Scheuner

Memorandum

cc: Felrice
Witcheck
Williams

U.S. Department of Transportation [redacted]
National Highway Traffic Safety Administration

Subject: ACTION: Draft Evaluation-Congressman Timothy E. Wirth petition to issue an FMVSS to "limit the rollover propensity of passenger automobiles, utility vehicles, and pickup trucks.

Date: APR 28 1987

From: Michael M. Finkelstein
Associate Administrator for Research and Development

Reply to Attn of:

To: Barry Felrice
Associate Administrator for Rulemaking

We have reviewed the subject draft evaluation, and offer the following comments:

Section II B: The previous NHTSA research referred to in this section, i.e., "Development of Vehicle Rollover Maneuver", is not germane to the rollover issue raised in the petition, since it dealt exclusively with the development of a maneuver for untripped rollover on a flat dry pavement. This report, as well as many other studies of vehicle rollover accidents, has concluded that nearly all rollover accidents are of the tripped variety. Therefore it is not correct to conclude from the results of this study that a valid test for tripped rollover cannot be developed. Indeed, American Motors Corporation has shown videotapes to the NHTSA technical staff of a sled-type tripped rollover test device which they have employed in product liability litigation cases.

Previous research conducted by NHTSA and others concerning the mechanics of vehicle rollover has shown that the vehicle's rollover resistance is dependent to the "first order" on the ratio of the half-track to center of gravity height (rollover stability factor) for both tripped and untripped rollover (See DOT HS-804-089, Development of Vehicle Rollover Maneuver, pp 12-23). More recent research sponsored by NHTSA on the dynamics of tripped rollover (See User's Guide and Program Description for a Tripped Rollover Vehicle Simulation - Systems Technology Report 1216-2, 1985) examined the effects of suspension parameters, tire deformations, and various impact conditions on tripped rollover. This is a nonlinear, multi-degree of freedom simulation, representing the state-of-the-art in rollover dynamic analysis. It also reveals that the rollover stability factor remains the first order variable in affecting the tripped rollover threshold. This is shown in Figure 1 where the critical lateral velocity at impact needed to just cause tip over is plotted as a function of the rollover stability factor. Considering the basic physics of tripped rollover, it would be surprising indeed if an analysis of the accident data did not show a strong correlation between rollover rate and the rollover stability factor. We believe the accident data confirms the correlation.

Section II C: This section states that "a number of recent accident data analyses were reviewed as part of the analysis of the subject petition". It is clear however, that the inclusion of analyses in this draft has been very selective, and was designed to support a certain Rulemaking position. Other analyses, such as that being conducted by the Office of Crash Avoidance Research using the CARDfile accident data file, have been systematically ignored. We find this to be particularly distressing in light of the effort we expended in briefing the RM staff as to the fact that these analyses were in progress and what the results were indicating.

Section III: This section discusses the reasons for disaggregating the FARS data base into accidents involving only utility vehicles. The two reasons given for this are: 1) "the major focus of the request (petition) relates to utility vehicles." 2) "an analysis of the effects of vehicle, driver, environment and usage factors is most appropriately done by considering only one class of vehicle since many of the vehicle's basic characteristics, its accident exposure, and its involvement in various accident types are related to the mission and driver for which it was designed." In general, we would agree with this approach, provided that the latter statement were tested and shown to be true. However, the draft evaluation, simply drops the subject at this point, as if the mere stating of this thesis makes it true. We have examined this assertion using CARDfile and find that it cannot be sustained by an impartial examination of the accident data. Before discussing these findings, we will describe briefly, the size and scope of the CARDfile dataset used in this and subsequent analyses.

A subset of the total CARDfile database has been used, which consists of data from the states of Maryland(84-85), Texas(84-85), and Washington (83-85). A series of 19 passenger cars and 8 utility vehicles has been selected for analysis. Tables 1-8 identify the vehicle types, model years studied, their geometrical and center of gravity characteristics, and the number of rollover (RO) and single vehicle accidents (SVA) contained in each of the component and combined state files. The vehicles were chosen such that they would span, without significant gaps, the complete range of rollover stability factors from low slung American passenger cars such as the Chevrolet Camaro to tall vehicles such as the Jeep CJ-5. Table 9 provides an overall summary of the passenger vehicle and utility vehicle count in each of the state data sets used, as well as the totals.

Using these datasets, the subclasses of passenger cars and utility vehicles were tested for differences in each of 19 different factors, related to usage and risk exposure. The factors tested are listed in Table 10 and the results of this analysis are presented in bar chart form in Figures 2 and 3. Figure 2 shows the relative content of the dataset for utility vehicles and passenger cars broken down by each of the 19 risk factors. Those factors which showed a greater relative presence in the dataset were further examined by comparing the percent RO/SVA for utility vehicles against passenger cars. It can be observed from this data that no significant difference can be detected in usage or risk factors between the class of utility vehicles and passenger cars which would justify their disaggregation. We shall return to this question again later, during the discussion of the regression analysis using the CARDfile data. It should also be noted in passing, that there is no rationale based on the physical principles of tripped vehicle rollover, that would argue for the disaggregation employed in this draft evaluation.

Section III A: The draft evaluation refers to a study entitled "A Comparison of Light Truck and Passenger Car Occupant Protection", performed by CALSPAN for the MVMA. Table 1 from the CALSPAN report is reproduced and the conclusion is drawn that "utility vehicles overall are not involved in more accidents...". However, the CALSPAN report itself refrains from making any judgments relative to utility vehicles based on the data collected in the study. The following quote is taken from the conclusion section of the CALSPAN report (p.38): "Utility vehicles were deliberately omitted from conclusion (2) and (4), because of ambiguous results on that vehicle type. The small numbers of utility vehicles made it difficult to compare them with the other vehicles when controlling for confounding variables. While some of the results suggested high injury risks for utility vehicle drivers, the net results for utility vehicles are considered inconclusive."

Several references are cited in this section, to assess the overall safety record of utility vehicles. It would seem relevant to include in this assessment the conclusions from the most recent IIHS Status Report, Vol. 22, No. 2, published on February 28, 1987, entitled "Vehicle Size and Death Rates". This report contains an analysis of fatality rates by vehicle type, and is based on FARS data for the years of 1981-1985. We quote from page 4 of this report: "Small utility vehicles have, by a wide margin, the worst (occupant death) record of all. With 5.7 occupant deaths for every 10,000 registered in this category, these vehicles far outstrip automobiles and pickups in their fatality experience."

Section III C 1: This section addresses the shortcomings of the Kelly-Robertson report by reference to a critique of the analysis technique prepared by NCSA. It is notable, that despite flaws in the Kelly-Robertson report, NCSA concludes on page 1 of its critique the following: "In all likelihood, stability (factor) is an important consideration in the analysis of rollovers as the research of other authors such as Reinfurt et.al. (1980) has previously suggested." In fact, we are not aware of any research, either in the dynamics of vehicle rollover or in the statistical analysis of rollover accident data, that reaches a conclusion to the contrary, with the one exception of the present RM draft evaluation paper.

Section III C 2 a: In this section, univariate regression analyses are performed of RO/SVA versus rollover stability factor, using a subset of passenger vehicles consisting of only utility vehicles. While we are in agreement with the arguments set forth for using SVA as the exposure metric, we strongly disagree with the use of the FARS database to study vehicle rollover propensity. This was a significant flaw in the Kelly-Robertson paper, and it is no less a flaw in this draft evaluation. The FARS database is so strongly biased towards crashworthiness factors, such as roof crush strength, occupant ejection, steering column impalement, etc., as to make it completely inappropriate for the study of the relationship between rollover propensity and vehicle design characteristics. A much more reliable database, for this purpose, would be one in which all rollover and all single vehicle accidents regardless of injury level, was represented. The large state accident files or the CARDfile adaptation of these would be a suitable database for this application, but certainly not the FARS database. We note, interestingly, that the recent IIHS study cited above, which employed the FARS database, refrained from drawing any conclusions with respect to the rollover propensity of any particular make/model of vehicle.

As stated earlier, we also strongly disagree with the disaggregation of utility vehicles into a subclass for the purpose of analyzing the relationship between rollover rate and rollover stability factor. In addition to the reasons cited earlier, we submit that the restriction of the range of the independent variable, in this case the rollover stability factor, in any statistical regression analysis will invariably lead to larger effective scatter and lower correlation, regardless of the data being analyzed. Low correlations between the dependent variable (Percent RO/SVA) and the independent variable (Rollover Stability Factor) achieved in this way cannot be used as a basis for rejecting a much higher degree of correlation that exists when the unrestricted variable range is used. The situation is analogous to denying that a correlation exists between height and ability to play basketball, simply because no strong correlation was found when the population was restricted to the subclass of professional basketball players. Moreover, it is clear from an examination of the accident record itself that we are not dealing with separate data class here, i.e., one for utility vehicles and one for passenger cars. If this were so, one would expect to see the data arranged in separate and distinct clumps or clusters, as opposed to a continuous band. A scatter plot of the CARDfile data (Percent RO/SVA versus Rollover Stability Factor) for the various passenger car and utility vehicles that we have analyzed is presented in Figure 4. Obviously there is no indication that these data belong to separate classes. As a further test of this conclusion, we have plotted the residuals from a linear regression fit of this data in Figure 5. As can be seen, these tend to cluster more or less uniformly around the zero axis, again indicating that the data belong to a single class.

