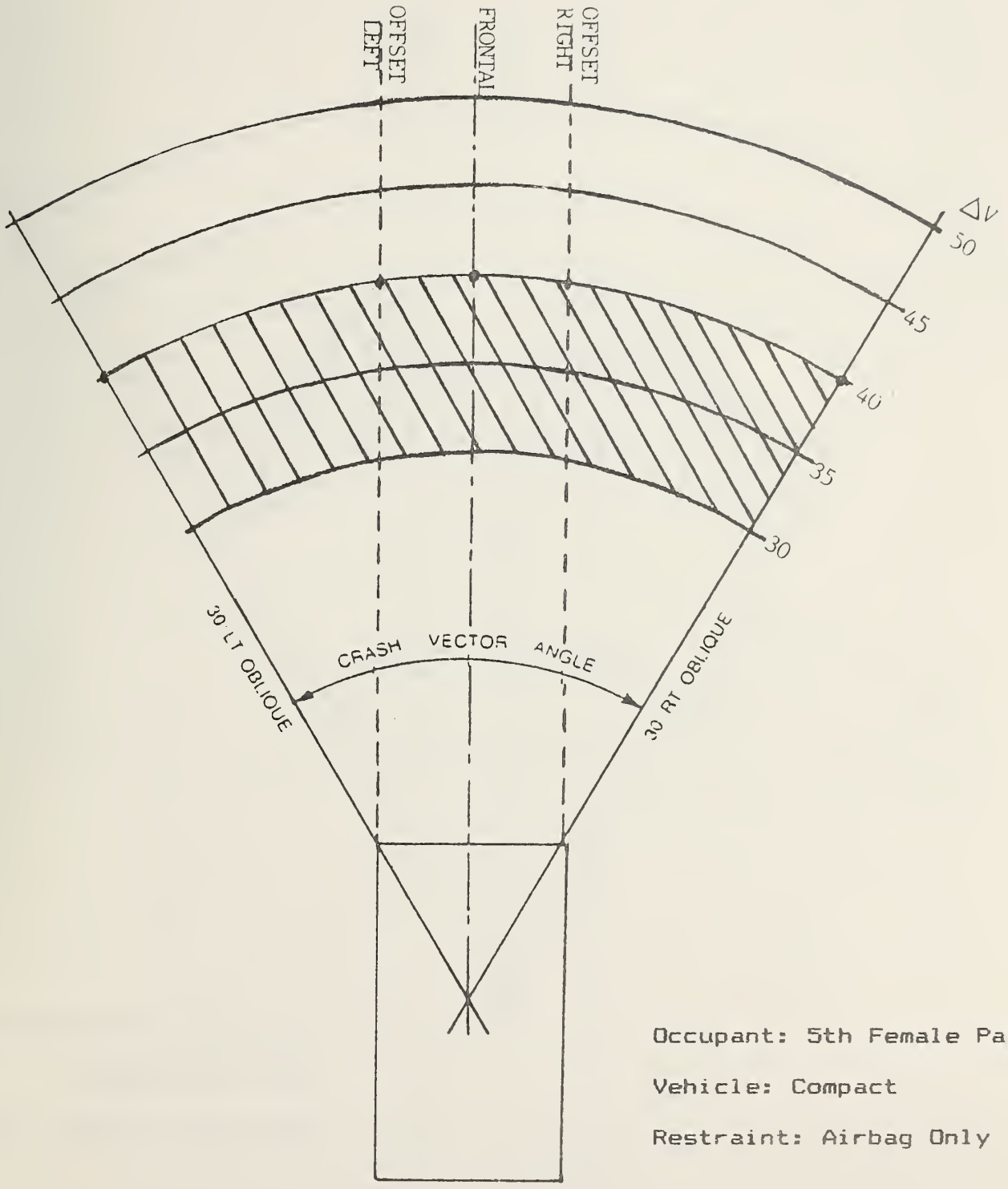
Occupant: 5th Female Pass.

Vehicle: Full Size

Restraint: Airbag + Belt

CRASH SURVIVABILITY ENVELOPE

Figure 42.



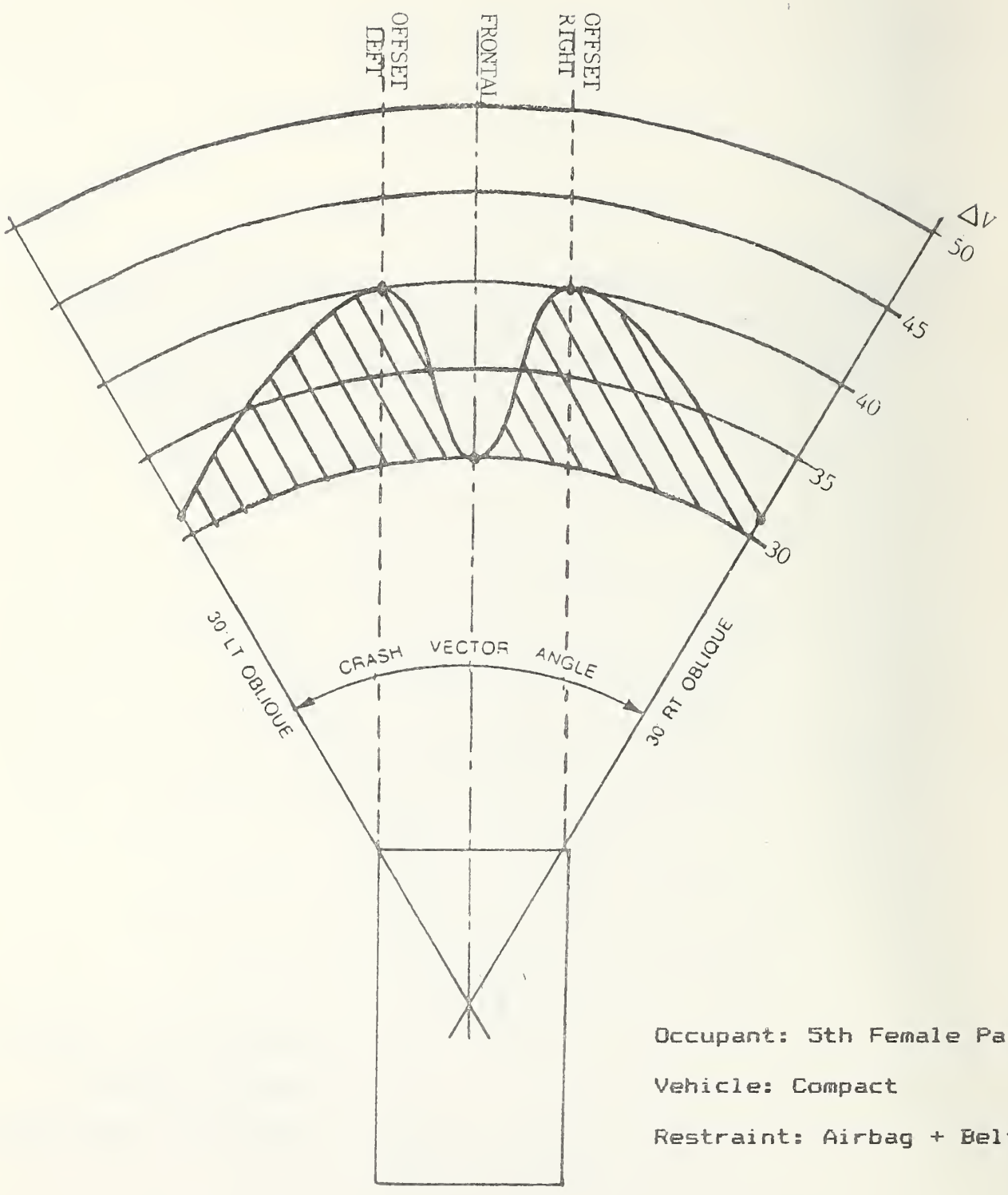
Occupant: 5th Female Pass.

Vehicle: Compact

Restraint: Airbag Only

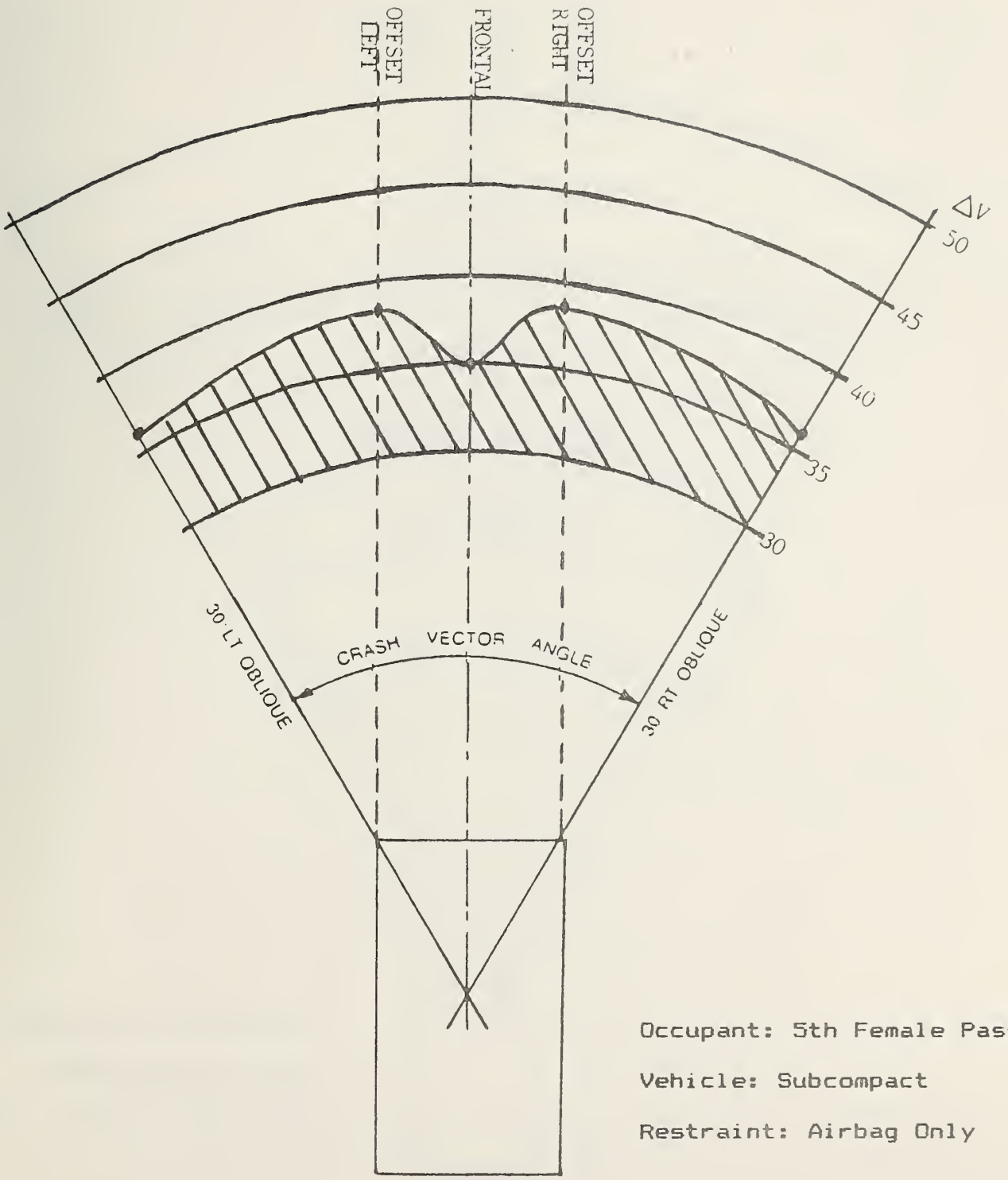
CRASH SURVIVABILITY ENVELOPE

Figure 43.



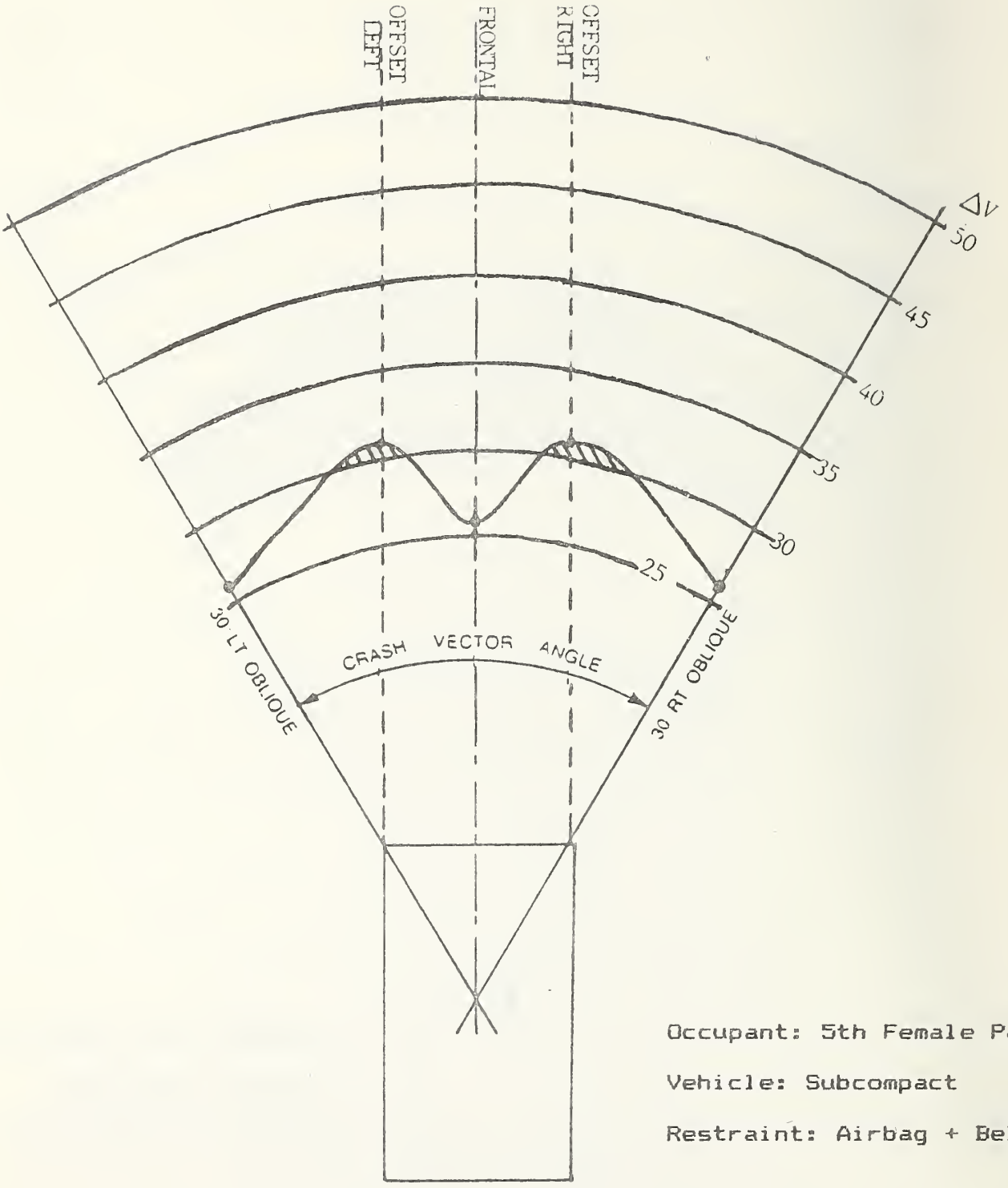
CRASH SURVIVABILITY ENVELOPE

Figure 44.



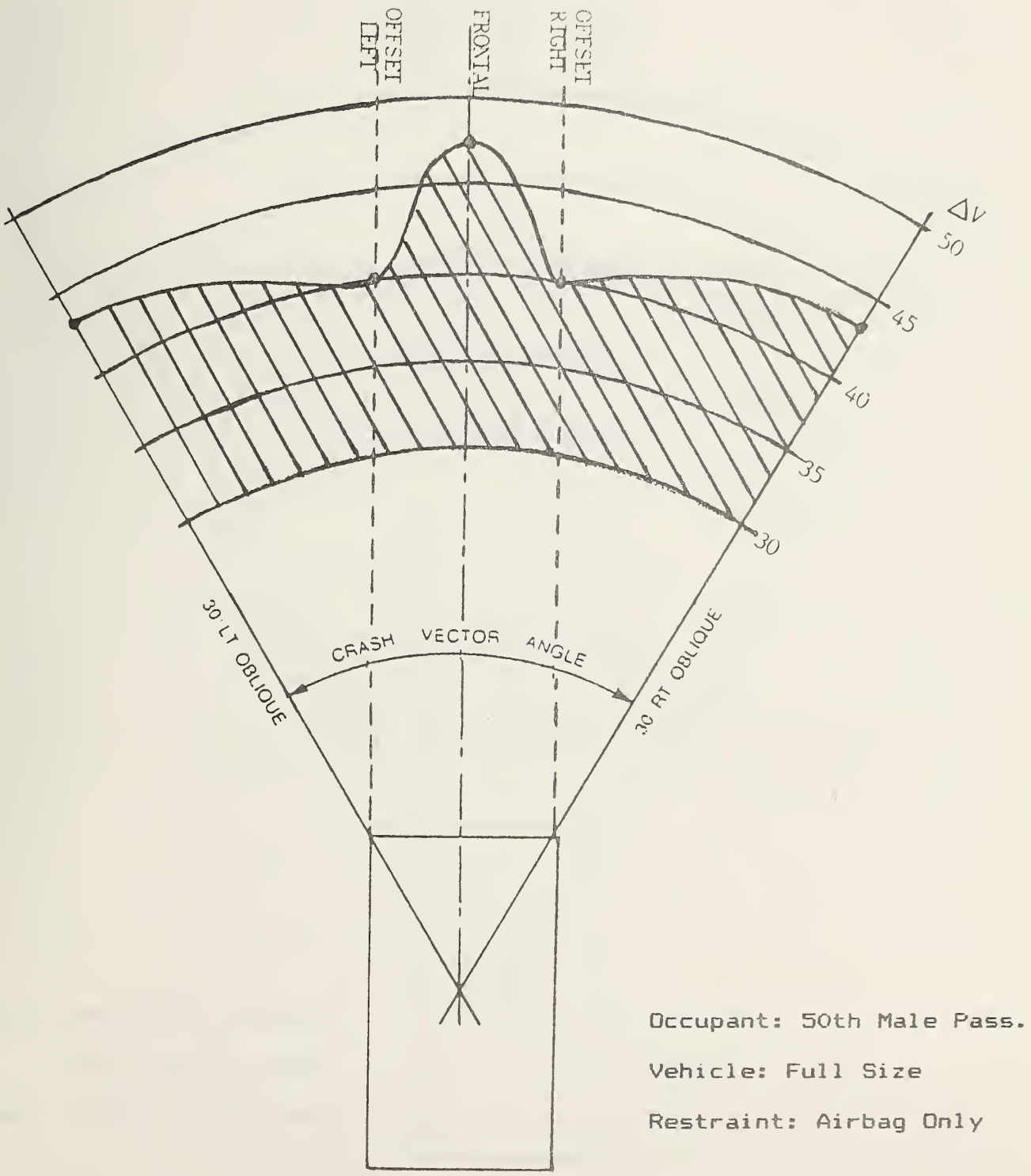
CRASH SURVIVABILITY ENVELOPE

Figure 45.



