EVALUATION OF THE 1960-1963 CORVAIR HANDLING AND STABILITY

JULY 1972

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U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
WASHINGTON, D.C. 20590

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National Highway Traffic Safety Administration
Motor Vehicle Programs
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TABLE OF CONTENTS

I. SUMMARY

In September 1970 the National Highway Traffic Safety Administration (NHTSA), Department of Transportation, began an evaluation of the handling and stability characteristics of the 1960-1963 Corvair vehicle, beginning with review of General Motors Corporation documents and test data. The existence of some of this information had been called to the Government's attention by Mr. Ralph Nader.

Analysis of General Motors documents, technical literature, and all available accident data was followed by a concentrated program of Government testing of the Corvair and contemporary vehicles during the spring and summer of 1971. Input-response type dynamic tests which could provide quantitative data were selected for this comparative test program. Support for the tests, conducted at College Station, Texas, was provided by the Texas Transportation Institute (TTI), Texas A&M Research Foundation. Testing was completed by July 15, 1971. Test data were reduced by TTI during the late summer and fall of 1971, and NHTSA analyzed the data as it became available.

To evaluate the objectivity of NHTSA testing and analysis, a three-man Advisory Panel of independent professional engineers was retained. The charge to the Panel was to review the scope and competence of the NHTSA investigation and specifically to identify any additional vehicle testing believed to be necessary to an objective, professional decision regarding the handling and stability characteristics of the 1960-1963 Corvair as a possible safety defect.

Evaluation of the extensive data obtained from General Motors and from other sources, analysis of the NHTSA input-response vehicle test data, and recommendations from the Advisory Panel employed in this case indicate that:

The 1960-1963 Corvair understeers in the same manner as conventional passenger cars up to about 0.4g lateral acceleration, makes a transition from understeer, through neutral steer, to oversteer in a range from about 0.4g to 0.5g lateral acceleration, and reaches its limit of control at 0.6g sustained lateral acceleration. This transition does not result in abnormal potential for loss of control.

The limited accident data available indicates that the rollover rate of the 1960-1963 Corvair is comparable to other light domestic cars.

The 1960-1963 Corvair compared favorably with the other contemporary vehicles used in the NHTSA Input Response Tests.

The handling and stability performance of the 1960-1963 Corvair does not result in an abnormal potential for loss of control or rollover and it is at least as good as the performance of some contemporary vehicles both foreign and domestic.

II. INTRODUCTION

The sequence of events that led to a Department of Transportation (DOT) decision to conduct extensive tests of the handling and stability characteristics of the 1960 through 1963 Corvair automobile began with a September 4, 1970, letter (Appendix I) from Mr. Ralph Nader to John A. Volpe, Secretary of Transportation. As a result of this input, the National Highway Traffic Safety Administration (NHTSA) undertook to analyze the vast amount of test data, documents, films, and other information known to General Motors (GM) about the design, testing, production, and use of the Corvair vehicle and to correlate this information with accident data and independent articles in the technical literature regarding Corvair performance.

This comprehensive analysis was completed by the end of December 1970. Mr. Nader wrote again to Secretary Volpe on December 15, 1970 (Appendix II) on the same subject, citing two specific GM proving ground reports that he felt were particularly critical to the case. These reports had been included in the NHTSA analysis.

Following receipt of a third letter from Mr. Nader to Secretary Volpe dated February 23, 1971 (Appendix III), the DOT, NHTSA initiated plans to compare the handling and stability characteristics of the 1960-1963 Corvair with the same characteristics of contemporary vehicles, through the use of a series of handling maneuvers. After a thorough in-house examination of vehicle handling state-of-the-art, a program of testing using input-response type vehicle dynamic tests, similar to those developed under Contract FH-11-7297 by the University of Michigan Highway Safety Research Institute (HSRI), was decided upon.

A contract (DOT-HS-065-1-077) was signed with the Texas Transportation Institute (TTI), Texas A&M Research Foundation, College Station, Texas, for use of the necessary facilities and support services. The testing program, supervised by NHTSA engineers, began in Texas in early March 1971. A subsequent letter from Mr. Gary B. Sellers, a Ralph Nader associate, to Mr. Rodolfo A. Diaz, Acting Associate Director, Motor Vehicle Programs, NHTSA, dated March 17, 1971 (Appendix IV), contained suggestions regarding testing procedure. Most of these suggestions were being implemented in the NHTSA testing plan. Because of program constraints, it was not feasible to test the vehicles under all of the suggested combinations of conditions.