The scatter plot and linear regression line for the total combined dataset (MD 84-85, TX 84-85, WA 83-85) are shown in Figure 6. This data set contains 39,956 single vehicle accidents and 4,910 rollover accidents for the sample vehicles. The R-squared statistic for this regression is 0.86, which indicates a very robust correlation between RO/SVA and rollover stability factor. This is to be expected based on the physical dynamics of vehicle rollover, as was discussed earlier.

The latter part of this section strikes us as an exercise in tortured logic which attempts to force unwilling data to fit a specious hypothesis, i.e., that the primary vehicle parameter that influences rollover is vehicle size rather than rollover stability factor. After having endorsed the Kelly-Roberston metric for rollover risk (Percent RO/SVA) in the first part of this section with the statement, "This (Percent RO/SVA) is the much more common approach to examining rollover tendencies, and is used in many of the earlier reports referenced in the Calspan/FHWA report.", it is then rejected in the second part in favor of Rollovers/1,000 Registered Vehicles. The draft evaluation is curiously silent on just why this new measure of rollover risk is superior, given that nearly all rollover accidents involve single vehicles. Notwithstanding this, the draft paper goes on to a linear regression analysis of RO/1,000 Registered Vehicles against rollover stability factor, obtaining as a result a higher correlation than was obtained using Percent RO/SVA, i.e., R-squared of 0.4063 versus 0.2086. This is quite an interesting result. However, we are motivated to ask why this should be the case, given the nature of the risk factor employed. We have attempted to duplicate this result using the combined CARDfile dataset consisting of MD(84-85) and TX(84-85). The result is given in Table 11. A comparison of the R-squared statistic can also be found in this table for both regressions using Percent RO/SVA and RO/1,000 Registered Vehicles. It is seen that the R-squared statistic is degraded from 0.84 to 0.66 when changing the rollover risk metric. It is likely that the result reported in the draft evaluation paper, which shows an increase in correlation when using RO/1,000 Registered Vehicles, is a spurious one, resulting from using the FARS database, and data with restricted range of the rollover stability factor.

The draft evaluation goes on to argue that since the variation in vehicle center of gravity is not great, the rollover stability factor will depend primarily on the track width. We have analyzed the data in Attachment 11 of the draft paper and find that the variation in the center of gravity height that was a cited in not significantly different from that of the track width, i.e., %15.88 for center of gravity height versus %22.87 for track width (See Figure 7 and Table 12). Nonetheless, it is then argued that since track width and wheelbase are both surrogate variables for vehicle size, and since wheelbase has lower inherent variability than track, that wheelbase should be used as the the independent regression variable. When linear regressions are performed of SVA/1000 Registered Vehicles, and RO/1000 Registered Vehicles against wheelbase, very high R-squared values of 0.835 and 0.837 are obtained respectively. It is then concluded that; "Based on these results, it seems that the vehicle factor that seems to have the greater influence on the single vehicle, and therefore the rollover accident involvement, is vehicle size. This is the conclusion that has been reached by several previous studies of passenger cars." We do not believe that this convoluted sequence of logic has proven anything of the kind, nor are we aware of any "previous studies" that have shown that vehicle size rather than rollover stability factor is the primary vehicle variable in predicting rollover rate. Interestingly, these "several previous studies" have not been identified in the list of references attached to this paper. //

We believe that the draft paper, in its desire to identify some variable other than rollover stability factor as the principal parameter in rollover accidents, has simply misinterpreted the role of wheelbase and track width. As the paper notes, these two factors are covariate, i.e., longer vehicles tend to have wider tracks and shorter vehicles tend to have narrower tracks. Consequently, they correlate with one another to a high degree. This is shown in Table 13 wherein various single and normalized vehicle parameters are correlated with one another for all the vehicles used previously in the CARDfile analysis. Given this fact, the track and wheelbase, when normalized by the center of gravity height, would also be expected to correlate. In fact, the normalized variables correlate better with one another than the track and wheelbase alone, as Table 13 and Figure 8a show. This indicates that $T/2H_{cg}$ and L/H_{cg} are in effect surrogate variables, and that anything that correlates with one of them will also correlate with the other. This is indeed the case as is shown in Figure 8b where RO/SVA is regressed against wheelbase divided by center of gravity height rather than against the rollover stability factor. Therefore, far from showing that vehicle size is a fundamentally different and more important parameter in rollover accidents than rollover stability factor, the draft paper has simply reaffirmed that wheelbase and track are covariate quantities. //

Before leaving this section, we would like to offer an observation as to why the degree of correlation seems to improve when wheelbase is substituted for rollover stability factor as shown in Figure 3 and Figure 6 of the draft evaluation paper. When RO/1,000 Reg. Vehicles is regressed against rollover stability factor, the R-squared statistic is 0.4063 (Figure 3), as opposed to an R-squared of 0.8371 when the independent variable is wheelbase (Figure 6). In this case, restricting the range of the independent variable has another consequence, in addition to those that we have mentioned previously. This is that the restricted range is also the range which has the greatest uncertainty associated with the independent variable. This is because utility vehicles are often equipped with oversize tires and/or raised suspensions, which alters the effective track width as well as the center of gravity height. Wheelbase is not subject to this variability, however, and is probably a better surrogate variable for the mean rollover stability factor than the average values computed from the data given in Attachment 11 of the draft evaluation. However, simply because this is true for a restricted class of vehicles does not imply that wheelbase or vehicle size is the primary vehicle parameter associated with rollover risk.

Lastly, while we have objected throughout this memorandum in disaggregating utility vehicles from passenger vehicles, we have nevertheless adopted this method to determine the extent to which the correlation between RO/SVA and rollover stability factor is degraded, when a database other than FARS is used. For this purpose, the utility vehicles listed in Table 1 were taken as a class and their rollover rate was regressed against rollover stability factor, as shown in Figure 9. The R-squared statistic for this regression is 0.50. Although the correlation is significantly reduced compared to the correlation obtained when automobiles and utility vehicles are treated as a single class, it nevertheless still indicates a strong relationship between rollover rate and rollover stability factor. This is in contrast to the data shown in Figure 1 of the draft paper, which show essentially no correlation between RO/SVA and rollover stability factor for fatal accidents.

Section IV A: One may conclude from the above analysis that:

(1) Rollovers are highly dangerous accidents.

(2) Utility vehicles are more likely to be involved in rollover crashes than most other types of vehicles.

(3) Vehicles' stability factors are strongly related to their propensity to roll over. This has been clearly demonstrated for passenger cars and utility vehicles.

We therefore concur that the petition has raised and documented, with the Kelly and Robertson report, an important highway safety issue. We disagree with the denial of the first three actions of the petition based on the criteria "that the previously discussed analyses indicate that the stability factor proposed in the petition is not an appropriate or accurate predictor of vehicle rollover accident involvement, and that agency action based on it would be unreasonable." We do not believe that the analysis provided in RM's draft evaluation can support this denial.

Further, this agency is about to send the Light Truck/Van Report to Congress. In that report, we provide information showing that multi-purpose passenger vehicles have a rollover rate (per registered vehicle) of about three times that found for cars. Clearly these vehicles (MPV's) are distinct from passenger cars and we should study them to find out why.

It is RD's recommendation, based on the foregoing, that the petition be granted.

In light of the above, we recommend that once the petition is granted, all relevant data and analyses available, be placed in the docket and that we solicit public opinion as to their merit. Proposed research, undertaken to improve our understanding of the mechanisms behind these accidents and the relative efficacy of various possible countermeasures, should also be made openly available for public appraisal.

The improved crash avoidance measures undertaken could include anti-lock braking systems, which would prevent the vehicles from going out of control during panic stops. Increased turning radii might also prevent a limited number of these accidents. Also, we recommend that in addition to the studies suggested by the draft evaluation, the agency immediately undertake the development of a tripped rollover test device similar to the sled device used by American Motors Corporation. This apparatus should then be used to evaluate and rank order the tripped rollover propensity of all new utility vehicles and light trucks. This information could be widely disseminated in a fashion similar to that utilized in the New Car Assessment Program, thereby providing important knowledge to safety conscious consumers who are considering purchasing this type of vehicle.

Crashworthiness countermeasures might include improved rollbars, glazing and side protection strengthening devices. We may also wish to consider a safety belt system which will promote their use. Restraint use should be extremely effective in providing a significant margin of extra protection for all occupants. It is suggested that, in our response to the petitioner, we state our intention to issue an Advanced Notice of Proposed Rulemaking for improved occupant protection in rollovers of utility vehicles.