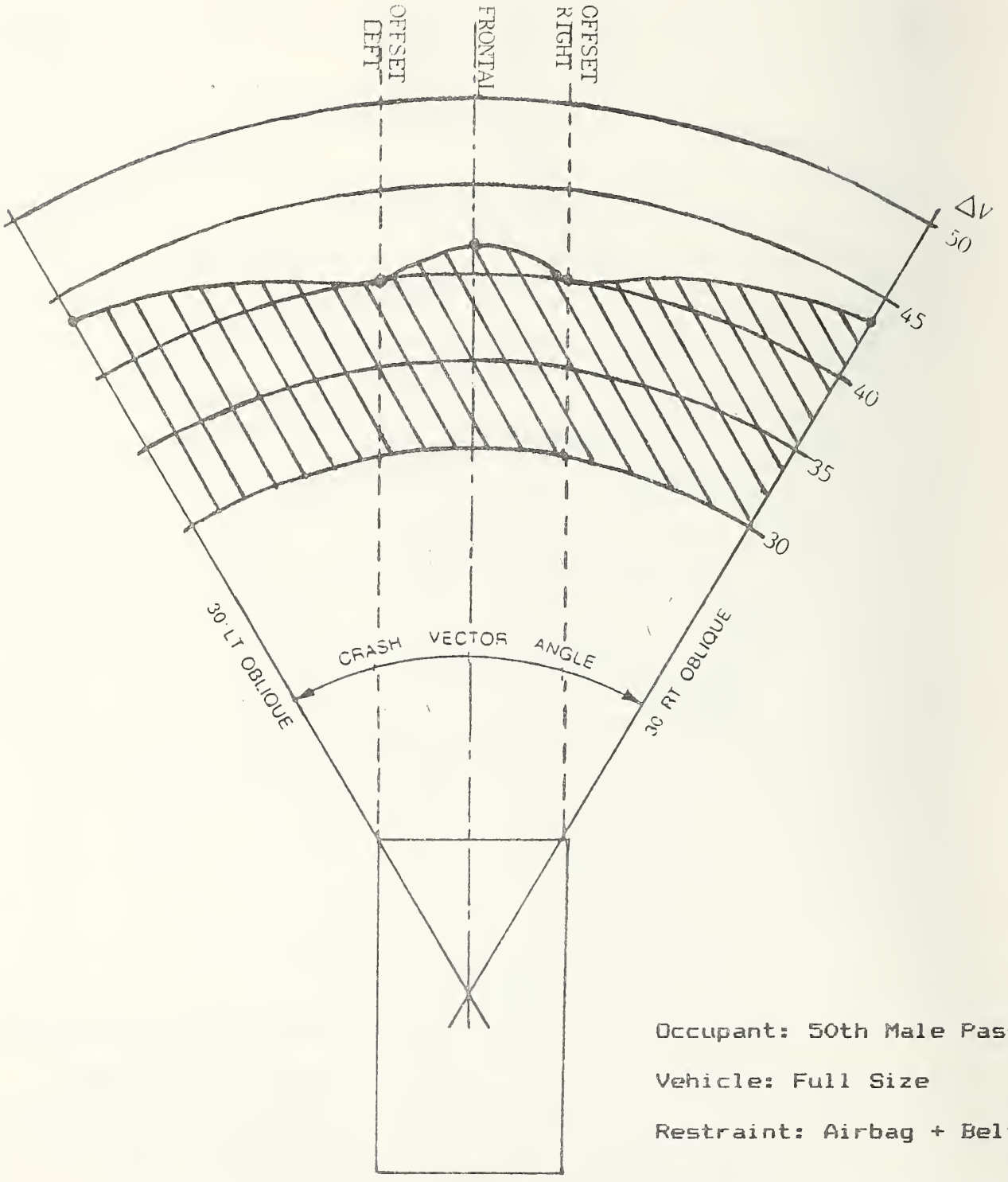
CRASH SURVIVABILITY ENVELOPE

Figure 46.



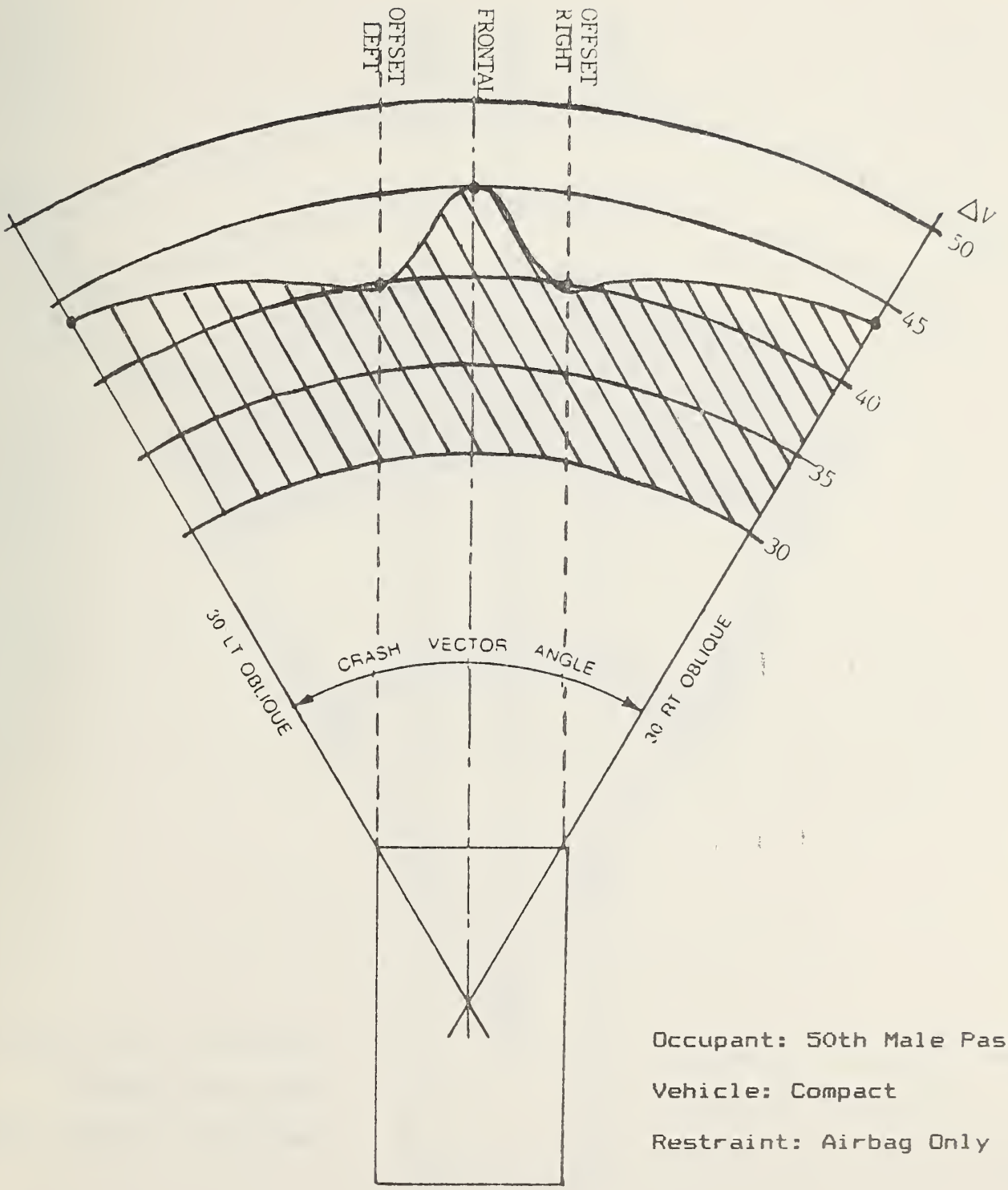
CRASH SURVIVABILITY ENVELOPE

Figure 47.



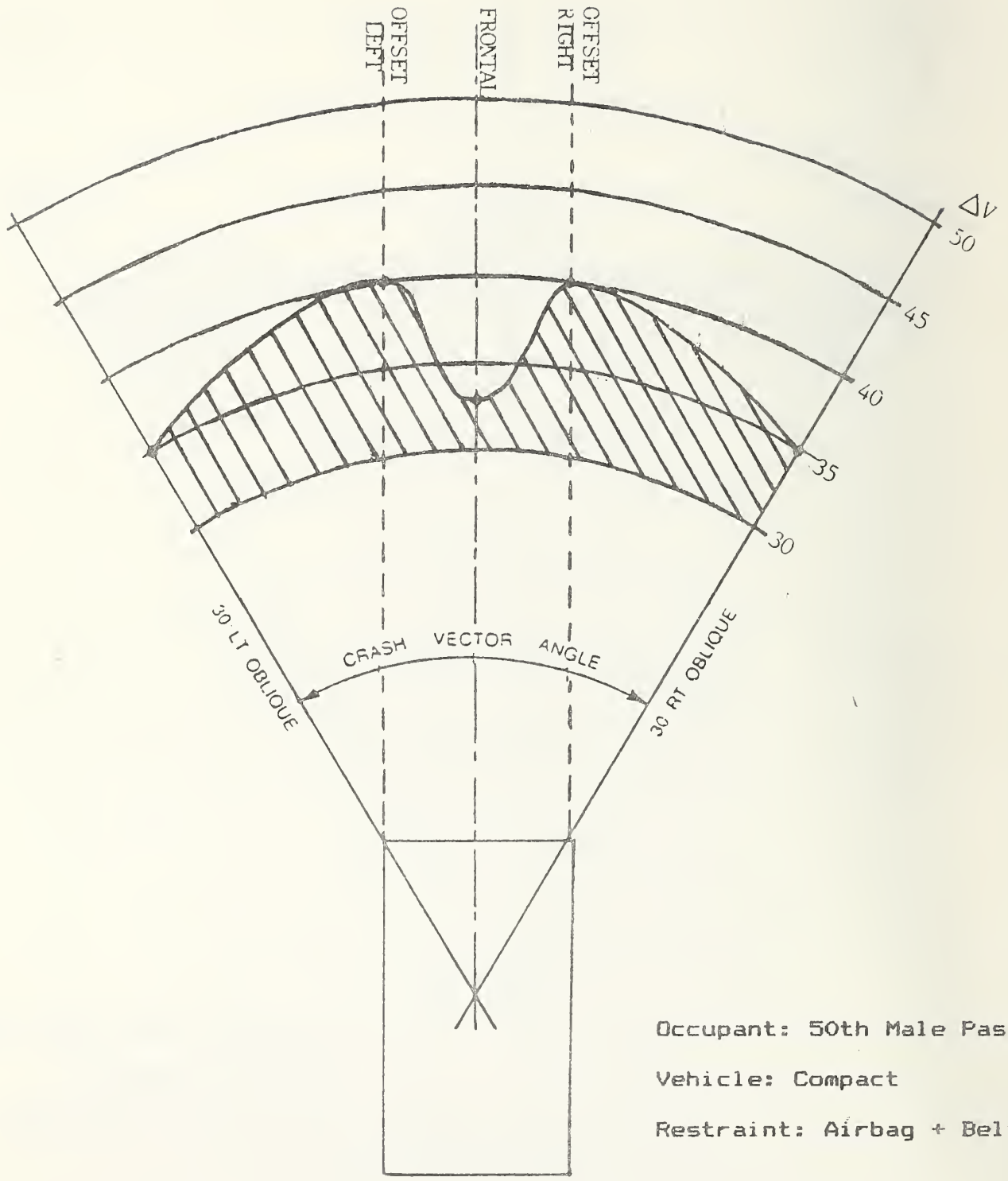
CRASH SURVIVABILITY ENVELOPE

Figure 48.



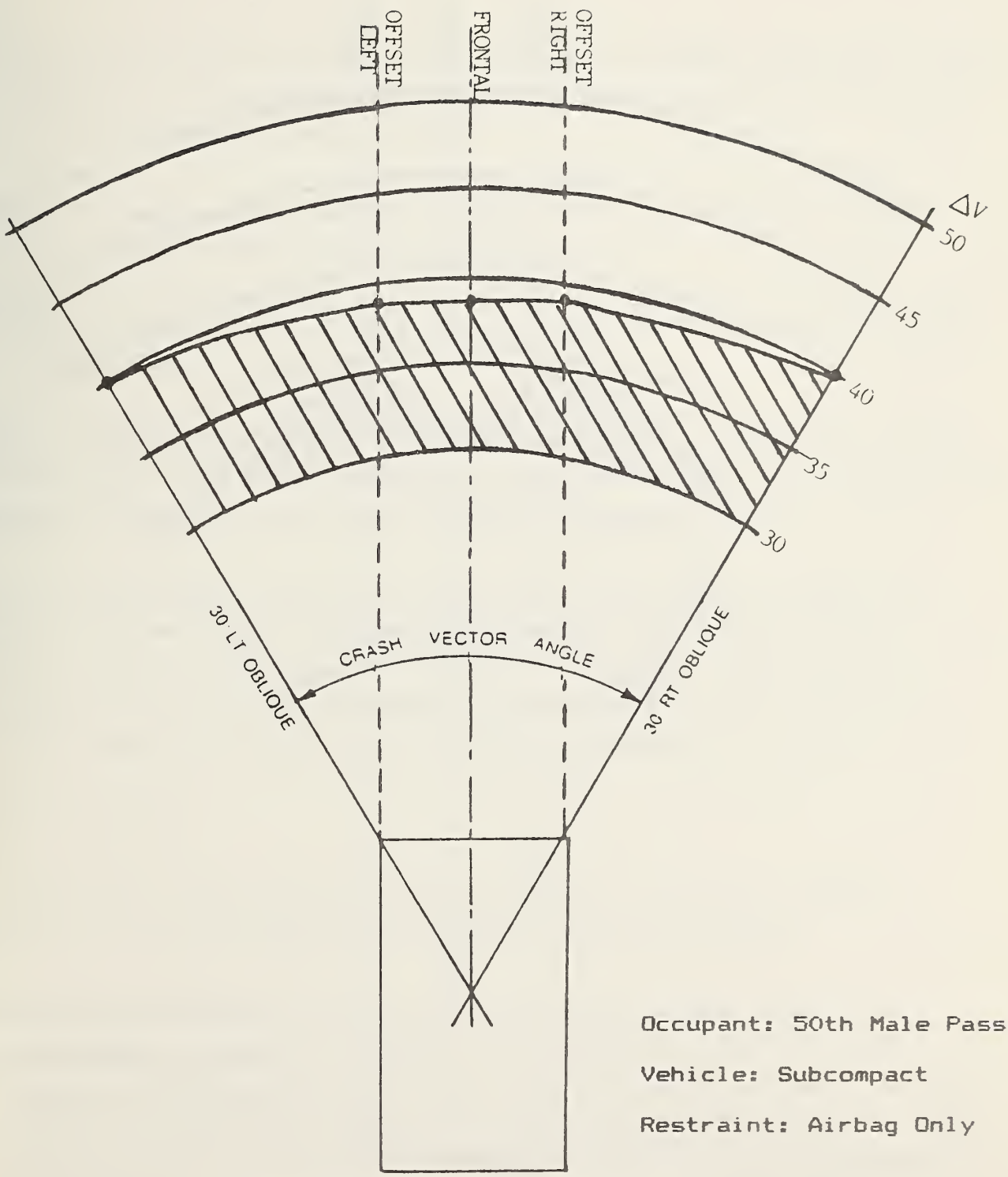
CRASH SURVIVABILITY ENVELOPE

Figure 49.



CRASH SURVIVABILITY ENVELOPE

Figure 50.