The actual testing, conducted on a seven-days per week basis, was completed on July 15, 1971. A final report of individual vehicle test results was submitted by TTI in November 1971.

When the actual test phase was completed and the voluminous test data were reduced, NHTSA engineers began an analysis of test results. This analysis is documented in Part II, B. 1 of this report.

As the test program neared completion, the NHTSA Administration, in order to obtain an independent professional evaluation of Corvair handling performance, convened an Advisory Panel of three men with diversified professional engineering backgrounds to look at all of the work done by NHTSA in analyzing the GM documents and in conducting the input-response tests in Texas. The Panel was instructed to determine whether the Government had done all that was reasonably necessary to a sound decision by the Administrator regarding the safety aspects of Corvair handling. Specifically, the Panel was requested to advise regarding any further testing necessary to a professionally sound basis for decision. The Panel met with NHTSA personnel on September 15-16, 1971, to obtain understanding of the NHTSA work to date. At that time, the Panel members received, for their independent analyses, an extensive and comprehensive set of documents, including the GM data, the Texas test data, and related technical literature and accident data. The Panel presented its initial findings at a meeting with the Administrator on December 15, 1971. The final Advisory Panel report was submitted in June 1972.

III. DISCUSSION

A. General: The Current State-of-the-Art

In the NHTSA evaluation of Corvair handling performance, two major questions were identified at the outset: (1) what was the current state-of-the-art in vehicle handling? and (2) what characteristics with respect to vehicle handling should be considered in making a determination of whether a safety related defect exists or does not exist?

The first question about the state-of-the-art in vehicle handling involves consideration of the existence of any standard for vehicle handling, the validity of different types of tests, the necessary scope of tests, and the necessary facilities and resources required for the conduct of tests? At present, there is no Federal Motor Vehicle Safety Standard for vehicle handling. Extensive research is being conducted by both the automotive industry and by Government in vehicle handling concepts. There is as yet no agreement among researchers as to the type of test best suited to a vehicle handling standard. The NHTSA research approach currently emphasizes input-response, vehicle dynamic tests (see discussion below), and these are the criteria now being tried in the development of a proposed Federal Motor Vehicle Safety Standard for Vehicle Handling.

The second question as to what characteristics should be considered was also studied quite carefully. The NHTSA analysis of the GM documents and related material was an examination of past events, and the significant handling criteria reviewed included limit of control tests, rollover tests, general proving ground tests, and tests of vehicles in the actual user operating environment. When it was decided that the Government would conduct additional testing of the 1960-1963 Corvair two test approaches were considered for comparison of handling and stability of contemporary vehicles: (1) Task Performance, and (2) Input-Response.

Task Performance tests, which include the driver-vehicle interface, were ruled out because of the inability to quantitatively measure the driver inputs and reactions.

Input-Response tests, eliminating the human driver as a controller and providing quantitative measurement of vehicle dynamics, were selected for the Government evaluation.

The question then became what input-response tests procedures should be used? As mentioned in the Introduction, HSRI had conducted a group of input-response tests under contract with NHTSA. The purpose had been to develop an automatic vehicle controller capable of being programmed for accurate repetition of a variety of steering and braking control inputs.

As of March 1971, the NHTSA had in preparation a proposal for additional vehicle handling testing which incorporated input-response maneuvers selected for use as a basic guide in the Texas test program. It is important to note that, while these tests were designed to employ instrumentation and finite measurements yielding quantitative data, they had never been validated nor had they been correlated with actual driving maneuvers.

In Mr. Seller's letter of March 17, 1971, suggestions regarding the testing procedure were offered. Most of these were incorporated in the test program, as follows:

> All the suggested vehicles, a 1962 Falcon, a 1960 Valiant, a 1963 Corvair, and a 1967 Corvair, were included. In addition, two rear-engine imports, a 1962 Volkswagen and a 1963 Renault, were tested to cover the range of contemporary vehicles used on the highway. The Corvair and all other vehicles were tested only in their standard production configurations.

The tests incorporated maneuvers that represented dynamic or transient maneuvers, such as the J-turn or the hard hairpin turn, modified "J"-turns, and other avoidance maneuvers with braking in turns. All tests were conducted on high coefficient dry pavement; vehicle movements from gravel to pavement were not included.