A typographical error was found on page 11. On the 9th line under Other Recommendations, the phrase "test vehicles equipped the roll bars", the word should be "with".

Attachment 11: The center of gravity height value for the Chevrolet Blazer is in error. According to the report No. VRTC-87-0061, entitled "Center of Gravity Height Measurements for Selected Cars and Utility Vehicles", the correct value should be 27.20 inches.

Attachment

cc: Chief Counsel
Associate Administrator for Plans and Policy
Associate Administrator for Enforcement

FIGURE 1

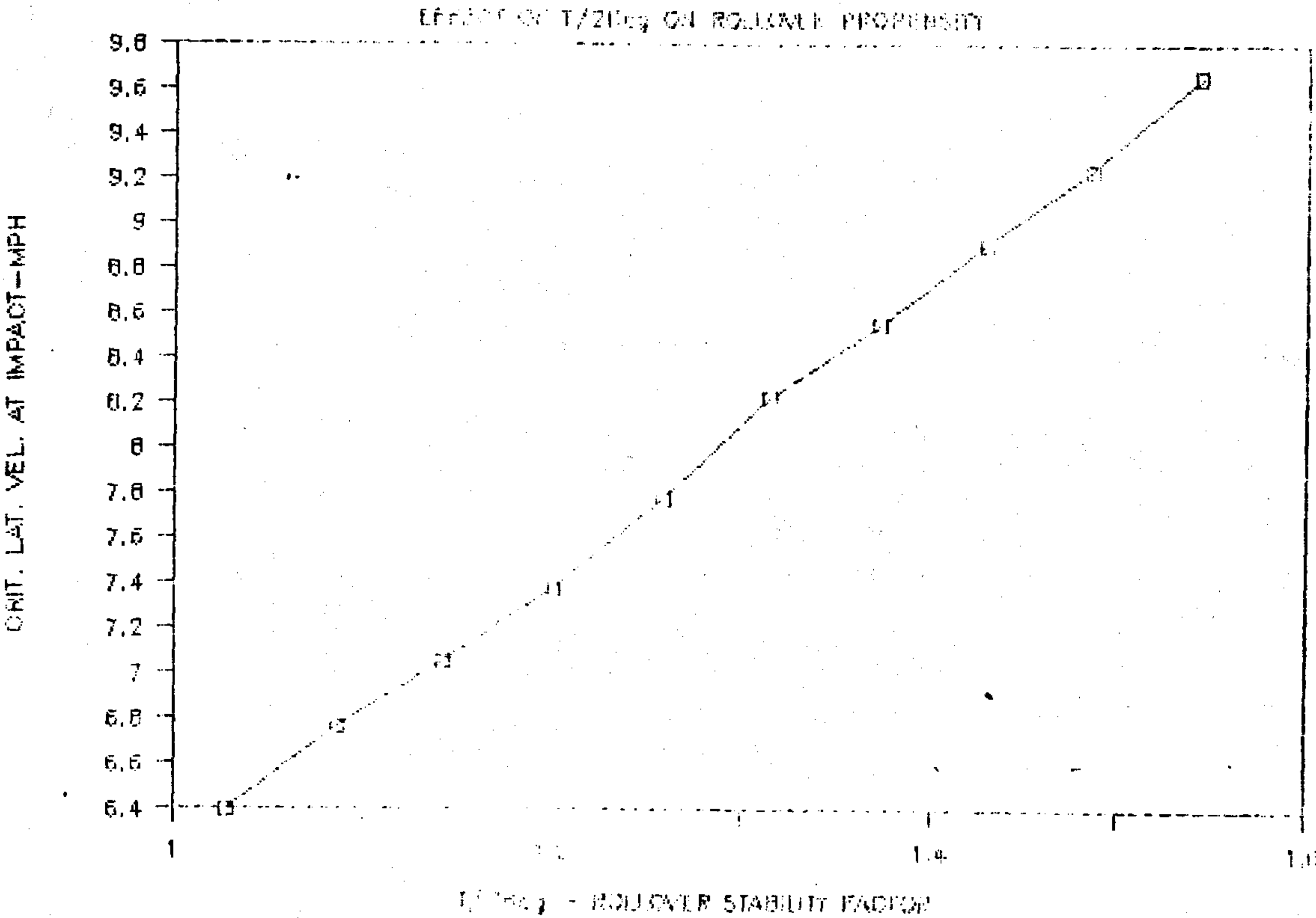
CRIT. LAT. VEL. AT IMPACT—MPH
9.8
9.6
9.4
9.2
9
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
1
1.4