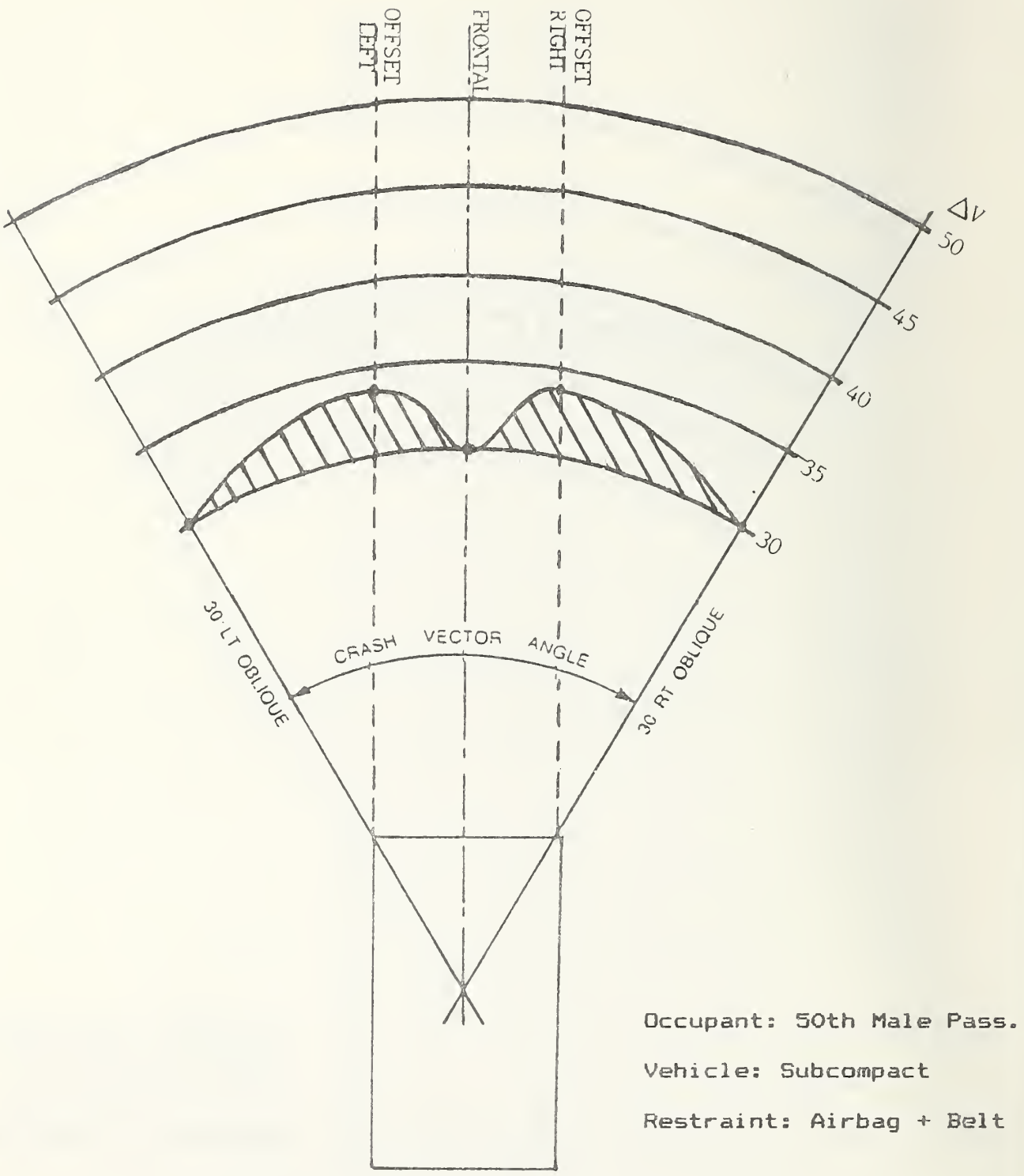
Occupant: 50th Male Pass.

Vehicle: Subcompact

Restraint: Airbag Only

CRASH SURVIVABILITY ENVELOPE

Figure 51.



CRASH SURVIVABILITY ENVELOPE

Figure 52.

a. the out-of position mode with the child's chest placed six inches from the dash with the airbag system deploying directly into the child's chest (no belt system),

b. the normally seated mode with the child restrained by both an airbag and a three-point belt system,

c. the normally seated mode with the child restrained by an airbag system only.

Figure 53 shows the results of the child portion of the study. Since only the frontal mode was studied for the child, the results had to be presented differently than for the other passenger sizes.

As was the case with the driver analysis, a sufficient number of computer runs were made for each condition to determine the velocity at which the Crash Survivability Limit is reached. As previously described, this velocity is reached whenever one of the conditions defined in Section 1.2.4 is either met or exceeded.

3.3 Conclusions

By inspecting Figures 35 through 53, several things are readily apparent and the following conclusions have been reached.

1. As was the case for the driver and as one might expect, the Survivability Margin is generally highest for the full size car which has a relatively soft crash pulse and slightly larger interior dimensions within which to bring the passenger to rest. Conversely, this margin is generally lowest for the subcompact car with its relatively hard crash pulse and more confining interior.

CRASH SURVIVABILITY LIMIT FOR SIX YEAR OLD CHILD

FRONTAL IMPACT

Vehicle Size	Child Position	Restraint System	Velocity Limit MPH	Critical Mode
Full Size	6 in. to dash	Airbag Only	47.5	Crush
Full Size	Normally Seated	Airbag Only	40.0	Chest
Full Size	Normally Seated	Airbag + Belt	35.0	Chest
Compact	6 in. to dash	Airbag Only	39.0	Chest
Compact	Normally Seated	Airbag Only	35.0	Chest
Compact	Normally Seated	Airbag + Belt	30.0	Chest
Subcompact	6 in. to dash	Airbag Only	32.5	Chest
Subcompact	Normally Seated	Airbag Only	33.0	Chest
Subcompact	Normally Seated	Airbag + Belt	25.0	Chest

Figure 53.

2. The 95th percentile male has the greatest overall Survivability Margin as measured by the shaded areas in Figures 35 and 36 for the full size car. The 95th percentile male is closely followed by the 50th percentile male as shown in Figures 47 and 48 for the same full size car.

3. The restraint combination that gives the greatest survivability margins is the airbag system when used alone i.e. without the three-point belt restraint system. The addition of the belt system has the effect of adding an additional force system that increases with passenger stroke. By inspecting and comparing Figures 54 and 55 for the frontal mode, one may see the greater survivability limits attainable with the airbag system working alone as opposed to working in parallel with the three-point belt system. The trend observed here for the passenger in the frontal mode is typical of the other accident modes and the driver as well.

   Most of the currently used production webbing stretches approximately 7% at 2500 lb tensile load and was the webbing assumed for this study. However this webbing was not originally designed to be used in combination with an airbag but was designed to perform the entire restraint function acting alone. For this reason, it is our opinion that this webbing may be too stiff to be used in combination with an airbag as it generally results in the passenger experiencing higher head and chest g's than would be the case for the airbag system acting alone.

   One possible solution would be to use a "softer" webbing or to use a force limited belt. We suggest that additional computer simulations be conducted to determine just what the optimum webbing and force limiting properties would be for each vehicle

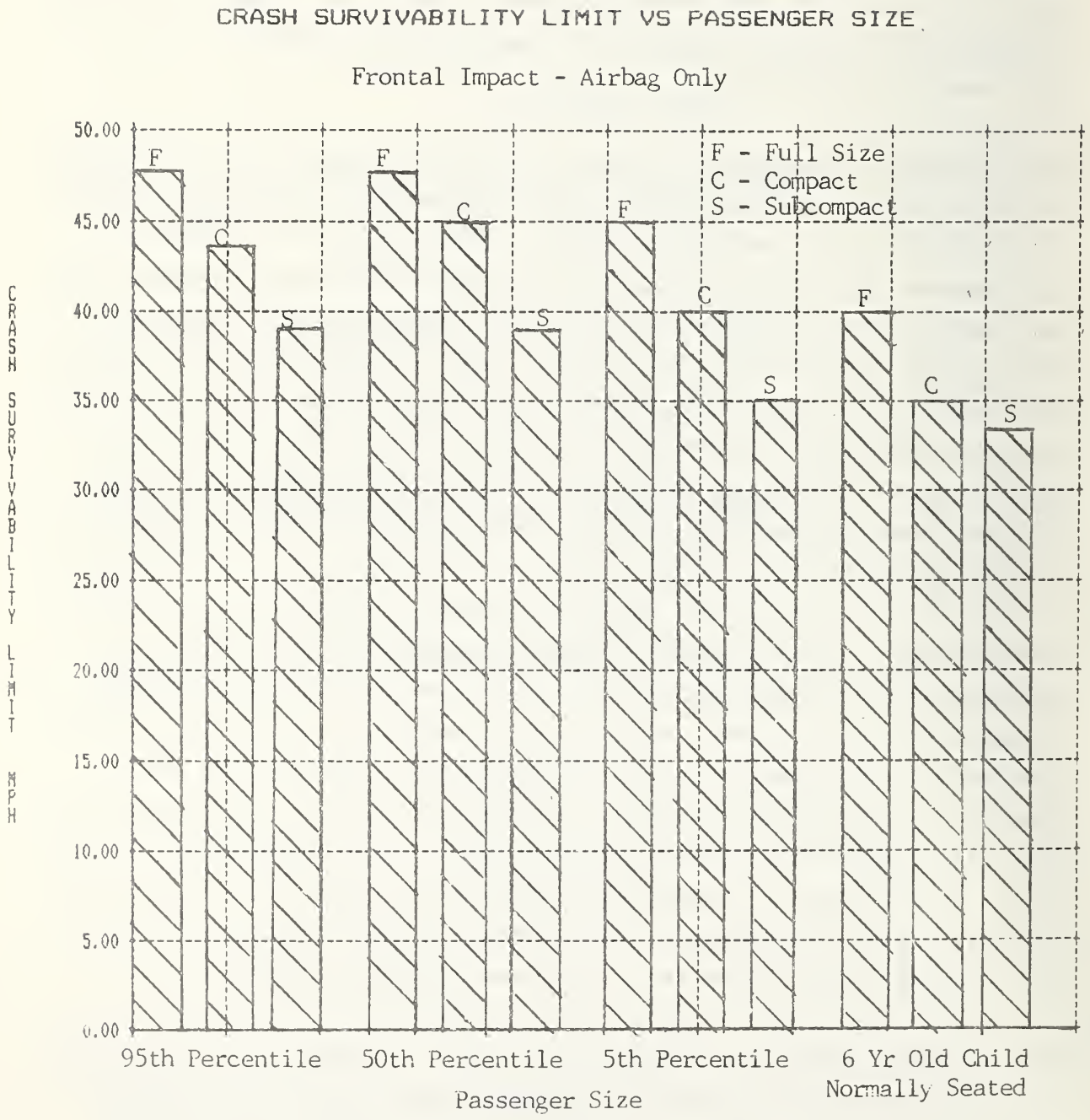

CRASH SURVIVABILITY LIMIT VS PASSENGER SIZE
Frontal Impact - Airbag Only
F - Full Size
C - Compact
S - Subcompact
CRASH SURVIVABILITY LIMIT MPH
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
95th Percentile
50th Percentile
5th Percentile
6 Yr Old Child Normally Seated
Passenger Size

Figure 54.

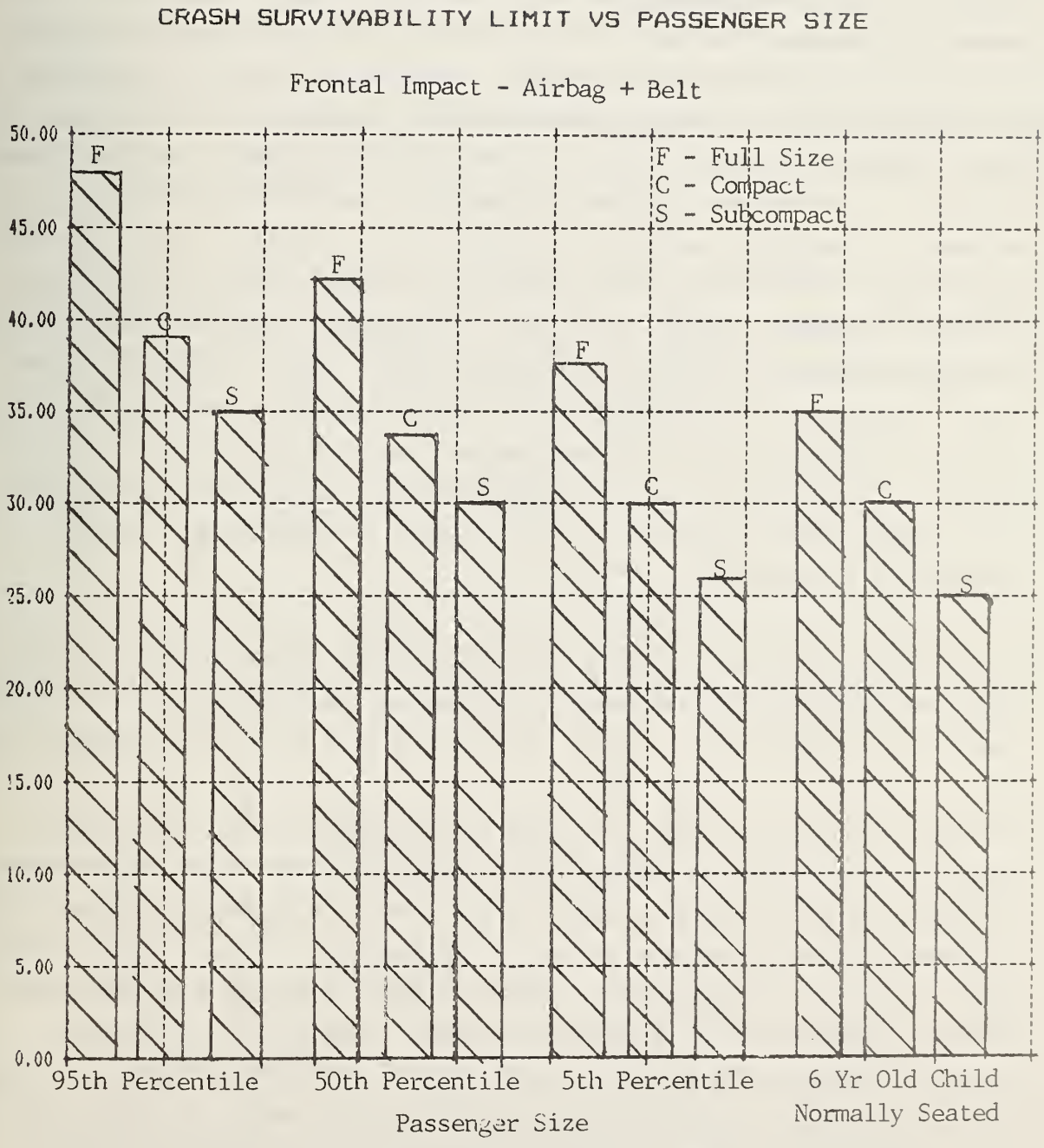

CRASH SURVIVABILITY LIMIT VS PASSENGER SIZE
Frontal Impact - Airbag + Belt
F - Full Size
C - Compact
S - Subcompact
CRASH SURVIVABILITY LIMIT MPH
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
F
C
S
F
C
S
F
C
S
F
C
S
95th Percentile
50th Percentile
5th Percentile
6 Yr Old Child
Normally Seated
Passenger Size

Figure 55.

size.

4. The full size vehicle is generally "vehicle crush critical" meaning that the passenger Survivability Limit is greater for restraint system induced injury than for the potential danger of injury presented by intruding structural surfaces. Another way of putting this is that the restraint system has the capability of protecting the passenger to velocities higher than the vehicle itself can withstand before becoming so severely deformed as to present a separate source of potentially serious injury to the passenger. Admittedly, the choice of crush value at which the vehicle becomes "crush critical" is somewhat subjective since it is based upon the author's personal experience. However, some limit should be placed upon the crush a given vehicle can attain before ceasing to provide passenger compartment integrity and posing a "dangerous" environment to the passenger. It was this realization that led to the imposition of the crush limits presented in Section 1.2.4.

5. The condition which had the lowest overall Survivability Limit was the 5th percentile female passenger restrained by the airbag and three-point belt system simultaneously in the subcompact car.

6. The Survivability Limit is generally highest for the larger vehicle occupants in larger cars and decreases with a decrease in occupant and/or vehicle size. This trend is shown graphically by Figures 54 and 55 where only the passenger in the frontal impact mode is shown although the trend is very similar for the other accident modes and the driver as well. The only difference between Figures 54 and 55 is the restraint system used. In Figure 54 the restraint system is the airbag only while in Figure 55 the restraint system is the airbag plus the three-point belt system.

7. For the restraint systems simulated for this study, the critical injury mode for the passenger is the chest in over 91% of the injury critical cases while the femurs are critical the other 9% of the time. Interestingly, the HIC is never the critical injury mode for the passenger. This is consistent with the author's experience for airbag restraint systems which provide support for the head thereby minimizing the head rotational velocity and ,correspondingly, the head G's.

8. Using the Survivability Margin curves contained in Figures 35 through 52 and the Survivability Limits shown in Figure 53 as a reference, the following ranking of Survivability Margin may be made for the right front passenger.