Off-design tire pressures were used on all vehicles tested in one maneuver, Steady Turn-Rough Road.

The skid number (effective coefficient of friction) of the surface used was the (highest) range found on the modern highway under dry conditions. The test requirements specified that the road surface had to have a skid number between 70 and 80 when measured in accordance with ASTM Method E-274-65T at 40 miles per hour. These conditions were met.

All vehicles were tested in a condition that represented the manufactuer's maximum recommended load.

All the test vehicles were equipped with instrumentation to measure acceleration and other relevant vehicle response and outriggers were provided to prevent overturning.

In addition, as suggested, a 24-hour guard was provided at the test site by an independent security guard agency to prevent any tampering with vehicles under tests. A request for the presence of independent outside observers was not granted.

B. Analysis of General Motors Documents and Related Material

1. Purpose and Scope

This analysis undertook to review and evaluate selected General Motors data specifically referenced by Mr. Ralph Nader, additional relevant General Motors and other manufacturers' data, Society of Automotive Engineers papers, and other technical publications concerning 1960-1963 Corvair handling and stability.

2. Background

The area of automotive production design, development and performance as it related to vehicle handling characteristics, is an area dependent upon the exercise of subjective engineering judgment. Satisfactory performance, as determined by this subjective evaluation, includes safe performance in the reasonable and normal operation of the vehicle, as well as in extreme maneuvers which may be encountered in some accident avoidance situations.

The dynamic results produced by the interaction of the driver, the vehicle, and the environment vary considerably, and research is underway in the private sector, as well as in Government, to improve the understanding of these relationships.

The subjectivity of handling evaluation, and the existing controversy over what even constitutes a good and safe handling vehicle, are exemplified by the absence of any Federal or voluntary minimum acceptable performance standards dealing with vehicle handling.

Research by the National Highway Traffic Safety Administration is developing a set of test procedures preliminary to the establishment of minimum vehicle handling performance levels that can be expressed in objective terms to form the basis for a definitive standard. These procedures indicate a promising approach to handling definition but require much additional refinement through additional research to correlate the procedures with actual road and operating conditions experienced by a broad cross section of vehicles.

Recognizing then the absence of known and acceptable quantitative techniques permitting analysis in terms of absolute values for minimum acceptable safe handling performance characteristics, this analysis relies in great measure upon a general comparison of the handling performance characteristics of the Corvair with those of contemporary vehicles. In making this comparison, reference is made to a lateral acceleration limit of control for individual vehicles which is established by skilled test drivers but not considered to be an absolute value. Also used in the comparison are available data drawn from accident records to show the frequency of accidents with major damage resulting from rollover.

3. Control Characteristics

a. General Discussion

In order to evaluate vehicle dynamics in a turn, it is necessary to describe the meaning of the terms understeer and oversteer. Simply stated, an understeering vehicle will generate a larger radius with increasing lateral acceleration without any change in steering angle. Under the same conditions, an oversteering vehicle will tend to generate a smaller radius, with increasing lateral acceleration, without any change in steering angle. (See Illustration No. 1)