FIGURE 2

EXPOSURE FACTORS IN SVA BASES

FOR UTILITY VEHICLES VS PASSENGER CARS

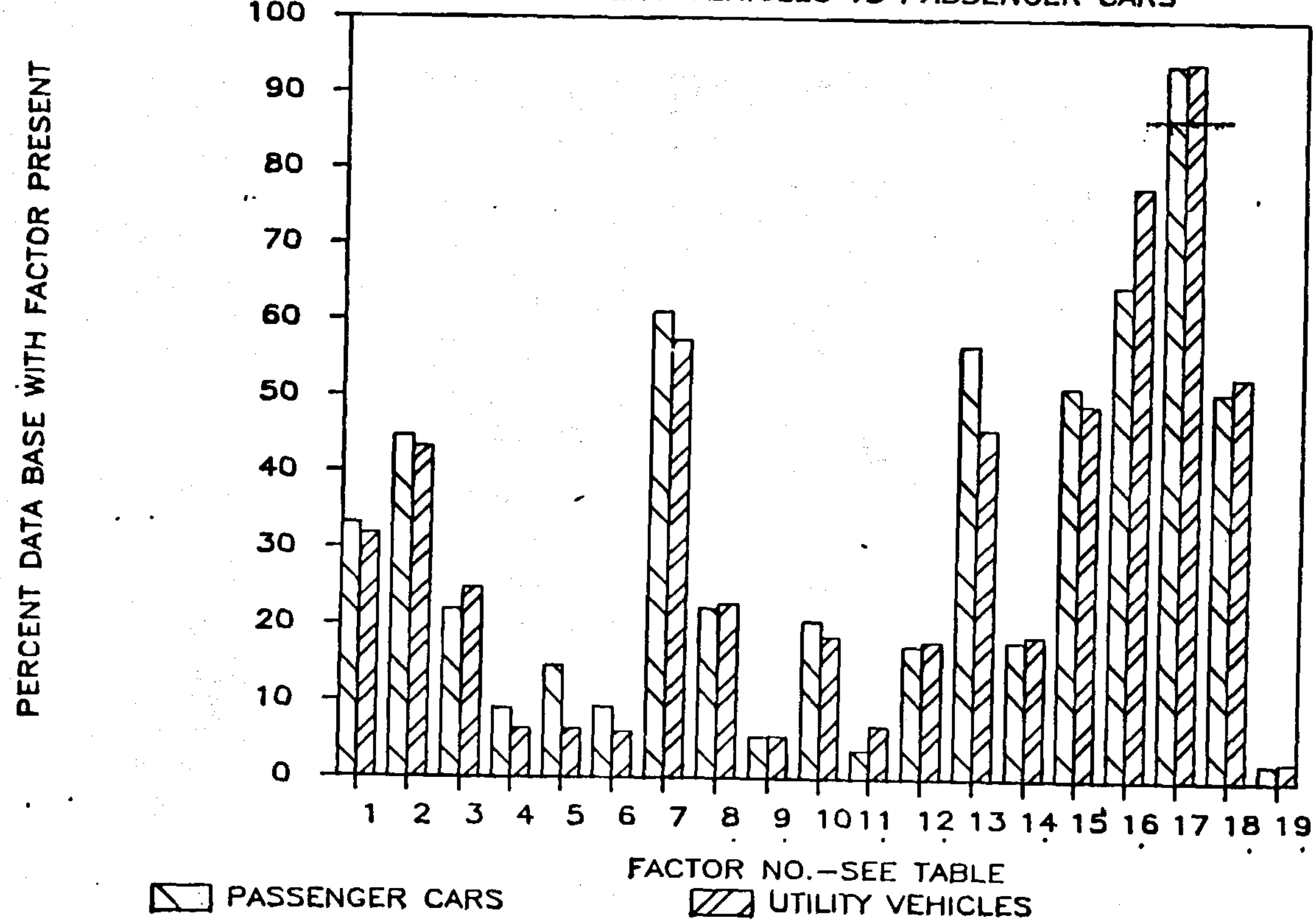

Figure 3

CONTROLLING FOR EXPOSURE RISK

FOR UTILITY VEHICLES VS PASSENGER CARS

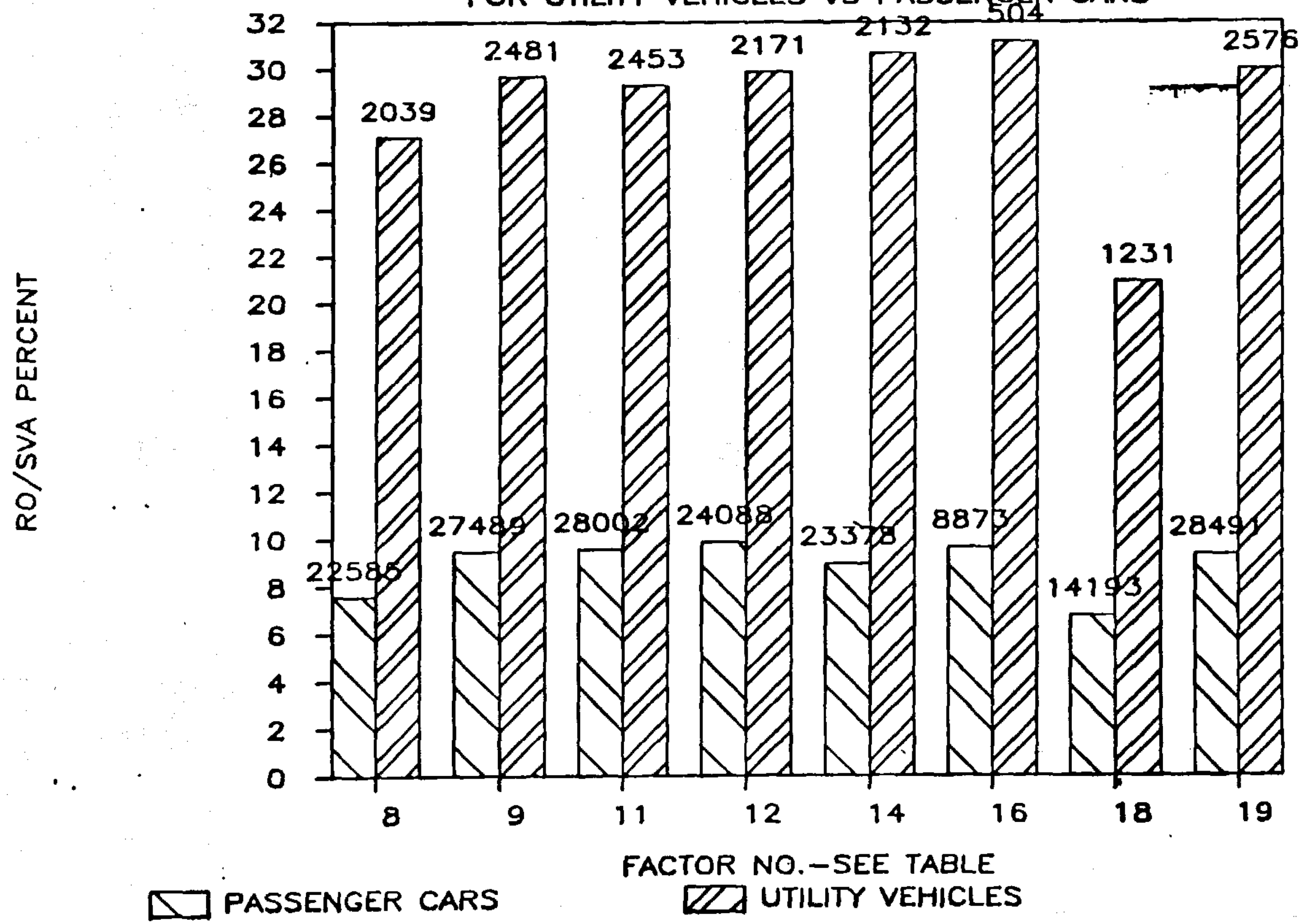

FIGURE 4

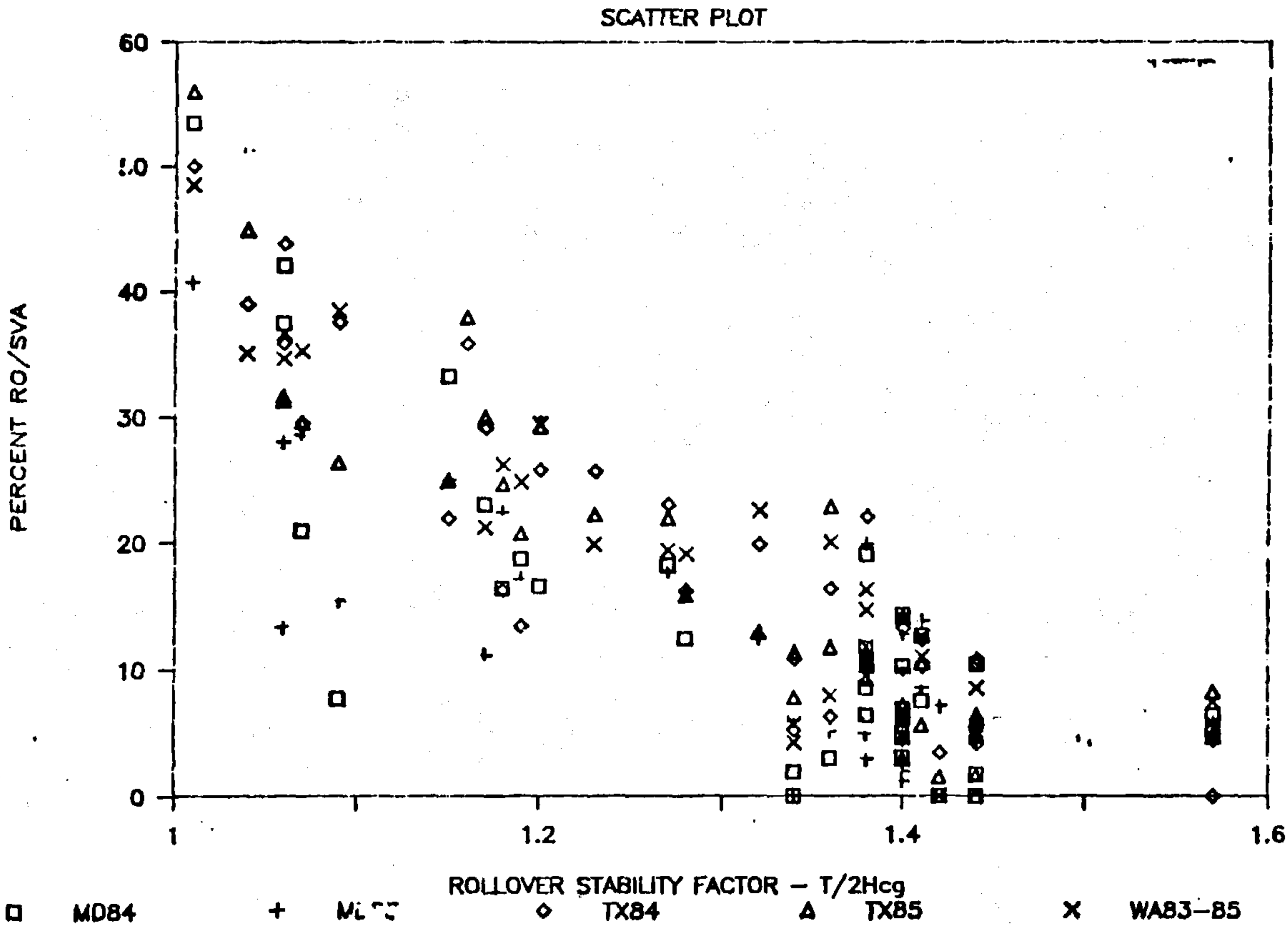
SCATTER PLOT
60
40
30
20
10
0
1
1.2
1.4
1.6
PERCENT RO/SVA
ROLLOVER STABILITY FACTOR – T/2Hcg
MD84
TX84
TX85
WA83–85

FIGURE 5

TX (84 & 85) MD (84 & 85) WA (83-85)
PLOT OF RESIDUAL (CORRESPONDING TO FIGURE #6)