Rank	Crash Mode	Vehicle	MPH	Pass.	Restraint	Criteria
1	Frontal	Full Size	47.5	95th	Airbag	Crush
	Frontal	Full Size	47.5	95th	Belt&Bag	Crush
	Frontal	Full Size	47.5	50th	Airbag	Crush
	Frontal	Full Size	47.5	OPC	Airbag	Crush
2	Frontal	Full Size	45.0	5th	Airbag	Femur
	Frontal	Compact	45.0	50th	Airbag	Femur
3	Oblique	Compact	44.2	95th	Belt&Bag	Chest&Crush
	Oblique	Compact	44.2	95th	Airbag	Crush
	Oblique	Compact	44.2	50th	Airbag	Crush
4	Oblique	Full Size	43.4	95th	Belt&Bag	Crush
	Oblique	Full Size	43.4	95th	Airbag	Crush
	Oblique	Full Size	43.4	50th	Airbag	Crush
	Oblique	Full Size	43.4	50th	Belt&Bag	Crush
	Oblique	Full Size	43.4	5th	Belt&Bag	Crush
	Oblique	Full Size	43.4	5th	Airbag	Crush
5	Frontal	Compact	43.0	95th	Airbag	Chest
6	Frontal	Full Size	42.0	50th	Belt&Bag	Chest
7	Offset	Full Size	40.1	95th	Airbag	Crush
	Offset	Full Size	40.1	95th	Belt&Bag	Crush
	Offset	Full Size	40.1	50th	Airbag	Crush
	Offset	Full Size	40.1	50th	Belt&Bag	Crush
	Offset	Full Size	40.1	5th	Airbag	Crush
	Offset	Full Size	40.1	5th	Belt&Bag	Crush

8	Frontal	Compact	40.0	5th	Airbag	Femur
	Oblique	Compact	40.0	5th	Airbag	Chest
	Oblique	Subcompact	40.0	50th	Airbag	Chest
	Frontal	Full Size	40.0	NSC	Airbag	Chest
9	Offset	Compact	39.9	95th	Airbag	Crush
	Offset	Compact	39.9	95th	Belt&Bag	Crush
	Offset	Compact	39.9	50th	Airbag	Crush
	Offset	Compact	39.9	50th	Belt&Bag	Crush
	Offset	Compact	39.9	5th	Airbag	Crush
	Offset	Compact	39.9	5th	Belt&Bag	Crush
10	Frontal	Compact	39.0	95th	Belt&Bag	Chest
	Offset	Subcompact	39.0	95th	Airbag	Crush
	Offset	Subcompact	39.0	95th	Belt&Bag	Crush
	Offset	Subcompact	39.0	50th	Airbag	Crush
	Offset	Subcompact	39.0	5th	Airbag	Crush
	Oblique	Subcompact	39.0	95th	Airbag	Chest
	Frontal	Compact	39.0	OPC	Airbag	Chest
11	Frontal	Subcompact	38.5	50th	Airbag	Chest
12	Frontal	Subcompact	38.0	95th	Airbag	Chest
13	Frontal	Full Size	37.5	5th	Belt&Bag	Chest
14	Oblique	Subcompact	37.0	95th	Belt&Bag	Chest
15	Oblique	Subcompact	36.0	5th	Airbag	Chest
16	Frontal	Subcompact	35.0	95th	Belt&Bag	Chest
	Frontal	Subcompact	35.0	5th	Airbag	Chest
	Oblique	Compact	35.0	50th	Belt&Bag	Chest

	Frontal	Full Size	35.0	NSC	Belt&Bag	Chest
	Frontal	Compact	35.0	NSC	Airbag	Chest
17	Offset	Subcompact	34.0	50th	Belt&Bag	Chest
18	Frontal	Compact	33.0	50th	Belt&Bag	Chest
	Frontal	Subcompact	33.0	NSC	Airbag	Chest
19	Frontal	Subcompact	32.5	OPC	Airbag	Chest
20	Oblique	Compact	31.2	5th	Belt&Bag	Chest
21	Offset	Subcompact	31.0	5th	Belt&Bag	Chest
22	Frontal	Compact	30.0	5th	Belt&Bag	Chest
	Frontal	Subcompact	30.0	50th	Belt&Bag	Chest
	Oblique	Subcompact	30.0	50th	Belt&Bag	Chest
	Frontal	Compact	30.0	NSC	Belt&Bag	Chest
23	Oblique	Subcompact	26.0	5th	Belt&Bag	Chest
24	Frontal	Subcompact	25.7	5th	Belt&Bag	Chest
25	Frontal	Subcompact	25.0	NSC	Belt&Bag	Chest

This completes the report describing the Crash Survivability Analysis conducted to meet the objectives of this program.

Appendix A

Computer Derived Crash Pulses

SUBCOMPACT CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET FD RATIO	DELTA V - MPH
.09	.055	.85	25

	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
TIME SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	25.000	0.000	0.000	25.000	0.000	0.000	25.000	0.000
0.005	0.769	24.972	2.138	2.318	24.873	2.196	0.474	24.983	2.148
0.010	2.983	24.778	4.154	4.636	24.491	4.370	1.853	24.863	4.191
0.015	6.375	24.274	6.046	6.955	23.856	6.499	4.017	24.547	6.129
0.020	10.536	23.352	7.815	9.273	22.966	8.561	6.778	23.960	7.963
0.025	14.964	21.953	9.462	11.591	21.822	10.534	9.893	23.048	9.692
0.030	19.125	20.079	10.985	13.909	20.423	12.394	13.091	21.787	11.317
0.035	22.517	17.786	12.385	16.227	18.770	14.121	16.092	20.183	12.837
0.040	24.731	15.182	13.662	18.545	16.863	15.691	18.633	18.273	14.253
0.045	25.500	12.414	14.816	20.864	14.702	17.081	20.494	16.121	15.563
0.050	24.731	9.645	15.847	23.182	12.287	18.271	21.510	13.809	16.770
0.055	22.517	7.042	16.755	25.500	9.617	19.236	21.594	11.436	17.871
0.060	19.125	4.749	17.539	21.857	7.020	19.965	20.738	9.106	18.868
0.065	14.964	2.874	18.201	18.214	4.822	20.484	19.017	6.919	19.761
0.070	10.536	1.476	18.740	14.571	3.024	20.826	16.581	4.961	20.549
0.075	6.375	0.553	19.155	10.929	1.626	21.027	13.642	3.300	21.232
0.080	2.983	0.049	19.448	7.286	0.627	21.124	10.459	1.977	21.810
0.085	0.769	-0.144	19.617	3.643	0.027	21.149	7.309	1.004	22.284
0.090	0.000	-0.172	19.663	0.000	-0.172	21.140	4.467	0.362	22.654
0.095	0.000	-0.172	19.663	0.000	-0.172	21.140	2.182	0.004	22.919
0.100	0.000	-0.172	19.663	0.000	-0.172	21.140	0.654	-0.144	23.079
0.105	0.000	-0.172	19.663	0.000	-0.172	21.140	0.015	-0.172	23.134

PGF = 25.5 G'S

SUBCOMPACT CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.09	.055	.85	30

TIME	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	30.000	0.000	0.000	30.000	0.000	0.000	30.000	0.000
0.005	0.920	29.966	2.566	2.773	29.848	2.636	0.566	29.979	2.577
0.010	3.568	29.735	4.986	5.545	29.392	5.244	2.216	29.836	5.030
0.015	7.625	29.132	7.258	8.318	28.631	7.800	4.805	29.459	7.357
0.020	12.602	28.028	9.382	11.091	27.567	10.275	8.107	28.756	9.559
0.025	17.898	26.356	11.360	13.864	26.198	12.642	11.833	27.665	11.636
0.030	22.875	24.114	13.190	16.636	24.526	14.877	15.658	26.156	13.588
0.035	26.932	21.371	14.874	19.409	22.549	16.950	19.247	24.239	15.415
0.040	29.580	18.257	16.410	22.182	20.268	18.836	22.287	21.954	17.116
0.045	30.500	14.946	17.799	24.955	17.683	20.508	24.512	19.379	18.693
0.050	29.580	11.634	19.040	27.727	14.794	21.940	25.728	16.614	20.144
0.055	26.932	8.520	20.135	30.500	11.601	23.103	25.828	13.776	21.470
0.060	22.875	5.778	21.082	26.143	8.494	23.984	24.804	10.990	22.672
0.065	17.898	3.536	21.882	21.786	5.866	24.612	22.745	8.373	23.748
0.070	12.602	1.863	22.535	17.429	3.715	25.030	19.832	6.031	24.699
0.075	7.625	0.760	23.040	13.071	2.042	25.280	16.317	4.045	25.524
0.080	3.568	0.157	23.399	8.714	0.848	25.404	12.510	2.463	26.225
0.085	0.920	-0.075	23.610	4.357	0.131	25.443	8.742	1.299	26.801
0.090	0.000	-0.108	23.674	0.000	-0.108	25.441	5.343	0.531	27.251
0.095	0.000	-0.108	23.674	0.000	-0.108	25.441	2.610	0.102	27.576
0.100	0.000	-0.108	23.674	0.000	-0.108	25.441	0.782	-0.075	27.777
0.105	0.000	-0.108	23.674	0.000	-0.108	25.441	0.018	-0.108	27.852

PGF = 30.5 G'S

SUBCOMPACT CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.09	.055	.85	35

	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
TIME SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	35.000	0.000	0.000	35.000	0.000	0.000	35.000	0.000
0.005	1.063	34.961	2.995	3.205	34.824	3.075	0.655	34.976	3.008
0.010	4.123	34.693	5.820	6.409	34.297	6.119	2.561	34.810	5.871
0.015	8.813	33.997	8.474	9.614	33.418	9.101	5.553	34.374	8.589
0.020	14.564	32.721	10.959	12.818	32.188	11.990	9.369	33.562	11.163
0.025	20.686	30.788	13.273	16.023	30.606	14.756	13.676	32.301	13.592
0.030	26.438	28.197	15.418	19.227	28.673	17.366	18.096	30.558	15.877
0.035	31.127	25.028	17.392	22.432	26.389	19.792	22.244	28.341	18.017
0.040	34.187	21.429	19.196	25.636	23.752	22.001	25.758	25.701	20.013
0.045	35.250	17.601	20.830	28.841	20.765	23.962	28.330	22.725	21.864
0.050	34.187	13.774	22.294	32.045	17.426	25.645	29.735	19.530	23.570
0.055	31.127	10.175	23.588	35.250	13.735	27.018	29.851	16.250	25.132
0.060	26.438	7.006	24.711	30.214	10.145	28.065	28.667	13.029	26.549
0.065	20.686	4.415	25.665	25.179	7.107	28.820	26.288	10.005	27.821
0.070	14.564	2.481	26.448	20.143	4.621	29.332	22.920	7.299	28.949
0.075	8.813	1.206	27.061	15.107	2.688	29.650	18.859	5.002	29.932
0.080	4.123	0.509	27.505	10.071	1.307	29.822	14.458	3.174	30.771
0.085	1.063	0.242	27.778	5.036	0.479	29.896	10.104	1.829	31.465
0.090	0.000	0.203	27.881	0.000	0.203	29.922	6.175	0.942	32.014
0.095	0.000	0.203	27.881	0.000	0.203	29.922	3.017	0.446	32.419
0.100	0.000	0.203	27.881	0.000	0.203	29.922	0.903	0.242	32.680
0.105	0.000	0.203	27.881	0.000	0.203	29.922	0.021	0.203	32.795

PGF = 35.25 G'S

SUBCOMPACT CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET FD RATIO	DELTA V - MPH
.09	.055	.85	40

	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
TIME SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	40.000	0.000	0.000	40.000	0.000	0.000	40.000	0.000
0.005	1.221	39.955	3.422	3.682	39.798	3.514	0.752	39.972	3.437
0.010	4.738	39.648	6.649	7.364	39.192	6.993	2.943	39.782	6.708
0.015	10.125	38.847	9.680	11.045	38.183	10.400	6.380	39.281	9.812
0.020	16.734	37.382	12.516	14.727	36.769	13.701	10.765	38.348	12.751
0.025	23.766	35.161	15.157	18.409	34.952	16.860	15.712	36.899	15.523
0.030	30.375	32.184	17.602	22.091	32.731	19.841	20.791	34.896	18.130
0.035	35.762	28.542	19.851	25.773	30.106	22.608	25.557	32.350	20.570
0.040	39.279	24.407	21.905	29.455	27.077	25.127	29.594	29.317	22.844
0.045	40.500	20.010	23.764	33.136	23.645	27.362	32.549	25.897	24.951
0.050	39.279	15.613	25.427	36.818	19.808	29.277	34.164	22.226	26.893
0.055	35.762	11.478	26.895	40.500	15.568	30.837	34.297	18.457	28.669
0.060	30.375	7.836	28.167	34.714	11.443	32.020	32.937	14.757	30.278
0.065	23.766	4.859	29.244	28.929	7.953	32.869	30.203	11.282	31.721
0.070	16.734	2.638	30.125	23.143	5.097	33.439	26.334	8.173	32.998
0.075	10.125	1.173	30.811	17.357	2.876	33.785	21.667	5.535	34.109
0.080	4.738	0.372	31.301	11.571	1.289	33.963	16.612	3.434	35.054
0.085	1.221	0.065	31.596	5.786	0.337	34.030	11.609	1.889	35.833
0.090	0.000	0.020	31.696	0.000	0.020	34.041	7.095	0.869	36.446
0.095	0.000	0.020	31.696	0.000	0.020	34.041	3.466	0.300	36.892
0.100	0.000	0.020	31.696	0.000	0.020	34.041	1.038	0.065	37.172
0.105	0.000	0.020	31.696	0.000	0.020	34.041	0.024	0.020	37.286

PDF = 40.5 G'S

SUBCOMPACT CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET FD RATIO	DELTA V - MPH
.09	.055	.85	45

TIME	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	45.000	0.000	0.000	45.000	0.000	0.000	45.000	0.000
0.005	1.372	44.950	3.850	4.136	44.773	3.953	0.845	44.969	3.867
0.010	5.322	44.604	7.481	8.273	44.093	7.867	3.306	44.755	7.547
0.015	11.375	43.705	10.892	12.409	42.956	11.700	7.168	44.192	11.040
0.020	18.800	42.059	14.083	16.545	41.370	15.414	12.094	43.144	14.347
0.025	26.700	39.563	17.055	20.682	39.329	18.968	17.652	41.516	17.467
0.030	34.125	36.219	19.807	24.818	36.834	22.323	23.358	39.266	20.400
0.035	40.178	32.128	22.340	28.955	33.885	25.438	28.713	36.405	23.147
0.040	44.128	27.482	24.653	33.091	30.482	28.273	33.248	32.998	25.707
0.045	45.500	22.542	26.747	37.227	26.625	30.789	36.567	29.156	28.081
0.050	44.128	17.602	28.621	41.364	22.315	32.946	38.381	25.031	30.268
0.055	40.178	12.957	30.275	45.500	17.552	34.703	38.531	20.798	32.268
0.060	34.125	8.865	31.710	39.000	12.917	36.039	37.003	16.640	34.081
0.065	26.701	5.521	32.925	32.500	8.996	36.998	33.932	12.737	35.708
0.070	18.800	3.026	33.920	26.000	5.788	37.643	29.585	9.243	37.148
0.075	11.375	1.379	34.696	19.500	3.293	38.037	24.342	6.280	38.402
0.080	5.322	0.480	35.253	13.000	1.510	38.243	18.663	3.920	39.469
0.085	1.372	0.135	35.590	6.500	0.441	38.324	13.042	2.184	40.349
0.090	0.000	0.084	35.707	0.000	0.084	38.342	7.971	1.038	41.043
0.095	0.000	0.084	35.707	0.000	0.084	38.342	3.894	0.399	41.550
0.100	0.000	0.084	35.707	0.000	0.084	38.342	1.166	0.135	41.870
0.105	0.000	0.084	35.707	0.000	0.084	38.342	0.026	0.085	42.004

PGF = 45.5 G'S

SUBCOMPACT CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.09	.055	.85	50

	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
TIME SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	50.000	0.000	0.000	50.000	0.000	0.000	50.000	0.000
0.005	1.523	49.944	4.278	4.591	49.748	4.393	0.938	49.966	4.296
0.010	5.907	49.561	8.313	9.182	48.993	8.741	3.669	49.729	8.386
0.015	12.625	48.563	12.103	13.773	47.734	13.001	7.956	49.104	12.268
0.020	20.865	46.735	15.650	18.364	45.972	17.127	13.423	47.940	15.943
0.025	29.635	43.966	18.954	22.955	43.706	21.077	19.592	46.133	19.410
0.030	37.875	40.254	22.013	27.545	40.936	24.805	25.925	43.636	22.671
0.035	44.593	35.713	24.829	32.136	37.663	28.267	31.868	40.461	25.725
0.040	48.977	30.557	27.401	36.727	33.886	31.419	36.901	36.679	28.571
0.045	50.500	25.074	29.729	41.318	29.606	34.216	40.586	32.415	31.210
0.050	48.977	19.591	31.814	45.909	24.823	36.615	42.599	27.837	33.642
0.055	44.593	14.435	33.655	50.500	19.535	38.570	42.765	23.138	35.867
0.060	37.875	9.895	35.252	43.286	14.392	40.057	41.069	18.524	37.884
0.065	29.635	6.183	36.606	36.071	10.040	41.126	37.660	14.192	39.695
0.070	20.865	3.413	37.716	28.857	6.479	41.847	32.836	10.314	41.298
0.075	12.625	1.586	38.582	21.643	3.709	42.290	27.017	7.025	42.694
0.080	5.907	0.588	39.204	14.429	1.731	42.523	20.713	4.405	43.883
0.085	1.523	0.204	39.583	7.214	0.544	42.618	14.475	2.479	44.865
0.090	0.000	0.149	39.718	0.000	0.149	42.642	8.847	1.207	45.640
0.095	0.000	0.149	39.718	0.000	0.149	42.642	4.322	0.497	46.208
0.100	0.000	0.149	39.718	0.000	0.149	42.642	1.294	0.204	46.568
0.105	0.000	0.149	39.719	0.000	0.149	42.642	0.029	0.149	46.721

PGF = 50.5 G'S

COMPACT CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET FD RATIO	DELTA V - MPH
.1	.06	.85	30

TIME	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	30.000	0.000	0.000	30.000	0.000	0.000	30.000	0.000
0.005	0.673	29.975	2.574	2.292	29.874	2.636	0.414	29.985	2.584
0.010	2.626	29.805	5.015	4.583	29.497	5.251	1.628	29.880	5.054
0.015	5.668	29.359	7.323	6.875	28.869	7.820	3.554	29.602	7.412
0.020	9.501	28.533	9.498	9.167	27.989	10.324	6.057	29.079	9.658
0.025	13.750	27.260	11.541	11.458	26.858	12.739	8.959	28.258	11.790
0.030	17.999	25.517	13.451	13.750	25.476	15.044	12.055	27.107	13.809
0.035	21.832	23.327	15.228	16.042	23.842	17.215	15.124	25.615	15.716
0.040	24.874	20.756	16.873	18.333	21.957	19.232	17.950	23.798	17.510
0.045	26.827	17.910	18.385	20.625	19.820	21.072	20.332	21.693	19.191
0.050	27.500	14.918	19.764	22.917	17.432	22.713	22.101	19.360	20.759
0.055	26.827	11.927	21.011	25.208	14.793	24.133	23.132	16.872	22.215
0.060	24.874	9.080	22.124	27.500	11.902	25.310	23.352	14.315	23.558
0.065	21.832	6.510	23.105	24.063	9.074	26.230	22.745	11.780	24.788
0.070	17.999	4.320	23.954	20.625	6.624	26.918	21.354	9.355	25.905
0.075	13.750	2.577	24.669	17.188	4.550	27.407	19.278	7.121	26.909
0.080	9.501	1.304	25.252	13.750	2.853	27.730	16.664	5.145	27.800
0.085	5.668	0.478	25.702	10.313	1.534	27.920	13.697	3.478	28.579
0.090	2.626	0.031	26.020	6.875	0.591	28.010	10.588	2.146	29.245
0.095	0.673	-0.138	26.204	3.437	0.025	28.035	7.556	1.153	29.798
0.100	0.000	-0.163	26.256	-0.000	-0.163	28.026	4.818	0.478	30.238
0.105	0.000	-0.163	26.256	-0.000	-0.163	28.026	2.566	0.078	30.565
0.110	0.000	-0.163	26.256	-0.000	-0.163	28.026	0.961	-0.109	30.780
0.115	0.000	-0.163	26.256	-0.000	-0.163	28.026	0.117	-0.161	30.882