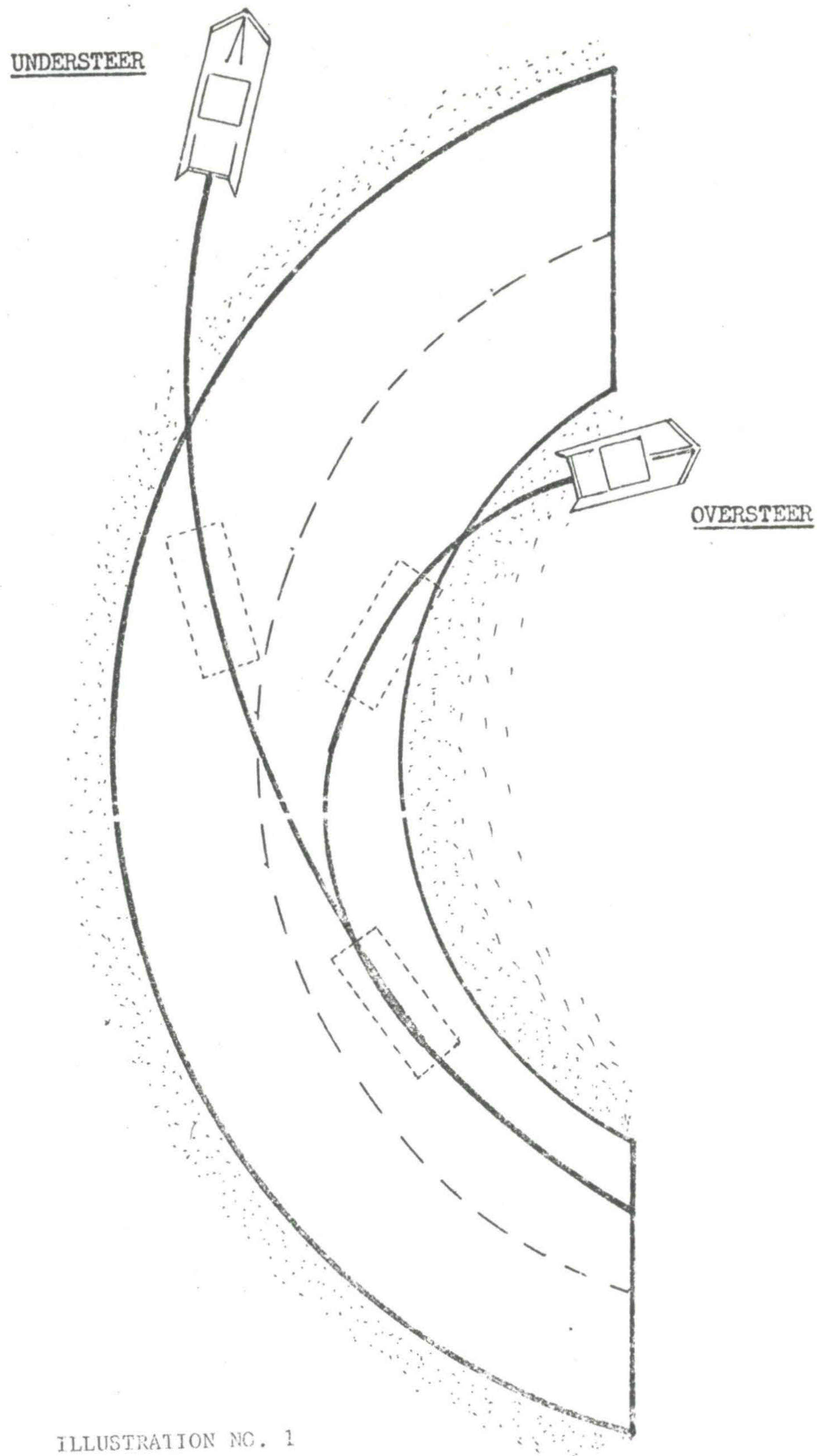


ILLUSTRATION NO. 1

OVERSTEER OR UNDERSTEER, AT LIMIT OF CONTROL, OR WITHOUT STEERING CORRECTION

A driver maintains path control of an understeering vehicle by increasing steering input as the vehicle drifts to the outside of a turn, while in an oversteering vehicle he decreases steering input as the vehicle drifts to the inside of the turn. Up to the vehicle's limit of control, these steering inputs are considered normal, instinctive path corrections.

Much has been said about the handling of Corvair concerning its understeering and oversteering characteristics. It has been alleged that the final oversteer characteristics of the Corvair are unsafe because of instinctive driver reaction based on past experience with understeering vehicles, since the typical conventional passenger car is basically an understeering vehicle. The basic understeer characteristics of a conventional car, however, may change under certain operating circumstances. For example, in a typical passenger car, acceleration decreases understeer and may actually induce oversteer, while braking tends to accentuate understeering characteristics. Drivers, though they may not be aware of their actions, do correct for these phenomena in everyday usage of their vehicles.

Basic research conducted by General Motors has established that a driver, characteristically, when confronted with an unexpected obstacle, will not attempt evasive maneuvers which will require lateral accelerations in excess of about 0.3g. In addition, the lateral acceleration that a driver will attempt decreases with vehicle speed. This phenomenon is substantiated by highway design authorities in the AASHO (American Association of State Highway Officials) manual entitled, "A Policy on Geometric Design of Rural Highways." Illustration No. 2 compares the lateral acceleration capability of typical American cars with AASHO design criteria. As can be clearly