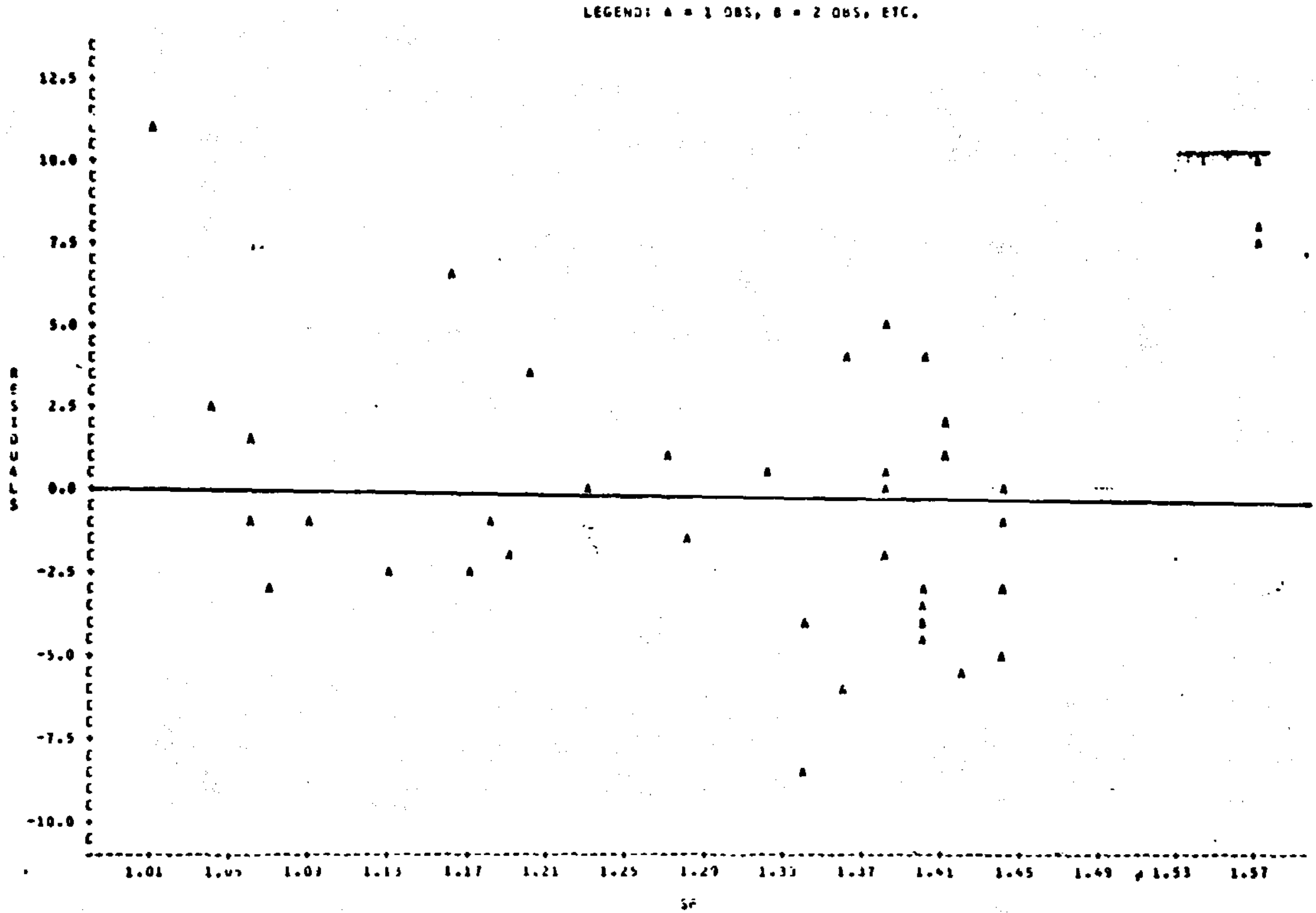

FIGURE 6

TX(84&85) MD(84&85) WA(83&84&85)