PGF = 27.5 G'S

COMPACT CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.1	.06	.85	35

TIME SEC	FRONTAL PULSE FR. G'S	FR. V. MPH	FR. C. IN	OBLIQUE PULSE OB. G'S	OB. V. MPH	OB. C. IN	OFFSET PULSE OF. G'S	OF. V. MPH	OF C IN
0.000	0.000	35.000	0.000	0.000	35.000	0.000	0.000	35.000	0.000
0.005	0.777	34.972	3.003	2.646	34.855	3.076	0.478	34.982	3.015
0.010	3.032	34.775	5.854	5.292	34.420	6.126	1.879	34.861	5.900
0.015	6.544	34.260	8.550	7.938	33.694	9.125	4.103	34.540	8.654
0.020	10.969	33.306	11.094	10.583	32.678	12.048	6.993	33.937	11.278
0.025	15.875	31.836	13.485	13.229	31.372	14.868	10.344	32.989	13.772
0.030	20.781	29.824	15.722	15.875	29.776	17.561	13.918	31.659	16.136
0.035	25.206	27.295	17.806	18.521	27.890	20.100	17.461	29.937	18.369
0.040	28.718	24.328	19.737	21.167	25.713	22.461	20.724	27.839	20.472
0.045	30.973	21.042	21.514	23.812	23.247	24.617	23.474	25.410	22.445
0.050	31.750	17.588	23.139	26.458	20.490	26.544	25.517	22.716	24.288
0.055	30.973	14.134	24.610	29.104	17.443	28.215	26.707	19.843	26.000
0.060	28.718	10.847	25.928	31.750	14.105	29.605	26.961	16.891	27.582
0.065	25.206	7.860	27.097	27.781	10.840	30.699	26.260	13.964	29.034
0.070	20.781	5.351	28.104	23.813	8.011	31.526	24.654	11.164	30.356
0.075	15.875	3.339	28.962	19.844	5.617	32.122	22.257	8.585	31.548
0.080	10.969	1.869	29.667	15.875	3.658	32.527	19.239	6.304	32.609
0.085	6.544	0.915	30.218	11.906	2.134	32.779	15.814	4.379	33.540
0.090	3.032	0.400	30.617	7.937	1.046	32.915	12.224	2.841	34.340
0.095	0.777	0.204	30.862	3.969	0.393	32.976	8.724	1.694	35.011
0.100	0.000	0.175	30.954	-0.000	0.175	32.997	5.562	0.915	35.551
0.105	0.000	0.175	30.954	-0.000	0.175	32.997	2.963	0.454	35.961
0.110	0.000	0.175	30.954	-0.000	0.175	32.997	1.110	0.238	36.241
0.115	0.000	0.175	30.954	-0.000	0.175	32.997	0.135	0.178	36.390

PGF = 31.75 G'S

COMPACT CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL. G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.1	.06	.85	40

TIME	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
SEC	FR. G'S	FR. V. MPH	FR. C. IN	OB. G'S	OB. V. MPH	OB. C. IN	OF. G'S	OF. V. MPH	OF C IN
0.000	0.000	40.000	0.000	0.000	40.000	0.000	0.000	40.000	0.000
0.005	0.887	39.967	3.433	3.021	39.834	3.515	0.546	39.980	3.446
0.010	3.462	39.744	6.690	6.042	39.337	7.001	2.145	39.842	6.743
0.015	7.471	39.155	9.773	9.063	38.509	10.429	4.685	39.475	9.891
0.020	12.524	38.066	12.680	12.083	37.349	13.769	7.984	38.786	12.890
0.025	18.125	36.388	15.413	15.104	35.858	16.993	11.810	37.704	15.741
0.030	23.726	34.090	17.971	18.125	34.036	20.070	15.890	36.186	18.443
0.035	28.779	31.203	20.354	21.146	31.882	22.973	19.936	34.220	20.997
0.040	32.788	27.815	22.562	24.167	29.397	25.672	23.661	31.824	23.401
0.045	35.363	24.063	24.595	27.187	26.581	28.137	26.801	29.050	25.657
0.050	36.250	20.120	26.453	30.208	23.433	30.340	29.133	25.975	27.765
0.055	35.363	16.176	28.136	33.229	19.954	32.252	30.492	22.695	29.723
0.060	32.788	12.424	29.644	36.250	16.144	33.843	30.782	19.325	31.533
0.065	28.779	9.036	30.977	31.719	12.416	35.096	29.982	15.983	33.194
0.070	23.726	6.149	32.135	27.188	9.186	36.042	28.148	12.786	34.707
0.075	18.125	3.852	33.119	22.656	6.452	36.727	25.412	9.841	36.071
0.080	12.524	2.173	33.927	18.125	4.216	37.193	21.966	7.237	37.286
0.085	7.471	1.084	34.560	13.594	2.476	37.483	18.055	5.039	38.352
0.090	3.462	0.496	35.019	9.062	1.234	37.643	13.956	3.283	39.270
0.095	0.887	0.272	35.302	4.531	0.488	37.715	9.961	1.974	40.039
0.100	0.000	0.240	35.411	-0.000	0.240	37.743	6.351	1.084	40.659
0.105	0.000	0.240	35.411	-0.000	0.240	37.743	3.383	0.557	41.131
0.110	0.000	0.240	35.411	-0.000	0.240	37.743	1.267	0.311	41.454
0.115	0.000	0.240	35.411	-0.000	0.240	37.743	0.154	0.242	41.628

PGF = 36.25 G'S

COMPACT CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.1	.06	.85	45

	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
TIME SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	45.000	0.000	0.000	45.000	0.000	0.000	45.000	0.000
0.005	1.003	44.963	3.861	3.417	44.813	3.955	0.618	44.977	3.876
0.010	3.915	44.710	7.524	6.833	44.250	7.876	2.427	44.821	7.584
0.015	8.450	44.045	10.990	10.250	43.314	11.732	5.299	44.406	11.123
0.020	14.165	42.813	14.257	13.667	42.002	15.488	9.030	43.627	14.494
0.025	20.500	40.915	17.327	17.083	40.316	19.113	13.357	42.403	17.698
0.030	26.835	38.316	20.198	20.500	38.254	22.573	17.972	40.686	20.733
0.035	32.550	35.051	22.872	23.917	35.819	25.835	22.549	38.462	23.599
0.040	37.085	31.219	25.348	27.333	33.008	28.866	26.762	35.753	26.298
0.045	39.997	26.975	27.626	30.750	29.822	31.633	30.313	32.616	28.828
0.050	41.000	22.515	29.706	34.167	26.262	34.104	32.951	29.137	31.191
0.055	39.997	18.055	31.589	37.583	22.327	36.244	34.488	25.428	33.385
0.060	37.085	13.811	33.273	41.000	18.018	38.022	34.816	21.616	35.410
0.065	32.550	9.979	34.760	35.875	13.802	39.418	33.911	17.835	37.268
0.070	26.835	6.714	36.049	30.750	10.148	40.468	31.837	14.220	38.957
0.075	20.500	4.115	37.140	25.625	7.056	41.221	28.742	10.889	40.479
0.080	14.165	2.217	38.033	20.500	4.527	41.726	24.844	7.944	41.832
0.085	8.450	0.985	38.728	15.375	2.559	42.034	20.421	5.458	43.017
0.090	3.915	0.320	39.225	10.250	1.154	42.193	15.785	3.472	44.033
0.095	1.003	0.066	39.524	5.125	0.311	42.253	11.266	1.991	44.882
0.100	0.000	0.030	39.626	-0.000	0.030	42.264	7.183	0.985	45.562
0.105	0.000	0.030	39.626	-0.000	0.030	42.264	3.826	0.389	46.074
0.110	0.000	0.030	39.626	-0.000	0.030	42.264	1.433	0.110	46.418
0.115	0.000	0.030	39.626	-0.000	0.030	42.264	0.174	0.033	46.594

PGF = 41 G'S

COMPACT CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET FD RATIO	DELTA V - MPH
.1	.06	.85	50

TIME SEC	FRONTAL PULSE FR. G'S G'S	FR. V. MPH	FR. C. IN	OBLIQUE PULSE OB. G'S G'S	OB. V. MPH	OB. C. IN	OFFSET PULSE OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	50.000	0.000	0.000	50.000	0.000	0.000	50.000	0.000
0.005	1.113	49.959	4.290	3.792	49.792	4.394	0.685	49.975	4.307
0.010	4.345	49.678	8.361	7.583	49.168	8.751	2.693	49.801	8.427
0.015	9.378	48.940	12.212	11.375	48.129	13.035	5.880	49.341	12.360
0.020	15.720	47.573	15.843	15.167	46.673	17.210	10.022	48.476	16.107
0.025	22.750	45.466	19.255	18.958	44.801	21.238	14.823	47.118	19.667
0.030	29.780	42.582	22.447	22.750	42.514	25.082	19.945	45.213	23.040
0.035	36.122	38.959	25.420	26.542	39.811	28.708	25.024	42.745	26.227
0.040	41.155	34.706	28.173	30.333	36.692	32.077	29.699	39.738	29.227
0.045	44.387	29.997	30.707	34.125	33.157	35.153	33.640	36.256	32.041
0.050	45.500	25.047	33.021	37.917	29.206	37.900	36.567	32.396	34.668
0.055	44.387	20.097	35.115	41.708	24.839	40.281	38.273	28.280	37.108
0.060	41.155	15.388	36.990	45.500	20.056	42.260	38.637	24.049	39.361
0.065	36.122	11.135	38.645	39.813	15.378	43.814	37.632	19.854	41.428
0.070	29.780	7.512	40.080	34.125	11.323	44.985	35.331	15.841	43.308
0.075	22.750	4.627	41.296	28.438	7.892	45.825	31.896	12.145	45.002
0.080	15.720	2.521	42.293	22.750	5.084	46.392	27.571	8.877	46.509
0.085	9.378	1.154	43.070	17.063	2.901	46.739	22.662	6.118	47.829
0.090	4.345	0.416	43.627	11.375	1.341	46.921	17.518	3.914	48.963
0.095	1.113	0.135	43.964	5.687	0.406	46.993	12.502	2.271	49.910
0.100	0.000	0.094	44.082	-0.000	0.094	47.010	7.971	1.154	50.670
0.105	0.000	0.094	44.082	-0.000	0.094	47.010	4.246	0.492	51.244
0.110	0.000	0.094	44.082	-0.000	0.094	47.010	1.590	0.183	51.631
0.115	0.000	0.094	44.082	-0.000	0.094	47.010	0.193	0.097	51.831

PGF = 45.5 G'S

INTERMEDIATE CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.11	.065	.85	30

	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
TIME SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	30.000	0.000	0.000	30.000	0.000	0.000	30.000	0.000
0.005	0.506	29.981	2.580	1.923	29.895	2.637	0.312	29.989	2.589
0.010	1.984	29.853	5.039	3.846	29.578	5.255	1.228	29.910	5.075
0.015	4.314	29.515	7.377	5.769	29.051	7.836	2.695	29.699	7.459
0.020	7.307	28.883	9.595	7.692	28.313	10.362	4.628	29.301	9.740
0.025	10.721	27.896	11.692	9.615	27.363	12.813	6.912	28.671	11.918
0.030	14.279	26.525	13.668	11.538	26.203	15.172	9.414	27.777	13.994
0.035	17.693	24.769	15.524	13.462	24.832	17.419	11.987	26.603	15.967
0.040	20.686	22.660	17.259	15.385	23.250	19.536	14.480	25.150	17.838
0.045	23.016	20.256	18.874	17.308	21.457	21.505	16.747	23.435	19.607
0.050	24.494	17.642	20.367	19.231	19.453	23.306	18.655	21.490	21.272
0.055	25.000	14.918	21.741	21.154	17.239	24.922	20.092	19.360	22.835
0.060	24.494	12.195	22.993	23.077	14.813	26.334	20.974	17.103	24.296
0.065	23.016	9.581	24.125	25.000	12.176	27.523	21.249	14.781	25.654
0.070	20.686	7.177	25.136	22.222	9.587	28.479	20.901	12.464	26.910
0.075	17.693	5.067	26.027	19.444	7.301	29.219	19.950	10.218	28.063
0.080	14.279	3.311	26.796	16.667	5.321	29.773	18.453	8.108	29.113
0.085	10.721	1.940	27.446	13.889	3.645	30.165	16.496	6.187	30.061
0.090	7.307	0.954	27.974	11.111	2.274	30.423	14.196	4.501	30.906
0.095	4.314	0.322	28.382	8.333	1.208	30.574	11.685	3.081	31.649
0.100	1.984	-0.016	28.670	5.556	0.446	30.645	9.113	1.940	32.289
0.105	0.506	-0.145	28.836	2.778	-0.011	30.662	6.629	1.079	32.827
0.110	0.000	-0.163	28.882	-0.000	-0.163	30.652	4.380	0.478	33.262
0.115	0.000	-0.163	28.882	-0.000	-0.163	30.652	2.497	0.104	33.594
0.120	0.000	-0.163	28.882	-0.000	-0.163	30.652	1.090	-0.088	33.824
0.125	0.000	-0.163	28.882	-0.000	-0.163	30.652	0.243	-0.155	33.952
0.130	0.000	-0.163	28.882	-0.000	-0.163	30.652	0.004	-0.163	33.977

PGF = 25 G'S

INTERMEDIATE CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.11	.065	.85	35

TIME SEC	FRONTAL PULSE FR. G'S G'S	FR. V. MPH	FR. C. IN	OBLIQUE PULSE OB. G'S G'S	OB. V. MPH	OB. C. IN	OFFSET PULSE OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	35.000	0.000	0.000	35.000	0.000	0.000	35.000	0.000
0.005	0.587	34.978	3.010	2.231	34.878	3.076	0.361	34.987	3.021
0.010	2.302	34.830	5.880	4.462	34.511	6.131	1.424	34.895	5.922
0.015	5.005	34.437	8.610	6.692	33.899	9.143	3.127	34.651	8.705
0.020	8.476	33.704	11.200	8.923	33.043	12.090	5.368	34.189	11.368
0.025	12.436	32.560	13.651	11.154	31.942	14.951	8.018	33.458	13.913
0.030	16.564	30.970	15.961	13.385	30.596	17.705	10.920	32.421	16.339
0.035	20.524	28.933	18.131	15.615	29.005	20.329	13.905	31.060	18.645
0.040	23.995	26.485	20.161	17.846	27.170	22.803	16.797	29.374	20.833
0.045	26.698	23.697	22.052	20.077	25.090	25.104	19.426	27.385	22.902
0.050	28.413	20.665	23.802	22.308	22.766	27.211	21.640	25.128	24.852
0.055	29.000	17.505	25.413	24.538	20.197	29.104	23.307	22.658	26.683
0.060	28.413	14.346	26.883	26.769	17.383	30.759	24.330	20.039	28.395
0.065	26.698	11.314	28.214	29.000	14.325	32.156	24.649	17.346	29.988
0.070	23.995	8.526	29.404	25.778	11.320	33.282	24.245	14.658	31.462
0.075	20.524	6.078	30.455	22.556	8.670	34.159	23.142	12.053	32.817
0.080	16.564	4.041	31.366	19.333	6.372	34.818	21.405	9.605	34.053
0.085	12.436	2.451	32.136	16.111	4.429	35.290	19.136	7.377	35.170
0.090	8.476	1.307	32.767	12.889	2.838	35.608	16.467	5.422	36.168
0.095	5.005	0.573	33.258	9.667	1.601	35.800	13.555	3.774	37.047
0.100	2.302	0.181	33.609	6.444	0.718	35.900	10.571	2.451	37.807
0.105	0.587	0.032	33.820	3.222	0.187	35.937	7.690	1.451	38.449
0.110	0.000	0.011	33.890	-0.000	0.011	35.943	5.081	0.754	38.971
0.115	0.000	0.011	33.890	-0.000	0.011	35.943	2.896	0.321	39.374
0.120	0.000	0.011	33.890	-0.000	0.011	35.943	1.265	0.098	39.659
0.125	0.000	0.011	33.890	-0.000	0.011	35.943	0.282	0.020	39.824
0.130	0.000	0.011	33.890	-0.000	0.011	35.943	0.005	0.011	39.870

PGF = 29 G'S

INTERMEDIATE CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.11	.065	.85	40

TIME	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
SEC	FR. G'S	FR. V.	FR. C.	OB. G'S	OB. V.	OB. C.	OF. G'S	OF. V.	OF C
	G'S	MPH	IN	G'S	MPH	IN	G'S	MPH	IN
0.000	0.000	40.000	0.000	0.000	40.000	0.000	0.000	40.000	0.000
0.005	0.668	39.975	3.440	2.538	39.861	3.516	0.411	39.985	3.452
0.010	2.619	39.806	6.721	5.077	39.443	7.007	1.621	39.881	6.769
0.015	5.695	39.360	9.943	7.615	38.747	10.450	3.558	39.603	9.951
0.020	9.646	38.525	12.806	10.154	37.773	13.819	6.109	39.078	12.997
0.025	14.152	37.223	15.609	12.692	36.520	17.090	9.124	38.246	15.908
0.030	18.848	35.414	18.253	15.231	34.988	20.238	12.426	37.066	18.683
0.035	23.354	33.096	20.738	17.769	33.178	23.239	15.823	35.516	21.323
0.040	27.305	30.311	23.064	20.308	31.090	26.069	19.113	33.598	23.828
0.045	30.381	27.138	25.230	22.846	28.724	28.703	22.106	31.334	26.197
0.050	32.332	23.687	27.237	25.385	26.079	31.116	24.624	28.767	28.431
0.055	33.000	20.092	29.085	27.923	23.155	33.285	26.521	25.955	30.530
0.060	32.332	16.497	30.773	30.462	19.953	35.183	27.686	22.975	32.493
0.065	30.381	13.047	32.302	33.000	16.473	36.788	28.049	19.911	34.321
0.070	27.305	9.874	33.672	29.333	13.054	38.085	27.589	16.853	36.014
0.075	23.354	7.089	34.883	25.667	10.038	39.098	26.334	13.888	37.571
0.080	18.848	4.771	35.935	22.000	7.424	39.863	24.358	11.102	38.992
0.085	14.152	2.961	36.827	18.333	5.212	40.416	21.775	8.567	40.279
0.090	9.646	1.660	37.560	14.667	3.402	40.792	18.738	6.342	41.430
0.095	5.695	0.825	38.133	11.000	1.994	41.027	15.425	4.467	42.445
0.100	2.619	0.378	38.548	7.333	0.989	41.155	12.029	2.961	43.326
0.105	0.668	0.209	38.803	3.667	0.386	41.212	8.751	1.824	44.070
0.110	0.000	0.185	38.899	-0.000	0.185	41.235	5.781	1.030	44.680
0.115	0.000	0.185	38.899	-0.000	0.185	41.235	3.296	0.538	45.154
0.120	0.000	0.185	38.899	-0.000	0.185	41.235	1.439	0.284	45.493
0.125	0.000	0.185	38.899	-0.000	0.185	41.235	0.321	0.195	45.696
0.130	0.000	0.185	38.899	-0.000	0.185	41.235	0.006	0.185	45.764