MAXIMUM LATERAL ACCELERATION

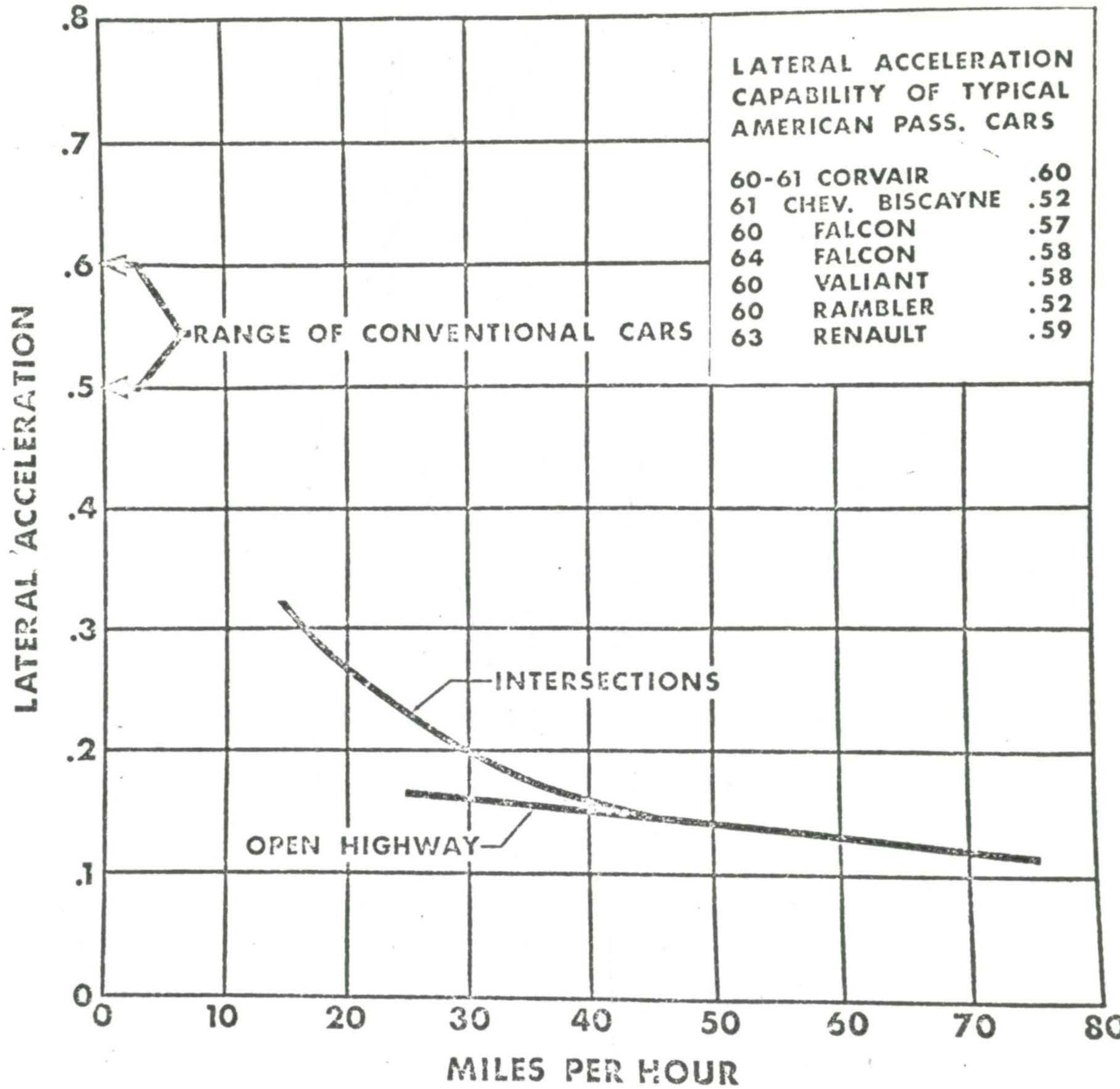


ILLUSTRATION NO. 2

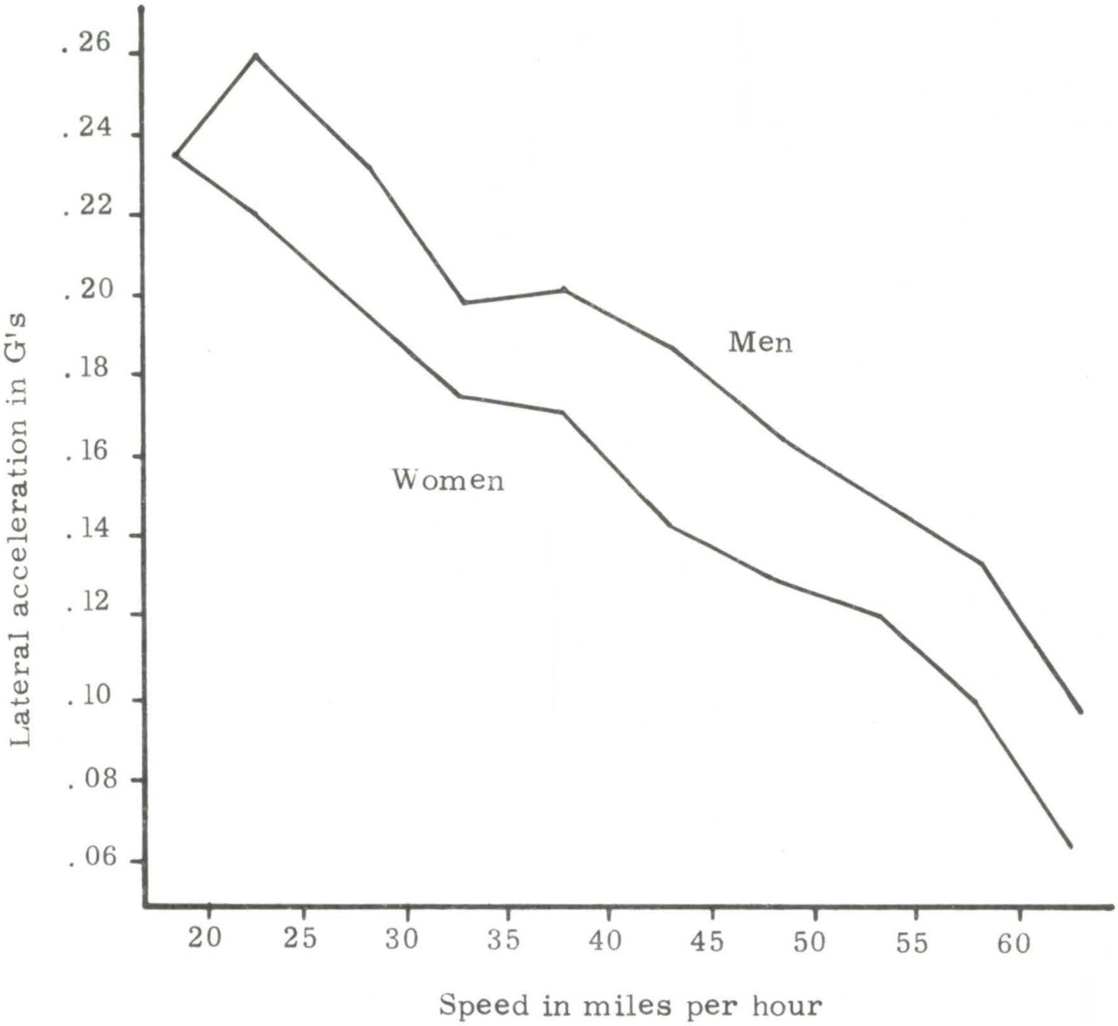
PRESENTED BY GENERAL MOTORS CORPORATION TO THE MICHIGAN STATE HEARINGS CONCERNING MICHIGAN SENATE BILL NO. 766-773.

FEBRUARY 21, 1966

seen, the passenger cars cited, including the Corvair, have limits of control well in excess of the 0.3g previously discussed.

The data analyzed demonstrated that the 1960-1963 Corvair understeers in the same manner as conventional passenger cars up to about 0.4g lateral acceleration. In the 1960-1963 Corvair, a transition from moderate understeer to moderate oversteer occurs between 0.4g and 0.5g lateral acceleration--values which would only be attempted by very skilled drivers. A study carried out by Malcolm Ritchie, William K. McCoy, and William L. Welde entitled, "A Study of the Relation Between Forward Velocity and Lateral Acceleration in Curves During Normal Driving." (Human Factors, June 1968), involved 10,290 observations of lateral accelerations peaking at 0.26g and diminishing with increasing velocity to 0.07g. (See Illustration No. 3) Typical vehicle lateral accelerations on two lane roads in rural areas are further described in an article extracted from Traffic Engineering and Control (Great Britain) published in July 1969, by Professor J. Emmerson. An excerpt from this article is as follows:

> The distribution of the speeds of cars on horizontal curves is of interest to highway engineers because the information can be compared to the theoretical speeds for which the curves have been designed. The Ministry of Transport defines design speed as:
>
> > The design speed of a highway is that chosen for the correlation of such features as sight distance, curvature and superelevation upon which the safe operation of vehicles depends. It is the maximum speed maintainable throughout the journey compatible with safety and comfort when weather



Lateral acceleration as a function of speed in curves. Speed values are the dividing points between groups. Based on 10,290 observations.