$RO/SVA = 110.4 - 71.8\ SF + e \quad R^2 = 0.86$

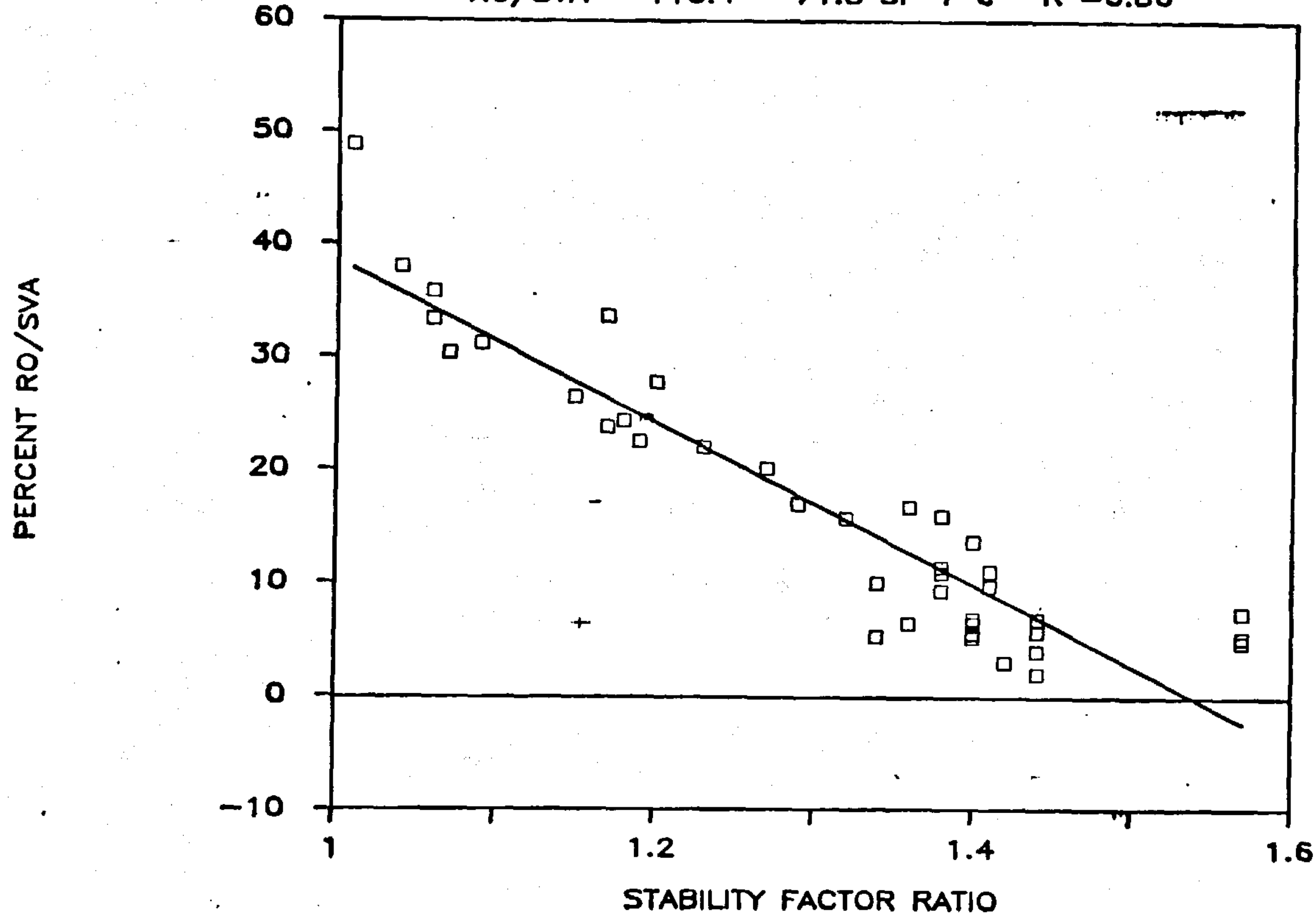

FIGURE 7

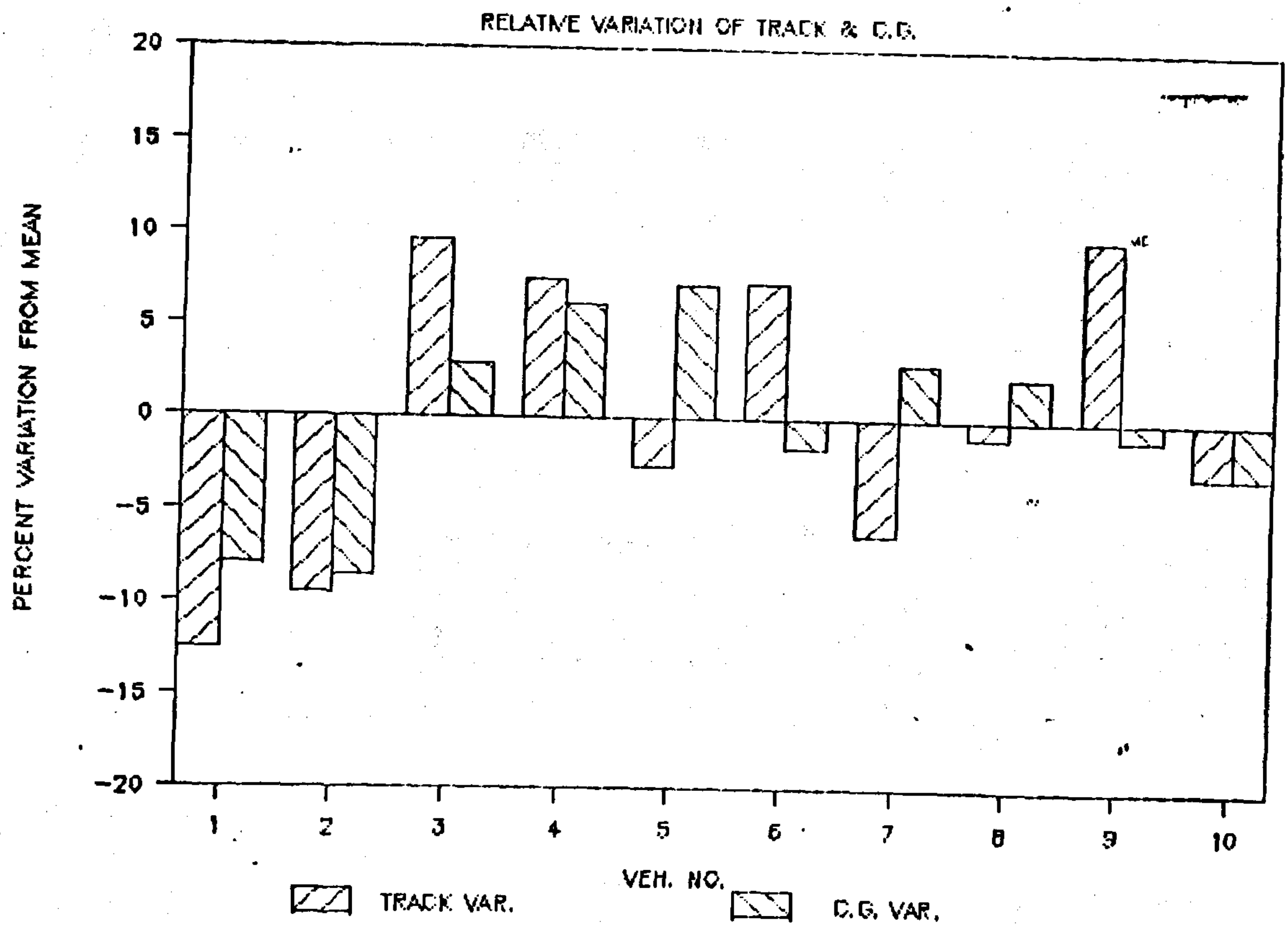
RELATIVE VARIATION OF TRACK & C.G.
PERCENT VARIATION FROM MEAN
20
15
10
5
0
−5
−10
−15
−20
1
2
3
4
5
6
7
8
9
10
VEH. NO.
TRACK VAR.
C.G. VAR.

FIGURE 8a

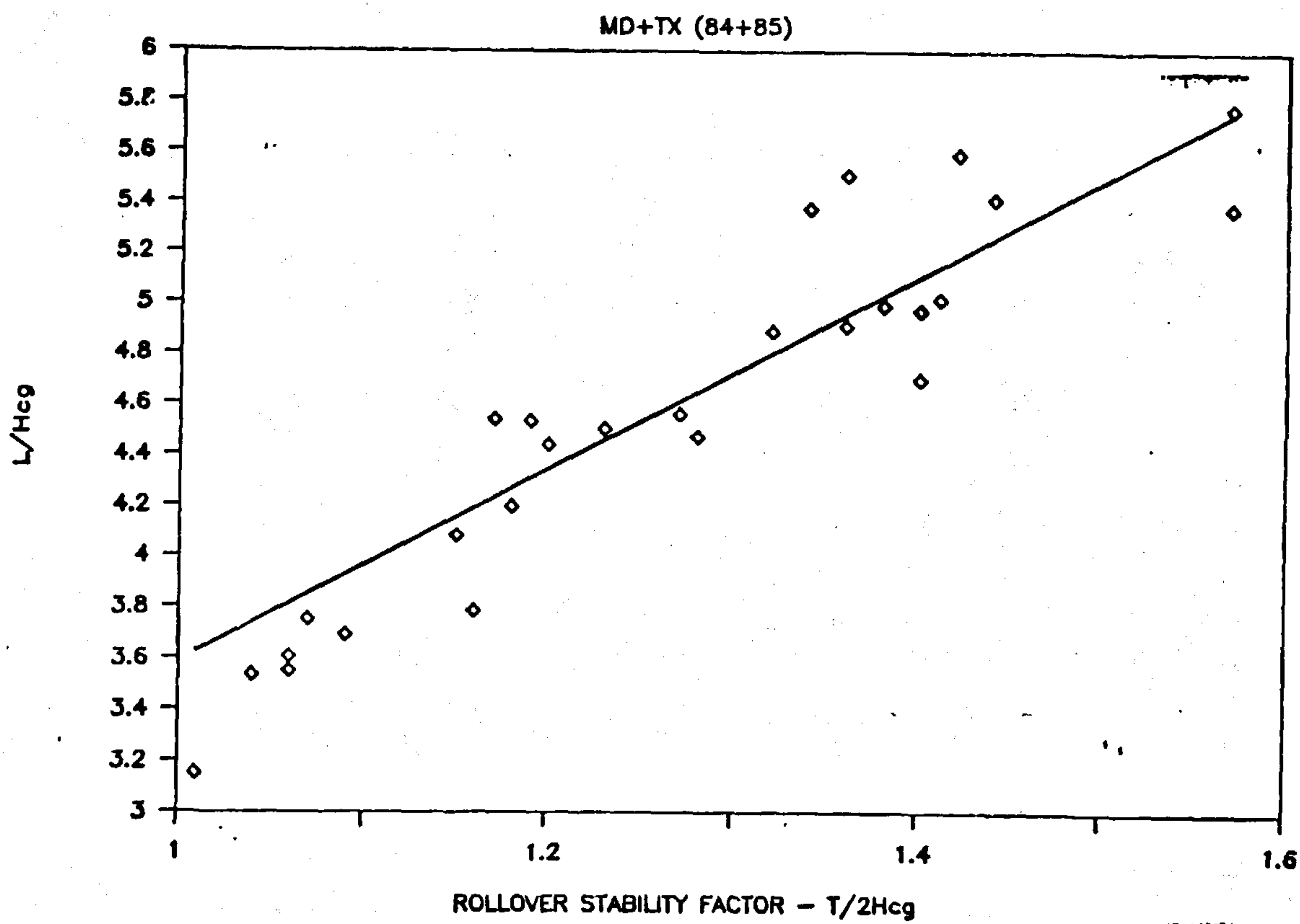
MD+TX (84+85)
L/Hcg
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
1
1.2
1.4
1.6
ROLLOVER STABILITY FACTOR – T/2Hcg

FIGURE 8b

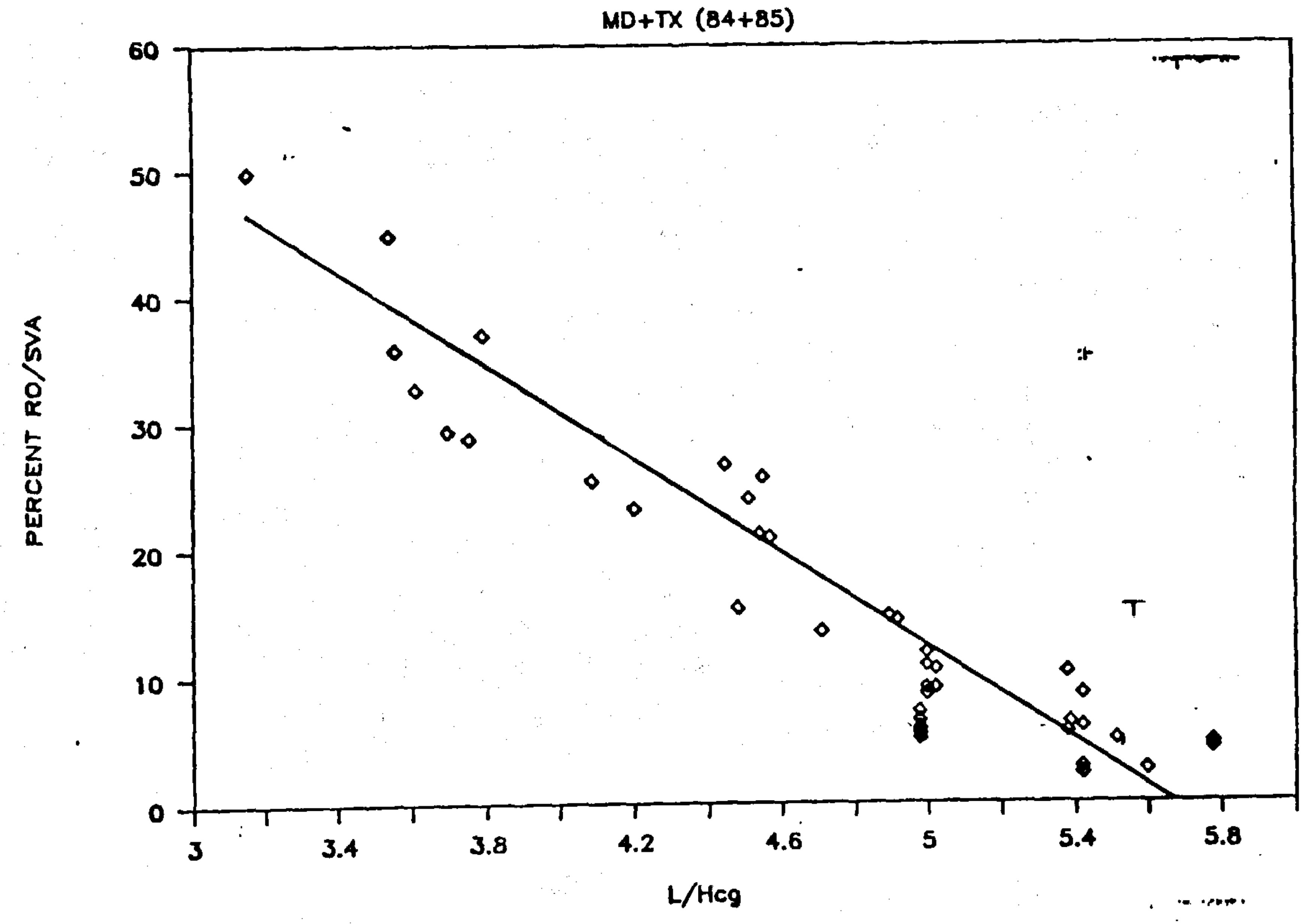
MD+TX (84+85)
60
50
40
30
20
10
0
PERCENT RO/SVA
3
3.4
3.8
4.2
4.6
5
5.4
5.8
L/Hcg