PGF = 33 G'S

INTERMEDIATE CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET FD RATIO	DELTA V - MPH
.11	.065	.85	45

TIME	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	45.000	0.000	0.000	45.000	0.000	0.000	45.000	0.000
0.005	0.754	44.972	3.870	2.865	44.843	3.955	0.464	44.983	3.984
0.010	2.957	44.781	7.560	5.731	44.371	7.883	1.830	44.865	7.614
0.015	6.428	44.277	11.071	8.596	43.586	11.756	4.016	44.552	11.192
0.020	10.888	43.335	14.402	11.462	42.486	15.545	6.895	43.959	14.618
0.025	15.974	41.866	17.553	14.327	41.071	19.224	10.299	43.020	17.890
0.030	21.276	39.823	20.524	17.192	39.343	22.764	14.027	41.688	21.009
0.035	26.362	37.206	23.316	20.058	37.300	26.139	17.860	39.939	23.976
0.040	30.822	34.063	25.927	22.923	34.943	29.320	21.575	37.774	26.790
0.045	34.293	30.481	28.359	25.788	32.271	32.280	24.953	35.218	29.451
0.050	36.496	26.587	30.611	28.654	29.286	34.990	27.796	32.320	31.960
0.055	37.250	22.528	32.684	31.519	25.986	37.425	29.937	29.147	34.315
0.060	36.496	18.470	34.576	34.385	22.371	39.555	31.251	25.783	36.518
0.065	34.293	14.576	36.289	37.250	18.443	41.353	31.661	22.324	38.568
0.070	30.822	10.994	37.822	33.111	14.584	42.803	31.142	18.871	40.465
0.075	26.362	7.950	39.176	28.972	11.179	43.933	29.726	15.525	42.209
0.080	21.276	5.234	40.349	24.833	8.228	44.784	27.495	12.380	43.801
0.085	15.974	3.191	41.343	20.694	5.732	45.394	24.580	9.519	45.239
0.090	10.888	1.722	42.157	16.556	3.689	45.806	21.151	7.007	46.525
0.095	6.428	0.780	42.791	12.417	2.100	46.057	17.411	4.891	47.658
0.100	2.957	0.276	43.246	8.278	0.965	46.188	13.578	3.191	48.639
0.105	0.754	0.085	43.520	4.139	0.284	46.240	9.877	1.907	49.466
0.110	0.000	0.057	43.615	-0.000	0.057	46.252	6.526	1.012	50.141
0.115	0.000	0.057	43.615	-0.000	0.057	46.252	3.720	0.455	50.663
0.120	0.000	0.057	43.615	-0.000	0.057	46.252	1.624	0.170	51.032
0.125	0.000	0.057	43.615	-0.000	0.057	46.252	0.362	0.069	51.248
0.130	0.000	0.057	43.615	-0.000	0.057	46.252	0.006	0.057	51.311

PGF = 37.25 G'S

INTERMEDIATE CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.11	.065	.85	50

	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
TIME SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	50.000	0.000	0.000	50.000	0.000	0.000	50.000	0.000
0.005	0.835	49.969	4.300	3.173	49.826	4.395	0.514	49.981	4.315
0.010	3.274	49.758	8.402	6.346	49.304	8.759	2.026	49.851	8.462
0.015	7.118	49.200	12.304	9.519	48.434	13.062	4.447	49.503	12.439
0.020	12.057	48.156	16.007	12.692	47.216	17.273	7.636	48.847	16.246
0.025	17.690	46.529	19.512	15.865	45.650	21.362	11.405	47.867	19.885
0.030	23.560	44.267	22.817	19.038	43.735	25.297	15.533	46.332	23.354
0.035	29.193	41.370	25.923	22.212	41.473	29.049	19.778	44.395	26.654
0.040	34.132	37.888	28.830	25.385	38.863	32.586	23.892	41.998	29.785
0.045	37.976	33.922	31.537	28.558	35.905	35.879	27.632	39.168	32.747
0.050	40.415	29.609	34.046	31.731	32.598	38.895	30.780	35.958	35.539
0.055	41.250	25.115	36.356	34.904	28.944	41.606	33.152	32.444	38.162
0.060	40.415	20.622	38.466	38.077	24.941	43.979	34.607	28.719	40.617
0.065	37.976	16.309	40.378	41.250	20.591	45.985	35.061	24.889	42.901
0.070	34.132	12.342	42.090	36.667	15.318	47.606	34.487	21.066	45.017
0.075	29.193	8.861	43.604	32.083	12.547	48.872	32.918	17.360	46.963
0.080	23.560	5.964	44.918	27.500	9.280	49.829	30.447	13.878	48.740
0.085	17.690	3.702	46.033	22.917	6.515	50.520	27.219	10.709	50.348
0.090	12.057	2.075	46.950	18.333	4.253	50.990	23.423	7.927	51.787
0.095	7.118	1.031	47.667	13.750	2.493	51.283	19.281	5.583	53.057
0.100	3.274	0.473	48.185	9.167	1.236	51.444	15.036	3.702	54.157
0.105	0.835	0.261	48.504	4.583	0.482	51.516	10.938	2.280	55.088
0.110	0.000	0.231	48.623	-0.000	0.231	51.543	7.227	1.288	55.850
0.115	0.000	0.231	48.623	-0.000	0.231	51.543	4.119	0.672	56.443
0.120	0.000	0.231	48.623	-0.000	0.231	51.543	1.799	0.356	56.866
0.125	0.000	0.231	48.623	-0.000	0.231	51.543	0.401	0.244	57.120
0.130	0.000	0.231	48.623	-0.000	0.231	51.543	0.007	0.231	57.205

PGF = 41.25 G'S

FULL SIZE CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.115	.07	.85	30

TIME	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	30.000	0.000	0.000	30.000	0.000	0.000	30.000	0.000
0.005	0.440	29.984	2.583	1.696	29.907	2.637	0.271	29.990	2.591
0.010	1.729	29.872	5.051	3.393	29.628	5.258	1.069	29.921	5.085
0.015	3.770	29.577	7.404	5.089	29.163	7.846	2.352	29.738	7.482
0.020	6.412	29.023	9.643	6.786	28.511	10.385	4.050	29.390	9.781
0.025	9.459	28.156	11.767	8.482	27.674	12.859	6.072	28.838	11.982
0.030	12.685	26.942	13.777	10.179	26.651	15.251	8.311	28.050	14.086
0.035	15.852	25.375	15.672	11.875	25.441	17.544	10.645	27.011	16.093
0.040	18.723	23.475	17.452	13.571	24.046	19.723	12.950	25.716	18.002
0.045	21.087	21.286	19.118	15.268	22.464	21.771	15.101	24.176	19.814
0.050	22.767	18.875	20.669	16.964	20.696	23.671	16.983	22.413	21.529
0.055	23.639	16.322	22.105	18.661	18.743	25.408	18.496	20.464	23.146
0.060	23.639	13.721	23.427	20.357	16.603	26.964	19.558	18.372	24.665
0.065	22.767	11.168	24.635	22.054	14.277	28.324	20.111	16.192	26.087
0.070	21.087	8.756	25.727	23.750	11.765	29.472	20.127	13.980	27.412
0.075	18.723	6.567	26.705	21.111	9.305	30.396	19.605	11.796	28.639
0.080	15.852	4.667	27.569	18.472	7.134	31.118	18.572	9.698	29.769
0.085	12.685	3.101	28.317	15.833	5.253	31.661	17.083	7.739	30.802
0.090	9.459	1.887	28.952	13.194	3.661	32.051	15.220	5.965	31.737
0.095	6.412	1.019	29.471	10.556	2.358	32.313	13.081	4.410	32.574
0.100	3.770	0.465	29.876	7.917	1.345	32.474	10.783	3.101	33.315
0.105	1.729	0.170	30.166	5.278	0.621	32.558	8.447	2.046	33.957
0.110	0.440	0.059	30.342	2.639	0.187	32.592	6.199	1.245	34.503
0.115	0.000	0.043	30.403	-0.000	0.043	32.600	4.161	0.679	34.951
0.120	0.000	0.043	30.403	-0.000	0.043	32.600	2.441	0.320	35.301
0.125	0.000	0.043	30.403	-0.000	0.043	32.600	1.132	0.128	35.554
0.130	0.000	0.043	30.403	-0.000	0.043	32.600	0.304	0.054	35.710
0.135	0.000	0.043	30.403	-0.000	0.043	32.600	0.001	0.043	35.768

PGF = 23.75 G'S

FULL SIZE CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.115	.07	.85	35

	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
TIME SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	35.000	0.000	0.000	35.000	0.000	0.000	35.000	0.000
0.005	0.515	34.981	3.013	1.982	34.891	3.077	0.317	34.988	3.023
0.010	2.020	34.851	5.892	3.964	34.565	6.134	1.249	34.908	5.932
0.015	4.405	34.506	8.637	5.946	34.022	9.154	2.748	34.694	8.728
0.020	7.492	33.859	11.249	7.929	33.261	12.116	4.732	34.287	11.409
0.025	11.052	32.845	13.726	9.911	32.282	15.001	7.095	33.642	13.977
0.030	14.822	31.427	16.069	11.893	31.087	17.791	9.711	32.722	16.431
0.035	18.521	29.596	18.279	13.875	29.673	20.466	12.438	31.507	18.771
0.040	21.876	27.376	20.354	15.857	28.043	23.007	15.130	29.995	20.997
0.045	24.638	24.819	22.296	17.839	26.195	25.395	17.644	28.195	23.110
0.050	26.601	22.001	24.104	19.821	24.130	27.611	19.844	26.136	25.108
0.055	27.621	19.018	25.778	21.804	21.847	29.636	21.611	23.858	26.993
0.060	27.621	15.979	27.317	23.786	19.347	31.450	22.852	21.414	28.764
0.065	26.601	12.996	28.723	25.768	16.629	33.034	23.498	18.866	30.421
0.070	24.638	10.178	29.995	27.750	13.694	34.370	23.517	16.282	31.964
0.075	21.876	7.621	31.134	24.667	10.819	35.446	22.907	13.731	33.393
0.080	18.521	5.401	32.138	21.583	8.283	36.284	21.699	11.279	34.709
0.085	14.822	3.570	33.008	18.500	6.085	36.914	19.961	8.990	35.911
0.090	11.052	2.152	33.744	15.417	4.224	37.365	17.783	6.916	36.999
0.095	7.492	1.138	34.347	12.333	2.703	37.668	15.285	5.101	37.973
0.100	4.405	0.491	34.815	9.250	1.519	37.851	12.599	3.570	38.833
0.105	2.020	0.146	35.150	6.167	0.673	37.945	9.869	2.338	39.579
0.110	0.515	0.016	35.350	3.083	0.166	37.979	7.243	1.402	40.212
0.115	0.000	-0.003	35.417	-0.000	-0.003	37.984	4.862	0.741	40.730
0.120	0.000	-0.003	35.417	-0.000	-0.003	37.984	2.852	0.321	41.135
0.125	0.000	-0.003	35.417	-0.000	-0.003	37.984	1.322	0.097	41.426
0.130	0.000	-0.003	35.417	-0.000	-0.003	37.984	0.355	0.011	41.604
0.135	0.000	-0.003	35.417	-0.000	-0.003	37.984	0.001	-0.003	41.667

PGF = 27.75 G'S

FULL SIZE CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.115	.07	.85	40

TIME	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	40.000	0.000	0.000	40.000	0.000	0.000	40.000	0.000
0.005	0.589	39.978	3.443	2.268	39.876	3.516	0.362	39.987	3.455
0.010	2.311	39.829	6.734	4.536	39.503	7.011	1.429	39.895	6.780
0.015	5.039	39.435	9.870	6.804	38.881	10.461	3.144	39.650	9.974
0.020	8.571	38.694	12.854	9.071	38.010	13.847	5.414	39.185	13.038
0.025	12.645	37.534	15.685	11.339	36.891	17.144	8.118	38.446	15.972
0.030	16.958	35.912	18.362	13.607	35.523	20.332	11.110	37.393	18.776
0.035	21.191	33.817	20.886	15.875	33.906	23.389	14.231	36.004	21.449
0.040	25.030	31.277	23.257	18.143	32.040	26.292	17.311	34.273	23.992
0.045	28.189	28.351	25.474	20.411	29.926	29.020	20.187	32.214	26.405
0.050	30.436	25.127	27.539	22.679	27.563	31.552	22.704	29.858	28.688
0.055	31.602	21.714	29.450	24.946	24.951	33.864	24.726	27.252	30.840
0.060	31.602	18.237	31.208	27.214	22.090	35.936	26.145	24.456	32.862
0.065	30.436	14.825	32.812	29.482	18.981	37.745	26.886	21.541	34.754
0.070	28.189	11.600	34.264	31.750	15.623	39.269	26.907	18.584	36.516
0.075	25.030	8.674	35.562	28.222	12.334	40.496	26.208	15.665	38.148
0.080	21.191	6.134	36.707	24.694	9.432	41.451	24.827	12.860	39.649
0.085	16.958	4.040	37.698	21.167	6.917	42.168	22.838	10.241	41.020
0.090	12.645	2.417	38.537	17.639	4.788	42.680	20.347	7.868	42.260
0.095	8.571	1.257	39.222	14.111	3.047	43.022	17.488	5.791	43.371
0.100	5.039	0.517	39.754	10.583	1.693	43.227	14.415	4.040	44.351
0.105	2.311	0.122	40.133	7.056	0.725	43.331	11.292	2.630	45.201
0.110	0.589	-0.027	40.359	3.528	0.145	43.366	8.287	1.559	45.921
0.115	0.000	-0.048	40.431	-0.000	-0.048	43.368	5.562	0.802	46.510
0.120	0.000	-0.048	40.431	-0.000	-0.048	43.368	3.263	0.323	46.970
0.125	0.000	-0.048	40.431	-0.000	-0.048	43.368	1.513	0.066	47.299
0.130	0.000	-0.048	40.431	-0.000	-0.048	43.368	0.406	-0.033	47.497
0.135	0.000	-0.048	40.431	-0.000	-0.048	43.368	0.001	-0.048	47.566

PGF = 31.75 G'S

FULL SIZE CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL.G'S SEC	OFFSET PD RATIO	DELTA V - MPH
.115	.07	.85	45

	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
TIME SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	45.000	0.000	0.000	45.000	0.000	0.000	45.000	0.000
0.005	0.658	44.976	3.874	2.536	44.861	3.956	0.405	44.985	3.887
0.010	2.584	44.809	7.577	5.071	44.444	7.887	1.598	44.882	7.629
0.015	5.635	44.368	11.109	7.607	43.748	11.770	3.515	44.608	11.225
0.020	9.584	43.540	14.469	10.143	42.775	15.579	6.053	44.088	14.675
0.025	14.139	42.243	17.658	12.679	41.523	19.290	9.077	43.262	17.980
0.030	18.961	40.429	20.676	15.214	39.994	22.879	12.422	42.086	21.139
0.035	23.694	38.087	23.522	17.750	38.186	26.321	15.911	40.532	24.152
0.040	27.986	35.247	26.198	20.286	36.100	29.591	19.356	38.597	27.020
0.045	31.519	31.976	28.701	22.821	33.736	32.666	22.572	36.294	29.742
0.050	34.030	28.370	31.034	25.357	31.094	35.521	25.386	33.660	32.319
0.055	35.335	24.555	33.195	27.893	28.173	38.131	27.647	30.746	34.750
0.060	35.335	20.667	35.184	30.429	24.975	40.471	29.234	27.620	37.035
0.065	34.031	16.851	37.003	32.964	21.498	42.518	30.061	24.361	39.174
0.070	31.519	13.246	38.650	35.500	17.744	44.247	30.085	21.055	41.168
0.075	27.986	9.974	40.126	31.556	14.066	45.643	29.304	17.791	43.017
0.080	23.694	7.134	41.430	27.611	10.821	46.735	27.760	14.654	44.720
0.085	18.961	4.793	42.563	23.667	8.009	47.560	25.535	11.726	46.277
0.090	14.139	2.978	43.525	19.722	5.630	48.157	22.750	9.073	47.688
0.095	9.584	1.681	44.316	15.778	3.683	48.564	19.553	6.750	48.954
0.100	5.635	0.854	44.935	11.833	2.168	48.818	16.117	4.793	50.074
0.105	2.584	0.412	45.383	7.889	1.087	48.958	12.626	3.217	51.049
0.110	0.658	0.246	45.659	3.944	0.438	49.022	9.266	2.018	51.878
0.115	0.000	0.221	45.764	-0.000	0.221	49.048	6.219	1.173	52.562
0.120	0.000	0.221	45.764	-0.000	0.221	49.048	3.648	0.636	53.099
0.125	0.000	0.221	45.764	-0.000	0.221	49.048	1.692	0.350	53.491
0.130	0.000	0.221	45.764	-0.000	0.221	49.048	0.454	0.239	53.738
0.135	0.000	0.221	45.764	-0.000	0.221	49.048	0.001	0.221	53.839