M. Richie, W. McCoy and Welde Study
HUMAN FACTORS JUNE 1968

Illustration No. 3

and traffic conditions are favorable and the geometric features of the highway are the controlling factors.

The values of the side-friction factor (lateral acceleration in g's minus road superelevation) recommended for design purposes on open roads vary from 0.18 for design speeds less than 30 mph to 0.15 for speeds in excess of 30 mph. For the case of slip roads (access ramps) at interchanges, slightly higher values are recommended in this country, whereas the values recommended in America vary from 0.16 at 40 mph up to 0.32 at 15 mph. At these levels of side-friction factor a skidding failure is unlikely to occur on most dry roads even when the cornering force is associated with braking force. "Comfort" rather than "safety" therefore represents the more critical condition, at least on dry roads. Under adverse weather conditions, a road alignment designed to those standards could well be uncomfortable" or even dangerous for vehicles travelling at the design speed, but, on the other hand, there is a natural reduction in vehicle speeds in bad weather irrespective of alignment which tends to compensate.

A number of tests have been carried out in other countries to measure side-friction factors either indirectly by measuring vehicle speeds--or more directly by means of ball-bank indicators or accelerometers. In this country the work of Leeming and Black and of Warren and Hazeldine is frequently quoted. In all tests, considerable variations in the uses of side-friction factors occur. Warren and Hazeldine report variations from 0.17 to 0.33 while Leeming and Black found that the average observer would rate 15 percent of the curves tested as uncomfortable when a value

> of 0.15 was experienced. Taragin found that the side-friction factors used by cars travelling at the average speed was about one-half of the value used by cars travelling at the 95th percentile speed. Average factors varied from about 0.08 on curves of 1,470 feet radius to about 0.20 on curves at 240 feet radius. This article describes the results of speed tests on cars at six sites on horizontal curves along two-lane roads in rural areas of Cheshire and Lancashire."

Data supplied by General Motors and Testimony by Dr. Thomas Manos, expert witness for plaintiffs in cases against GM, have established that a sustained lateral acceleration of 0.6g is the limit of control for the 1960-1963 Corvair; that is, 0.6g is the value beyond which the vehicles can no longer be maintained under control by the most skilled driver. This value, when viewed with other limit of control values, illustrates that the Corvair compares favorably with contemporary passenger cars. (See Illustration No. 4) It also was observed in GM films and reported on at least one road test (Autocar, January 6, 1961) that wheel hop (patter) occurs prior to incipient vehicle breakaway, at which time the Corvair can still be controlled, indicating that discernible warning is given to the driver prior to the limit of control.

Data were also scrutinized to determine if the 1960-1963 Corvair had a critical speed within the realm of its performance capabilities. A critical speed, that is, a speed beyond which the vehicle cannot be maintained under control in a straight line, is theoretically possible in an oversteering vehicle. One film reviewed (General Motors Film No. B-30, titled "Critical Speed Film) demonstrated that the Corvair did not have a critical speed, i.e., vehicle yaw oscillations were damped out without driver assistance after the induction

MEASURED MAXIMUM LATERAL ACCELERATION

AT LIMIT OF CONTROL

OF DOMESTIC AND FOREIGN PASSENGER CARS

Year	Name	Lat. Accel. "G" Units
1960	Rambler	0.52
1960	Falcon	0.57
1960	Valiant	0.58
1961	Chevrolet (Biscayne)	0.52
1961	Corvair	0.60
1964	Renault (Dauphine)	0.59
1964	Falcon	0.58
1964	Valiant	0.60
1964	Cadillac	0.59
1964	Chevrolet (Chevelle)	0.59
1964	Chevrolet (Chevy II)	0.59
1964	Volkswagen	0.57
1964	Opel	0.61
1964	Vauxhall	0.55