FIGURE 9

RO/SVA UTILITY VEHICLES

$140.4 - 98.03\ SF + e = RO/SVA \quad R^2 = .5$

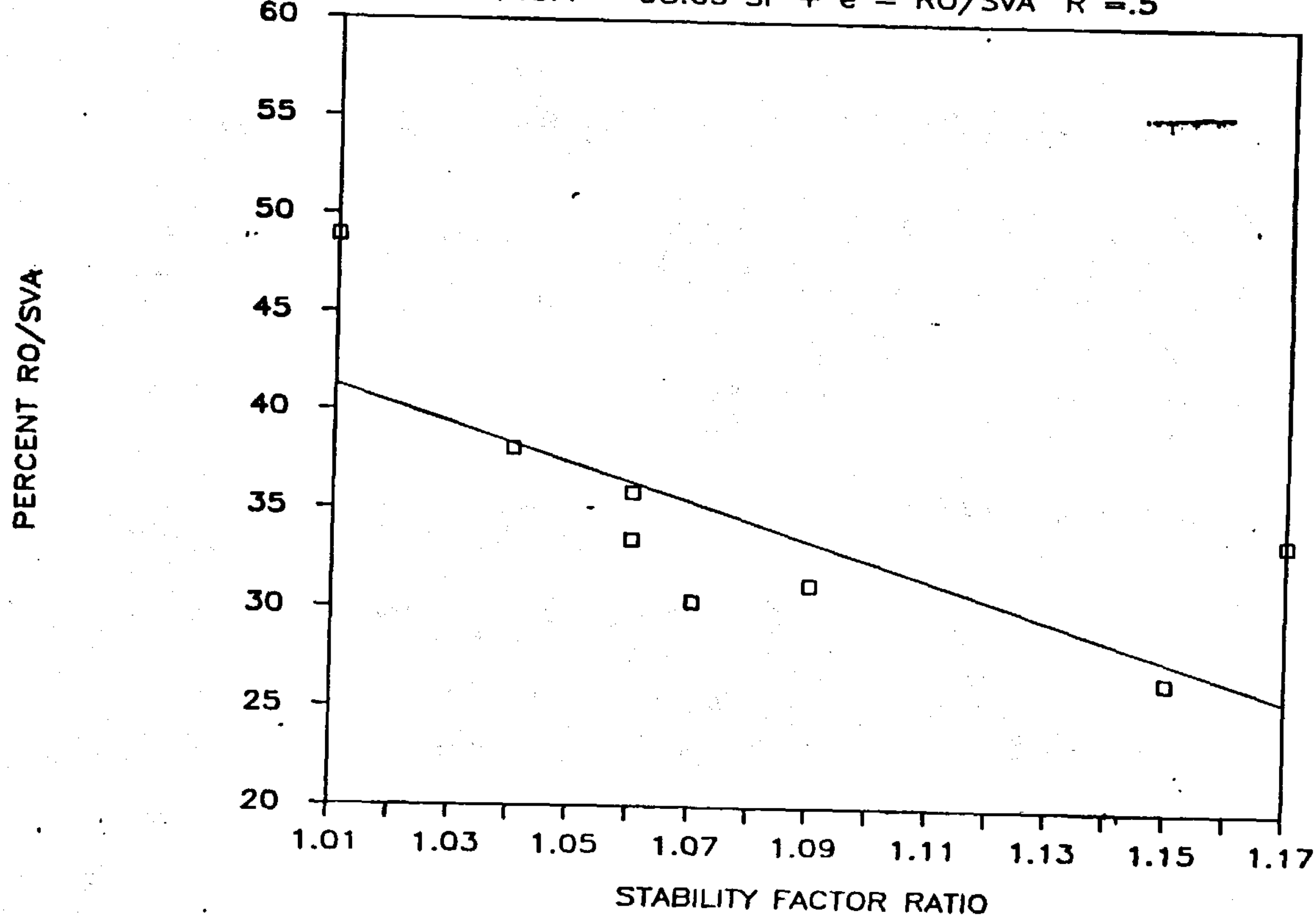

Table 1.a — Data Set Contents — Light Trucks and Utility Vehicles

CONTENTS OF INDIVIDUAL AND COMBINED DATA SETS							
Veh. No.	Make/Model	Year	MD 84 RO/SVA	MD 85 RO/SVA	TX 84 RO/SVA	TX 85 RO/SVA	MD+TX (84+85) RO/SVA
1	JEEP CJ-5	72-75	15/28	11/27	5/10	10/18	41/83
2	JEEP CJ-7	83-	15/40	9/32	28/64	26/82	78/218
3	CHEROKEE	75-83	3/9	3/12	4/18	3/12	13/51
4	FORD-BRONCO	73-83	12/55	10/35	94/216	67/226	183/532
5	CHEV.-BLAZER S-10	83	1/13	2/13	35/96	19/72	57/194
6	CHEV.-BLAZER	82	1/2*	1/3*	14/39	13/34	29/78
7	TOYOTA-LANDCRUISER	ALL	1/2*	3/6*	9/18	9/23	22/49
8	I. H. SCOUT	<79	8/19	2/15	23/64	21/67	54/165

Table 2 — Data Set Contents — Imported Passenger Cars

CONTENTS OF INDIVIDUAL AND COMBINED DATA SETS							
Veh. No.	Make/Model	Year	MD84 RO/SVA	MD 85 RO/SVA	TX 84 RO/SVA	TX 85 RO/SVA	MD+TX (84+85) RO/SVA
9	AUDI 4000	ALL	0/6*	2/16	6/30	6/46	14/98
10	DATSUN Z,ZX	ALL	20/139	12/120	72/540	95/667	199/1,466
11	DATSUN B210	ALL	56/298	45/262	72/535	93/446	329/1,541
12	RENAULT LE CAR	?	3/13	1/9	7/24	6/20	17/66
13	HONDA CIVIC	<83	26/142	24/135	67/290	53/241	170/808
14	TOYOTA COROLLA	<79	0/1*	0/0**	94/364	74/332	168/697
15	VW BEETLE	<80	45/272	40/178	137/532	118/478	340/1,460
16	VW RABBIT	ALL	23/184	28/174	50/306	43/270	144/934
17	MAZDA GLC	<80	2/12	3/10	20/77	17/58	42/157

Table 3 – Data Set Contents – Domestic Passenger Cars

CONTENTS OF INDIVIDUAL AND COMBINED DATA SETS							
Veh. No.	Make/Model	Year	MD 84 RO/SVA	MD 85 RO/SVA	TX 84 RO/SVA	TX 85 RO/SVA	MD+TX (84+85) RO/SVA
18	CAD. DEVILLE/BROUGHAM	81–84	0/13	1/14	2/59	1/66	4/152
19	CHEV. CITATION	80–81	11/128	6/123	31/279	25/269	73/799
	OLDS. OMEGA		2/17	3/15	5/49	6/53	16/134
	BUICK SKYLARK		3/47	1/34	8/76	9/87	21/244
	PONTIAC PHOENIX		8/26	3/30	19/71	9/73	32/200
20	CHEV. CHEVETTE	79	0/0**	0/0**	15/91	8/89	23/180
21	CHEV. CORVETTE	73	1/5*	0/4*	0/11	1/12	2/32
22	CHEV. CAMERO	ALL	38/398	20/393	92/2,074	99/2,241	249/5,106
	PONTIAC FIREBIRD		14/271	18/301	48/1,132	53/1,089	133/2,793
23	CHEV. MALIBU	78–81	9/146	6/140	21/326	31/340	67/954
	OLDS. CUTLASS		10/202	4/186	60/829	43/767	118/1,983
	CHEV. MONTE CARLO		8/78	1/78	44/629	40/653	93/1,438
	BUICK CENTURY/REGAL		7/101	1/90	30/505	25/541	63/1,237
	PONTIAC LEMANS		1/32	8/39	7/118	3/103	19/292
24	CHRYSLER CORDOBA	77–81	0/53	2/39	7/171	2/129	11/392
	DODGE DIPLOMAT		2/19	1/17	4/39	2/31	9/106
	DODGE MIRADA		0/6	0/5*	1/18	0/15	1/44
	CHRYSLER LEBARON		1/55	2/48	11/101	4/96	18/300
25	FORD MUSTANG	79–81	14/186	15/174	64/518	55/486	148/1,364
	MERCURY CAPRI		6/47	8/39	14/139	5/143	33/368
26	FORD LTD	79–81	1/82	3/61	68/620	72/629	144/1,392
	MERCURY MARQUIS		0/12	0/14	4/77	6/77	10/180
27	AMC CONCORD	80	4/134	5/99	1/16	3/13	13/262