PGF = 35.5 G'S

FULL SIZE CAR CRASH PULSES

PULSE DUR. SEC	TIME MAX OBL. G'S SEC	OFFSET FD RATIO	DELTA V - MPH
.115	.07	.85	50

	FRONTAL PULSE			OBLIQUE PULSE			OFFSET PULSE		
TIME SEC	FR. G'S G'S	FR. V. MPH	FR. C. IN	OB. G'S G'S	OB. V. MPH	OB. C. IN	OF. G'S G'S	OF. V. MPH	OF C IN
0.000	0.000	50.000	0.000	0.000	50.000	0.000	0.000	50.000	0.000
0.005	0.732	49.973	4.305	2.821	49.845	4.395	0.451	49.983	4.319
0.010	2.875	49.788	8.419	5.643	49.381	8.764	1.778	49.869	8.476
0.015	6.270	49.297	12.342	8.464	48.607	13.077	3.911	49.564	12.471
0.020	10.664	48.376	16.075	11.286	47.524	17.310	6.735	48.986	16.304
0.025	15.732	46.933	19.617	14.107	46.132	21.433	10.099	48.067	19.975
0.030	21.098	44.914	22.969	16.929	44.430	25.420	13.822	46.757	23.483
0.035	26.364	42.308	26.130	19.750	42.418	29.243	17.704	45.029	26.830
0.040	31.139	39.148	29.100	22.571	40.097	32.876	21.537	42.875	30.015
0.045	35.070	35.508	31.879	25.393	37.467	36.291	25.115	40.313	33.038
0.050	37.865	31.497	34.468	28.214	34.527	39.461	28.246	37.382	35.898
0.055	39.316	27.251	36.867	31.036	31.277	42.359	30.762	34.140	38.597
0.060	39.316	22.925	39.075	33.857	27.718	44.957	32.527	30.661	41.133
0.065	37.865	18.679	41.092	36.679	23.850	47.228	33.448	27.035	43.508
0.070	35.070	14.668	42.918	39.500	19.672	49.145	33.475	23.357	45.720
0.075	31.139	11.028	44.554	35.111	15.581	50.693	32.606	19.725	47.771
0.080	26.364	7.868	45.999	30.722	11.970	51.902	30.887	16.235	49.659
0.085	21.098	5.262	47.254	26.333	8.841	52.814	28.412	12.977	51.386
0.090	15.732	3.243	48.318	21.944	6.193	53.472	25.313	10.025	52.950
0.095	10.664	1.800	49.191	17.556	4.027	53.918	21.757	7.440	54.352
0.100	6.270	0.879	49.874	13.167	2.342	54.195	17.933	5.262	55.593
0.105	2.875	0.388	50.366	8.778	1.139	54.344	14.048	3.509	56.671
0.110	0.732	0.203	50.667	4.389	0.417	54.409	10.310	2.175	57.587
0.115	0.000	0.176	50.778	-0.000	0.176	54.432	6.920	1.234	58.341
0.120	0.000	0.176	50.778	-0.000	0.176	54.432	4.059	0.638	58.934
0.125	0.000	0.176	50.778	-0.000	0.176	54.432	1.882	0.319	59.364
0.130	0.000	0.176	50.778	-0.000	0.176	54.432	0.505	0.196	59.632
0.135	0.000	0.176	50.778	-0.000	0.176	54.432	0.002	0.176	59.738

PGF = 39.5 G'S

Appendix B

"BDRACR" Description

ADDENDUM TO "DRACR" USER'S MANUAL TO UPDATE TO "BDRACR"

This addendum to the DRACR User's Manual has been written to describe the changes and new features which have been added to the DRACR computer program. This new version of DRACR is now known as BDRACR - the prefix "B" denoting the major change made since the previous version i.e. the addition of a belt restraint system.

The modifications made to DRACR since Revision A of the User's Manual was published in August of 1983 are of two types. The first type was the discovery of a few minor "bugs" which, although not affecting the results appreciably were technically errors that should be corrected. The second type of modification was the addition of some new features to the model. These new features will now be discussed.

NEW FEATURES

The features which have been added to DRACR are as follows.

1. A new contact algorithm for head/airbag contact has been added for improved simulation accuracy.

2. A windshield algorithm has been added so windshield impact with the head can be detected. This is simply a "detection" algorithm to stop the run and signal the user that such an impact has occurred.

3. The capability of simulating more than one type of restraint system has been added. Previously, only a driver airbag system could be simulated. With the new capabilities, the user has a choice of simulating:

a. driver airbag only,

b. 3-point continuous loop belt system only,

c. 3-point continuous loop belt system in combination with airbag,

d. 3-point separate belts (not continuous loop) in combination with airbag,

e. 2-point belt systems or lap belt only systems in combination with the airbag. These can be simulated by using option "d" with the force characteristics of the appropriate belt set to zero.

4. The capability of allowing seat bottom deflection has been added. The previous model restricted the H-point to move along a horizontal line; in this version the seat bottom deflection is computed and the H-point is allowed to move vertically as well as horizontally.

5. The subroutine "SPRING" used in the original model was more complex than necessary. This complexity also resulted in a rare case in which under conditions of rebound where the hysteresis portion of the curve was being used and where the first two or last two points of the table were involved, the algorithm would give an erroneous result. This has been fixed in this new release by using an entirely new algorithm in subroutine "SPRING" and by modifying subroutine "UPDATE".

Since some new input has been added to the program, a new table which summarizes the input file is included. This new table

replaces Table 1 in the current User's Manual. In addition, some new figures have been included.

TABLE 1

BDRACR INPUT FILE DESCRIPTION (S35FR50)

Line No.	Location In Line	Variable Name and Units	Variable Description	Value
1	1	Y(4),mph	Vehicle impact velocity	35.0
1	2	Y(6),deg	Head angle (Fig.5)	1.0
1	3	Y(7),deg	Torso angle (Fig.5)	-16.
2	1	ZL,lb	Lower body weight	71.04
2	2	ZT,lb	Torso weight	62.9
2	3	ZH,lb	Head weight	12.54
2	4	RT,in	H-pt to torso C.G. (Fig.5)	14.0
2	5	RN,in	H-pt to neck pivot (Fig.5)	20.5
2	6	RH,in	Neck pivot to head C.G. (Fig.5)	4.53
2	7	RTOPH,in	H-pt to head top (Fig.5)	29.75
3	1	XTUO,in	Upper anchor to torso X coordinate (Fig.1)	5.5
3	2	YTUO,in	Upper anchor to torso Y coordinate (Fig.1)	5.0

3	3	ZTUO,in	Upper anchor to torso Z coordinate (Fig.1)	8.25
3	4	RTU,in	H-Point to upper torso/belt contact point (Fig.1)	16.3
3	5	XTLO,in	Lower anchor to torso X coordinate (Fig.1)	4.75
3	6	YTLO,in	Lower anchor to torso Y coordinate (Fig.1)	6.00
3	7	ZTLO,in	Lower anchor to torso Z coordinate (Fig.1)	15.5
3	8	RTL,in	H-Point to lower torso/belt contact point (Fig.1)	4.5
3	9	XLO,in	Lap anchor to lap X coordinate (Fig.1)	5.75
3	10	YLO,in	Lap anchor to lap Y coordinate (Fig.1)	6.00
3	11	ZLO,in	Lap anchor to lap Z coordinate (Fig.1)	13.5
4	1	NPN	No. pts in neck torque vs angle curve	3
4	2	NKR	No. pts in knee force vs crush curve	5

4	3	NV	No. pts in vehicle g's vs time curve	23
4	4	NSF	No. pts in seat friction vs displacement curve	3
4	5	NPG	No. pts in gas flow vs time curve	12
4	6	NPC	No. pts in column force vs crush curve	7
4	7	NPW	No. pts in st. wheel force vs crush curve	9
4	8	NPWRP	No. pts in pos. wheel torque vs angle curve	5
4	9	NPWRN	No. pts in neg. wheel torque vs angle curve	5
4	10	NPCRP	No. pts in column resistance vs pos. angle curve	3
4	11	NPCRN	No. pts in column resistance vs neg. angle curve	3
4	12	NUT	No. pts in torso belt force vs deflection curve	3
4	13	NL	No. pts in lap belt force vs deflection curve	3

4	14	NPLG	No. pts in pelvic girdle force vs deflection curve	5
5	1	NPTOR	No. pts in torso force vs deflection curve	6
5	2	NPSBD	No. pts in seat bottom force vs deflection curve	6
5	3	SUN,lb/in	Seat friction unload slope	2500.
5	4	SKR,lb/in	Knee Restraint unload slope	1827.
5	5	STB,lb/in	Torso belt unload slope	1133.
5	6	SLB,lb/in	Lap belt unload slope	2008.
6	All	GEN(1,K),msec	Gas flow time	Fig.6
7	All	GEN(2,K),lb/sec	Gas flow rate	Fig.6
8	All	COL(1,K),in	Column stroke	Fig.6
9	All	COL(2,K),lb	Column stroking force	Fig.6
9	All	SFN(1,K),in	Seat friction displacement	Fig.6
10	1	ATMOP,psia	Local atmospheric pressure	14.7
10	2	PGZ,psig	Initial airbag presure	-14.7
10	3	GTZ,deg R	Temperature of gas entering	1601.

			airbag	
10	4	U,in lbf/lbm degR	Gas constant	662.
10	5	PN1	Polytropic gas exponent - flow	1.4
10	6	PN2	Polytropic gas exponent - comp.	1.4
10	7	PN3	Polytropic gas exponent - exp.	1.4
10	8	DELTAM,in	Distance between torso C.G. and pt. where rad. of gyration ends.	0.0
11	1	TTAW,deg	St. wheel angle (Fig.3)	25.
11	2	RIP,in	Radius of assumed circular inflator and airbag package	2.5
11	3	WWH,lb	St. wheel weight	5.72
11	4	WIP,lb	Weight of airbag + inflator pkg.	4.5
11	5	RCOL,in	Distance from column pivot to column C.G. (Fig.3)	18.7
11	6	DCN,ft-lb-sec/rad	Head/neck damping coefficient	3.25
11	7	SFC	Seat friction coefficient	0.3
11	8	SBDF,lb-sec/ft	Seat bottom damping coefficient	360.
12	1	BSLIP,in	Amount of belt slip allowed per iteration for torso/lap belt	0.20

			force equilibrium	
12	2	DRCF	Friction coefficient between belt and latch plate (D-ring).	0.3
12	3	AWLT,in	Active webbing length for torso belt.	63.00
12	4	AWLL,in	Active webbing length for lap belt	35.50
12	5	TSLIM,in	Total amount of slip allowed before belt geometry violated.	5.0
12	6	SBSKPD,lb/in	Base of seat back spring constant	1200
13	1	XTWS,in	X coordinate top of windshield (Fig.5)	19.0
13	2	YTWS,in	Y coordinate top of windshield (Fig.5)	42.5
13	3	THEWS,deg	Windshield angle (from horiz.) (Fig.5)	38.5
13	4	WSLG,in	Windshield length (top to bottom) (Fig.5)	24.1
14	1	VC1	Vent discharge coefficient subsonic flow	0.7
14	2	VC2	Vent discharge coefficient sonic flow	0.7

14	3	AV,sq in	Vent area	1.5
14	4	SA,in	Airbag major axis Length (Fig.2)	12.0
14	5	SC,in	Airbag minor axis length (Fig.2)	6.0
14	6	X1,in	Horizontal ref. distance to center of rim (Fig.5)	20.5
14	7	Y1,in	Vertical ref. distance to center of rim (Fig.5)	25.5
15	1	TTAC,deg	St. column angle (Fig.3)	25.0
15	2	MU	St. column coeff. of friction	0.0
15	3	LSCZ,in	Column ref. dim. to shear cap. (Fig.3)	4.3
15	4	LFWZ,in	Column ref. dim. to fwd column support point from LSCZ (Fig.3)	14.6
15	5	LBAZ,in	Column ref. dim. to aft column support pt. (Fig.3)	8.9
15	6	LBFZ,in	Column ref. dim. to fwd column support pt. (Fig.3)	12.6
15	7	WC,lb	Column weight (stroking part)	7.4

16	1	LF,in	Femur length	14.3
16	2	THFO,deg	Initial femur angle (Fig.1)	8.0
16	3	THLO,deg	Initial tibia angle (Fig.1)	55.7
16	4	XSTOP,sec	Run stop time	.125
16	5	STEP,sec	Integration interval	.001
16	6	PINT1,sec	Print interval for PRINT1 variables	.005
16	7	PINT2,sec	Print interval for PRINT2 variables	.005
16	8	EPSLON	Convergence criteria used in numerical solutions	.01
17	1	XWH,in	Ref. distance from center of wheel rim to wheel pivot (Fig.4)	2.5
17	2	RIMRAD,in	Radius of st. wheel rim (Fig.2)	7.50
17	3	X2Z,in	Horiz. H-pt ref. dim. (Fig.5)	28.00
17	4	Y2Z,in	Vertical H-pt. ref. dim. (Fig.5)	12.88
17	5	WB,in	Width of body	17.9

17	6	WH,in	Width of head	6.1
17	7	SLKL,in	Initial slack in lap belt (measured normal to surface)	0.5
17	8	SLKT,in	Initial slack in torso belt (measured normal to surface)	0.5
18	All	TUT(1,K),in	Torso belt stretch	Fig.6
19	All	TUT(2,K),lb	Torso belt force	Fig.6
20	All	TL(1,K),in	Lap belt stretch	Fig.6
21	All	TL(2,K),lb	Lap belt force	Fig.6
22	All	FPG(1,K),in	Pelvic girdle deflection	Fig.6
23	All	FPG(2,K),lb	Pelvic girdle force	Fig.6
24	All	FTOR(1,K),in	Torso deflection	Fig.6
25	All	FTOR(2,K),lb	Torso force	Fig.6
26	All	SFN(1,K),in	Seat friction deflection	Fig.6
27	All	SFN(2,K),lb	Seat friction force	Fig.6
28	All	FNECK(1,K),deg	Head/torso rel. ang.	Fig.6
29	All	FNECK(2,K),deg	Neck rotational resistance	Fig.6

30	All	VEHGS(1,K),msec	Crash pulse time	Fig.6
31	All	VEHGS(2,K),g's	Crash pulse g's	Fig.6
32	All	KRN(1,K),in	Knee displacement	Fig.6
33	All	KRN(2,K),lb	Knee force (sum of two knees)	Fig.6
34	All	WHE(1,K),in	Wheel crush displacement	Fig.6
35	All	WHE(2,K),lb	Wheel crush force	Fig.6
36	All	WHRP(1,K),deg	Positive wheel rotation w/r to column (top toward w/s)	Fig.6
37	All	WHRP(2,K),in-lb	Wheel resistance to pos. wheel rotation	Fig.6
38	All	WHRN(1,K),deg	Negative wheel rotation w/r to column (top toward driver)	Fig.6
39	All	WHRN(2,K),in-lb	Wheel resistance to neg. wheel rotation	Fig.6
40	All	COLRP(1,K),deg	Positive column rotation (upward)	Fig.6
41	All	COLRP(2,K),in-lb if T-2;lb if T-1	Column resistance to pos. column rotation	Fig.6
42	All	COLRN(1,K),deg	Negative column rotation (downward)	Fig.6

43	All	COLRN(2,K),in-lb if T-2;lb if T-1	Column resistance to neg. column rotation	Fig.6
44	All	SBD(1,K),in	Seat bottom deflection	Fig.6
45	All	SBD(2,K),lb	Seat bottom force	Fig.6

Note: YTUO, YTLO, and YTL are "into the paper"

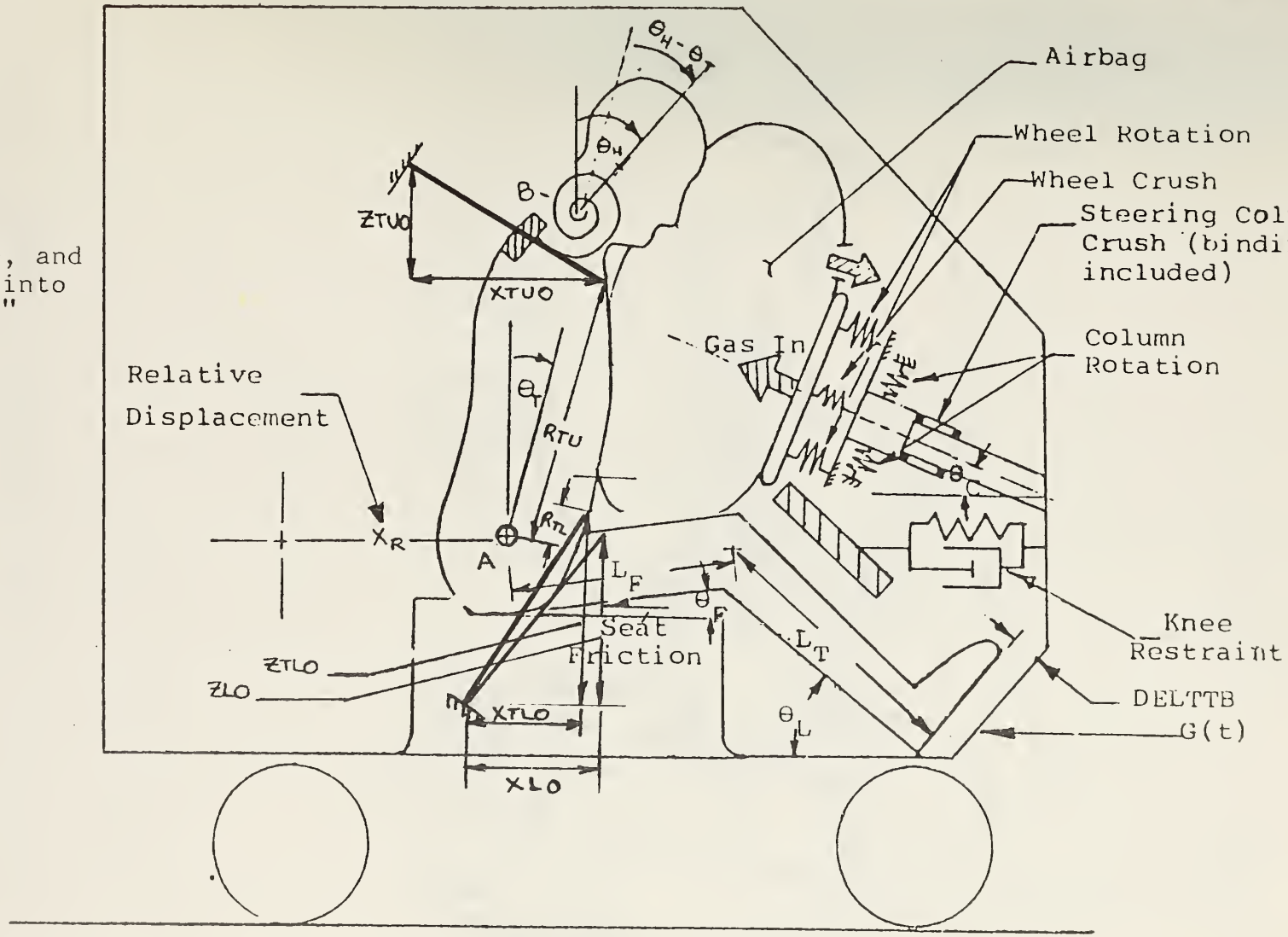


Figure 1. Schematic of BDRACR Computer Model

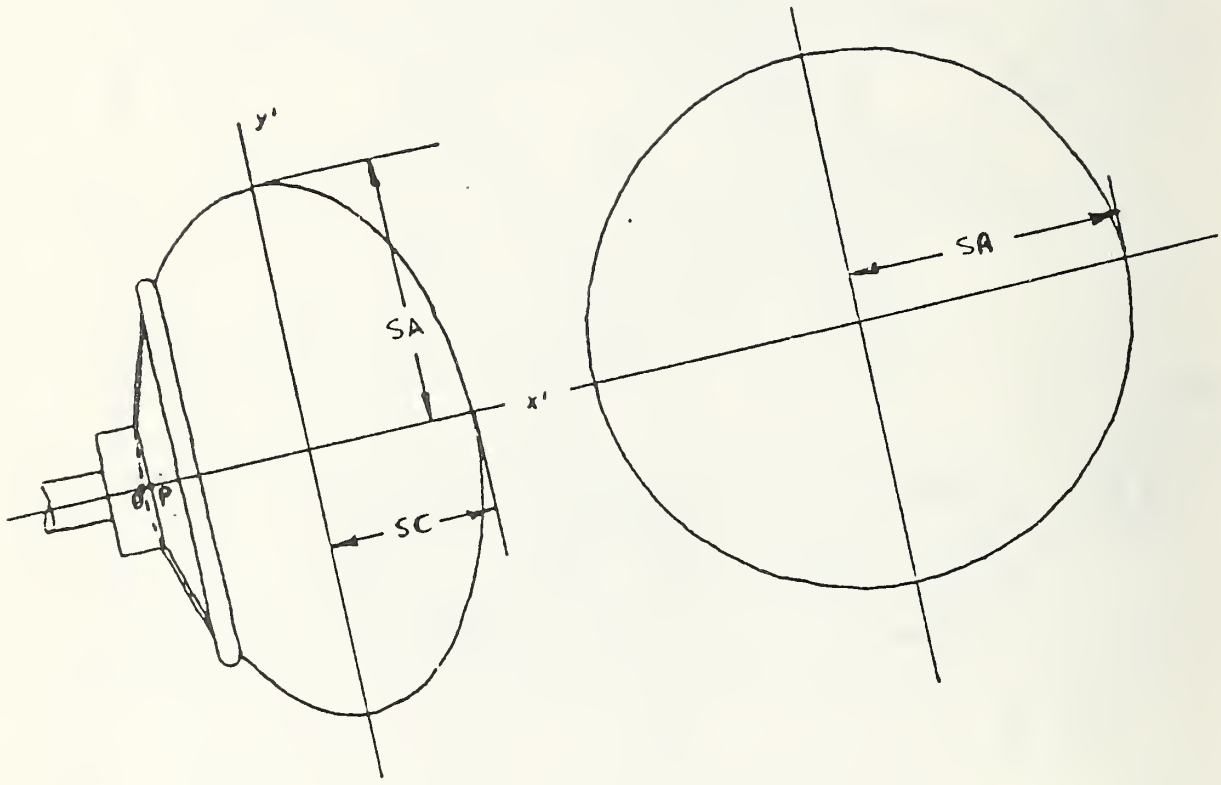
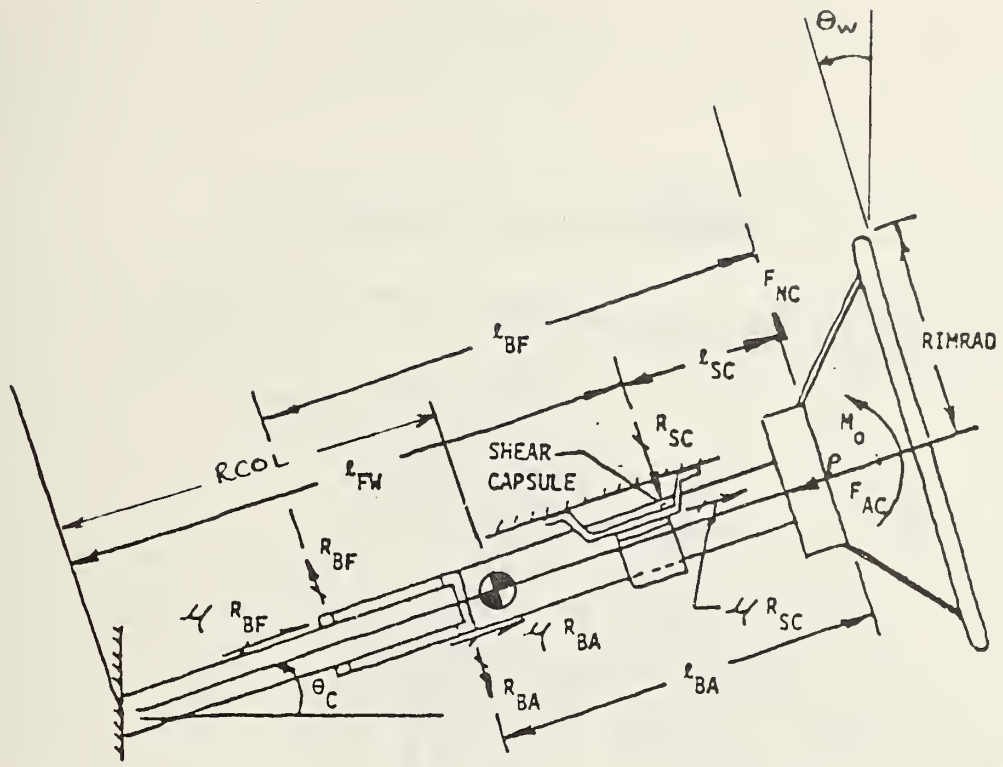


Figure 2. BDRACR Airbag



R_{SC} = Reaction at Shear Capsule

R_{BA} = Reaction at Aft Bushing

R_{BF} = Reaction at Forward Bushing

μ = Coefficient of Friction

M_o = Applied Moment

F_{AC} = Applied Axial Force

F_{NC} = Applied Normal Force

Figure 3. Geometry of BDRACR Steering Column

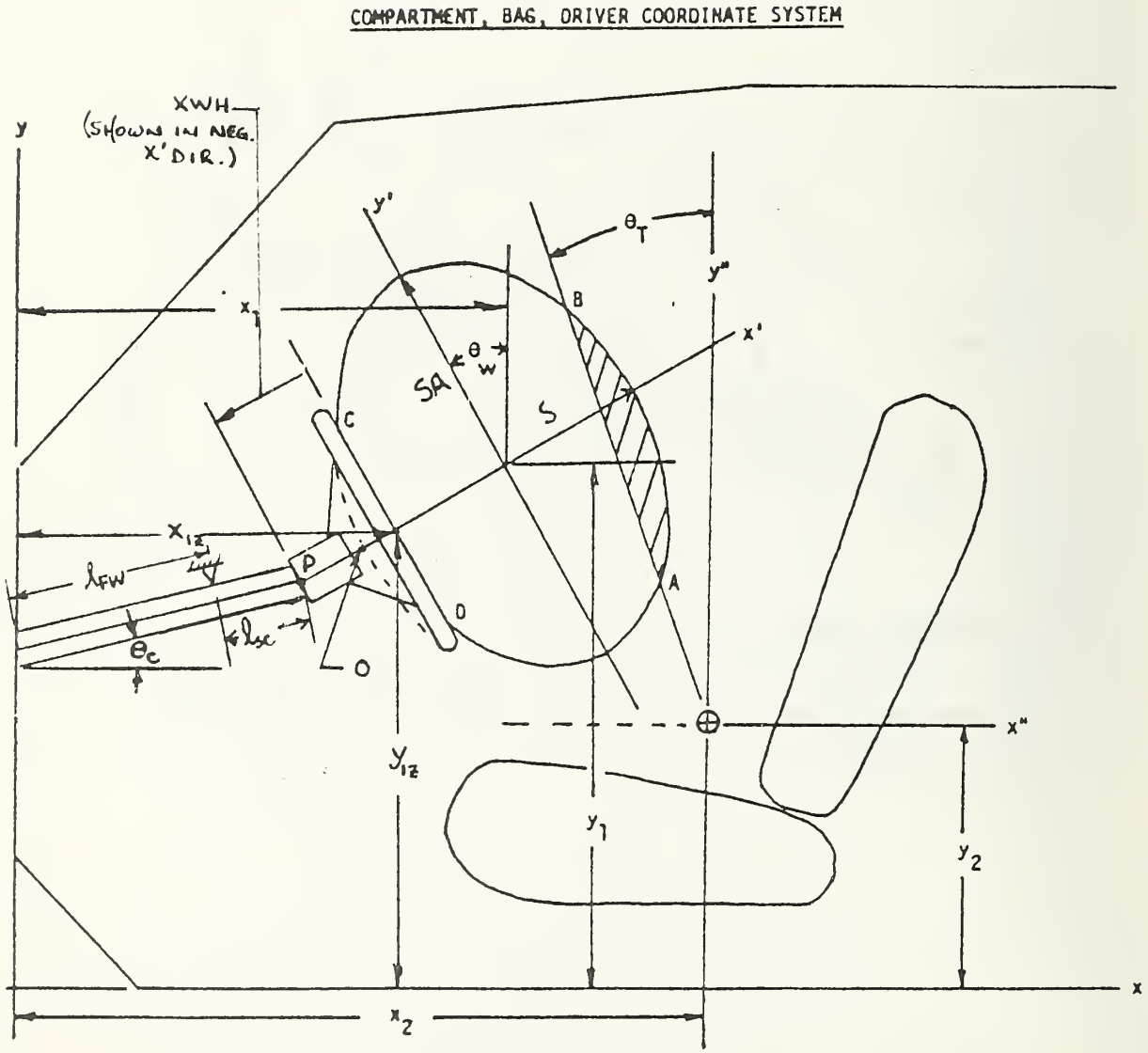


Figure 4 Geometrical Representation of the Airbag Parameters

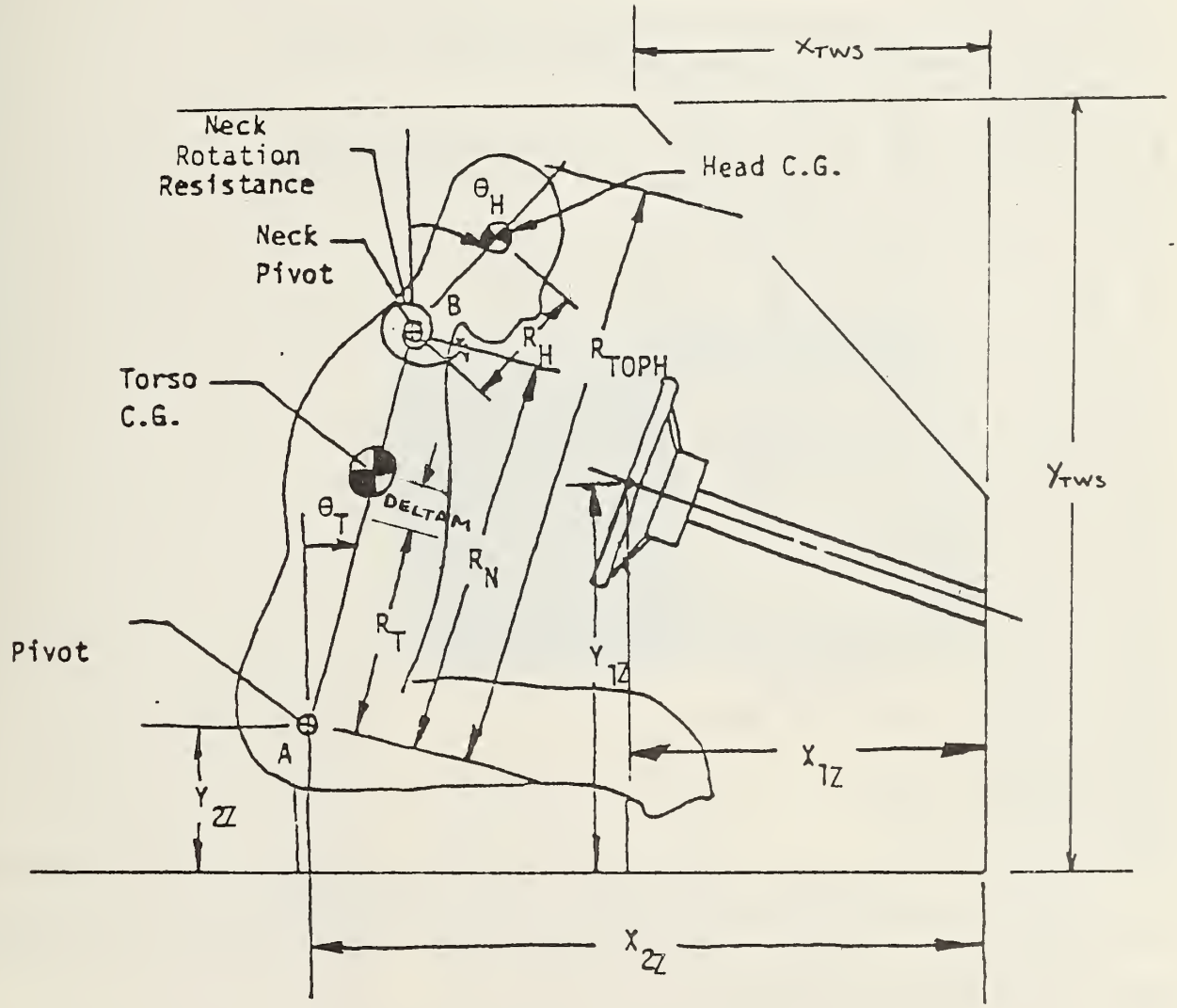


Figure 5. Driver Nomenclature

BDRACR INPUT FILE (S35FR50)

```
1 35.,1.,-16.
2 71.04,62.9,12.54,14.0,20.5,4.53,29.75
3 5.5,5.,8.25,16.3,4.75,6.,15.5,4.5,5.75,6.,13.5
4 3,5,23,3,12,7,9,5,5,3,3,3,3,5
5 6,6,2500.,1827.,1133.,2008.
6 0.,13.,18.,23.,28.,33.,38.,43.,48.,58.,68.,120.
7 0.,0.,.99,2.47,3.45,3.94,3.45,1.97,1.28,.25,0.,0.
8 -10.,0.,0.5,1.0,1.5,2.5,5.
9 0.,0.,2000.,2500.,2500.,2500.,3700.
10 14.7,-14.7,1601.,662.,1.4,1.4,1.4,0.0
11 25.,2.5,5.72,4.5,18.7,3.25,0.3,360.
12 0.20,0.3,63.,35.5,5.,1200.
13 19.,42.5,38.5,24.13
14 0.7,0.7,1.5,12.0,6.0,20.5,25.5
15 25.,0.,4.3,14.6,8.9,12.6,7.4,
16 14.3,8.,55.7,.125,.001,.005,.005,.01
17 2.5,7.50,28.0,12.88,17.9,6.1,0.5,0.5
18 -10.,0.0,4.41
19 0.,0.,2500.
20 -10.,0.0,2.49
21 0.,0.,2500.
22 -10.,0.,1.5,2.,3.
23 0.,0.,500.,2000.,8000.
24 -10.,0.,.2,.4,.6,.8
25 0.,0.,30.,72.,175.,350.
26 -10.,0.,1.
27 70.6,70.6,70.6
28 -80.,17.,90.
29 117.,0.,-87.
30 0.0,5.0,10.0,15.0,20.0,25.0,30.0,35.0,40.0,45.0,50.0,55.0,60.0,65.0
   ,70.0,75.0,80.0,85.0,90.0,95.0,100.0,105.0,250.0
31 0.0,1.1,4.1,8.8,14.6,20.7,26.4,31.1,34.2,35.3,34.2,31.1,26.4,20.7
   ,14.6,8.8,4.1,1.1,0.0,0.0,0.0,0.0,0.0
32 -10.,3.5,5.86,6.84,7.8
33 0.,0.,2140.,2837.,3200
34 -10.,0.,.59,1.38,2.56,3.35,3.74,3.86,4.09
35 0.,0.,1278.,1710.,1740.,1893.,2048.,2356.,4820.
36 -10.,0.,10.,24.,30.
37 0.,0.,5000.,6000.,10000.
38 -10.,0.,10.,24.,30.
39 0.,0.,5000.,6000.,10000.
40 -10.,0.,10.
41 0.,0.,4000.
42 -10.,0.,10.
43 0.,0.,4000.
44 -10.,0.,3.93,6.1,7.28,9.13
45 0.,0.,337.,1461.,1461.,2540.
```

Figure 6. BDRACR Input File

TL 242 .F5827

Fitzpatrick, Mich

Crash survivabil
computer study

Form DOT F 1720.2 (8-70)
FORMERLY FORM DOT F 1700.11

DOT LIBRARY
00092213