Table 4 – Vehicle Data – Light Trucks and Utility Vehicles

VEHICLE GEOMETRIC AND ROLL STABILITY DATA							
Veh. No.	Make/Model	Year	L–IN.	H–IN.	T/2–IN.	T/2H	SOURCE
1	JEEP CJ–5	72–75	83.5	26.5	26.8	1.01	8,13
2	JEEP CJ–7	83–	93.5	26.3	27.9	1.06	1,13
3	JEEP CHEROKEE	75–83	108.7	26.6	30.7	1.15	2,6,12
4	FORD BRONCO	73–83	104.7	27.9	30.0	1.07	9,12
5	CHEV. BLAZER S–10	83	100.5	27.2	29.6	1.09	8,10,12
6	CHEV. BLAZER	82	106.5	28.1	32.6	1.17	1,12
7	TOYOTA LANDCRUISER	ALL	98.0	27.7	29.1	1.04	10,11,12
8	I.H. SCOUT	<79	100.0	27.7	29.3	1.06	6,12,13

Table 5 — Vehicle Data — Imported Passenger Cars

VEHICLE GEOMETRIC AND ROLL STABILITY DATA							
Veh. No.	Make/Model	Year	L–IN.	H–IN.	T/2–IN.	T/2H	SOURCE
9	AUDI 4000	ALL	99.8	20.4	26.9	1.32	5,9
10	DATSUN Z,ZX	ALL	91.3	19.4	27.2	1.40	5,9
11	DATSUN B210	ALL	92.1	20.3	24.2	1.19	5,9
12	RENAULT LE CAR	ALL	95	20.9	24.5	1.17	5,9
13	HONDA CIVIC	<83	94.5	20.7	26.3	1.27	5,9
14	TOYOTA COROLLA	<79	93.3	20.7	25.5	1.23	5,9
15	VW BEETLE	<80	94.5	22.5	26.6	1.18	5,9
16	VW RABBIT	ALL	94.5	21.1	27.0	1.28	5,9
17	MAZDA GLC	<80	91.1	20.5	24.6	1.20	5,9

Table 6. – Vehicle Data – Domestic Passenger Cars

VEHICLE GEOMETRIC AND ROLL STABILITY DATA							
Veh. No.	Make/Model	Year	L–IN.	H–IN.	T/2–IN.	T/2H	SOURCE
18	CAD. DEVILLE/BROUGHAM	81–84	121.4	21.7	30.8	1.42	5,9
19	CHEV. CITATION OLDS. OMEGA BUICK SKYLARK PONTIAC PHOENIX	80–81	104.9	21.0	28.9	1.38	8,4
20	CHEV. CHEVETTE	79	97.3	19.8	27.0	1.36	1,5
21	CHEV. CORVETTE	73	98.0	18.2	28.6	1.57	1,5
22	CHEV. CAMERO PONTIAC FIREBIRD	ALL	108.0	18.7	29.4	1.57	5,9
23	CHEV. MALIBU OLDS. CUTLASS CHEV. MONTE CARLO BUICK CENTURY/REGAL PONTIAC LEMANS	78–81	108.0	21.7	30.4	1.40	5,9
24	CHRYSLER CORDOBA DODGE DIPLOMAT DODGE MIRADA CHRYSLER LEBARON	77–81	112.7	20.8	30.0	1.44	5,9
25	FORD MUSTANG MERCURY CAPRI	79–81	100.4	20.0	28.3	1.41	5,9
26	FORD LTD MERCURY MARQUIS	79–81	114.0	21.2	28.4	1.34	5,9
27	AMC CONCORD	80	108.0	19.6	26.7	1.36[1]	

TABLE 7

DATA SET CONTENTS FOR
WASHINGTON STATE (83-85)

NO VEH	% RO/SVA	NO. RO	NO. SVA
1	48.5	47	97
2	36.7	11	30
3	30.8	4	13
4	35.4	63	178
5	38.5	20	52
6	9.1	1	11
7	35.8	53	148
8	34.8	32	92
9	22.7	5	22
10	5.3	84	1594
11	24.9	222	892
12	21.3	10	47
13	19.5	165	846
14	20.1	139	691
15	26.3	248	944
16	19.1	144	752
17	29.5	33	112
18	11.1	1	9
19a	14.8	59	398
b	10.4	5	48
c	11.9	10	84
d	16.4	11	67
20	20.2	23	114
21	12.5	1	8
22a	5.8	95	1650
b	7.4	59	792
23a	6.3	13	207
b	4.7	15	319
c	6.8	15	221
d	6.7	11	164
e	6.3	4	63
24a	8.5	10	117
b	4.9	4	82
c	0.0	0	4
d	5.2	4	77
25a	12.7	64	505
b	11.1	25	225
26a	5.8	4	69
b	4.2	1	24
27	8.0	23	287

TABLE 8

DATA SET CONTENTS FOR TX & MD (84&85) AND WA (83-85)

NO. VEH.	%RO/SVA	NO. RO	NO. SVA
1	48.9	88	180
2	35.9	89	248
3	26.6	17	64
4	30.4	216	710
5	31.3	77	246
6	33.7	30	89
7	38.1	75	197
8	33.5	86	257
9	15.8	19	120
10	13.7	283	2060
11	22.6	551	2433
12	23.9	27	113
13	20.3	335	1654
14	22.1	307	1388
15	24.5	588	2404
16	17.1	288	1686
17	27.9	75	269
18	3.1	5	161
19a	11.0	132	1197
b	11.5	21	182
c	9.5	31	328
d	16.1	43	267
20	16.8	46	273
21	7.5	3	40
22a	4.9	353	7156
b	5.4	192	3585
23a	7.0	82	1171
b	5.7	130	2272
c	6.5	108	1659
d	5.3	74	1401
e	5.6	20	357
24a	4.1	21	509
b	7.0	13	187
c	2.1	1	48
d	5.8	22	377
25a	11.2	209	1869
b	9.9	58	587
26a	10.1	148	1461
b	5.4	11	204
27	6.6	36	549

Table 9 — Contents of Individual and Combined Data Sets

SUMMARY OF DATA SET CONTENTS				
	MD 84	MD 85	TX 84	TX 85
RO/SVA	368/3,465	307/3,156	1,323/11,195	1,174/11,085
	MD (84+85)	TX (84+85)	WA(83+84+85)	
RO/SVA	675/6,621	2,497/22,280	1738/11,055	
	MD+TX (84+85)	WA(83+84+85)+MD+TX(84+85)		
RO/SVA	3,172/28,901	4910/39,956		

TABLE 10

1 LOCATION OF THE INITIAL IMPACT WAS OFF THE ROADWAY

2 LOCATION OF INITIAL IMPACT WAS ON THE SHOULDER

3 LOCATION OF INITIAL IMPACT WAS ON THE ROAD

4 LAND USE AT THE CRASH SITE IS RURAL

5 LAND USE AT CRASH SITE IS URBAN

6 ROADWAY HAS RISE OR DROP AT ACCIDENT SITE

7 DARK AT TIME OF CRASH

8 AREA OF SITE IS NON-STRAIGHT

9 SKIDDING OCCURRED JUST PRIOR TO THE CRASH

10 THE ROADWAY WAS WET

11 THE ROADWAY WAS SNOWY

12 THE WEATHER WAS RAINY SNOWY OR OTHER

13 THE DRIVER WAS LESS THAN 25 YRS OLD

14 THERE IS INDICATION OF DRUG OR ALCOHOL USE BY DRIVER

15 NO RESTRAINTS IN USE BY THE DRIVER

16 DRIVER MALE

17 NO EVIDENCE OF COMPONENT FAILURE CITED

18 SPEED CITED AS DRIVER ERROR

19 SLEEP OR GROSS INATTENTIVENESS CITED.