Year	Name	Lat. Accel. "G" Units
1964	Corvette	0.69
1964	Corvair	0.68
1965	Rambler Amer.	0.60
1965	Falcon	0.59
1965	Valiant	0.58
1965	Cadillac	0.60
1965	Chevrolet (Chevelle)	0.55
1965	Chevrolet (Chevy II)	0.58
1965	Chevrolet (Impala)	0.61
1965	Volkswagen	0.57
1965	Mercedes "600"	0.62
1965	Buick Electra	0.64
1965	Ford Fairlane	0.62
1965	Corvair	0.70

ILLUSTRATION NO. 4

PRESENTED BY GENERAL MOTORS CORPORATION

TO THE MICHIGAN STATE HEARINGS

CONCERNING MICHIGAN SENATE BILL NO. 766-733 of a transient (step steering input and release at 80 mph). Simply stated, with the vehicle travelling in a straight line at about 80 mph (maximum speed) the driver rotated the steering wheel as quickly as possible through a pre-determined arc and immediately released it, leaving the vehicle free to seek its own path. The "fishtailing" motions of the vehicle diminished rapidly and the vehicle resumed its course. For comparative purposes, in another film a conventional contemporary automobile under comparable conditions did exhibit divergent yaw oscillations, i.e., "fishtailing" motions increased rapidly and the vehicle would have gone out of control had not the driver intervened.

b. Transition from Understeer to Oversteer

The analysis has examined, within the limits of available data, the predictability of the Corvair performance during the transition from understeer through neutral steer to oversteer. The question asked was: Does the transition from understeer to oversteer occur abruptly without warning, leaving the driver with insufficient time to take appropriate action?

In evaluating this transition, as indicated earlier, limitations in the state-of-the-art of vehicle control have been a serious constraint. Neither Government nor industry research has been successful in quantifying the quality of vehicle control characteristics, particularly those involving lateral dynamics. Vehicle controllability is directly related to the degree of difficulty experienced by a driver in keeping a vehicle on a desired course. The driver, the vehicle, and the course are all interrelated elements of control. Optimum or compatible vehicle qualities are difficult to define without a definition of the driver, his level of skill, habits, and performance. Little work has been done to quantitatively relate vehicle control characteristics to suitably derived criteria of operational safety or accident reduction.

It has been established (as discussed on pages 13-18) that the average driver will not normally attempt maneuvers involving more than 0.3g lateral acceleration at low speeds and the lateral acceleration he is willing to attempt is reduced even further as the vehicle speed increases. In view of this, it is apparent that the driver is not likely to experience the Corvair transition from understeer to oversteer in normal driving except possibly at very low speeds.

In an extreme situation, when a driver involuntarily encounters lateral acceleration of 0.4g - 0.5g (Corvair's transitional state), he typically makes a brake application resulting in wheel lock up. In this situation, both understeering and oversteering vehicles are uncontrollable. When encountering this range of lateral acceleration, assuming the driver does not make a brake application, a considerable degree of skill still is necessary to maintain control of any vehicle.

If a driver does have the skill to drive at these levels of lateral acceleration (0.4g to 0.5g), or is required to do so because of circumstances beyond his control, only a moderate amount of steering movement, either in understeer or oversteer, is required on the 1960-1963 Corvair. A driver is not likely to have any awareness of the transition without deliberately having some reference and taking readings in some way as to change in steering wheel angle because of the normal variations in the steering wheel angle required to maintain path direction. As the driver makes the transition, he would not be making large increases in the steering wheel input and in a split second be required to make large decreases in the steering wheel input because of the vehicle's characteristics. The rate of the transition will be dependent upon vehicle speed and the severity of the immediate maneuver.

For the lateral acceleration range of 0.5g to 0.6g the 1960-1963 Corvair is in stable oversteer. The oversteer does not become self-energizing or unstable until the limit of control is exceeded. Figure 4 in SAE Handbook Supplement, Vehicle Dynamics Terminology, J670b illustrates this condition for the constant speed test. (See Illustration No. 5) In this Figure, the curve which represents the vehicle in an understeer mode that changes to an oversteer mode shows that the vehicle first is in stable or controllable oversteer from the neutral steer point to the divergent instability boundary. Beyond the divergent instability boundary, the oversteer becomes self-energizing and divergently unstable.

In the control of a vehicle it is not just a matter of having understeer or oversteer, but what is important is how much understeer or oversteer a vehicle has and how it responds to the driver's inputs. A vehicle with large amounts of either understeer or oversteer may be equally difficult to control.

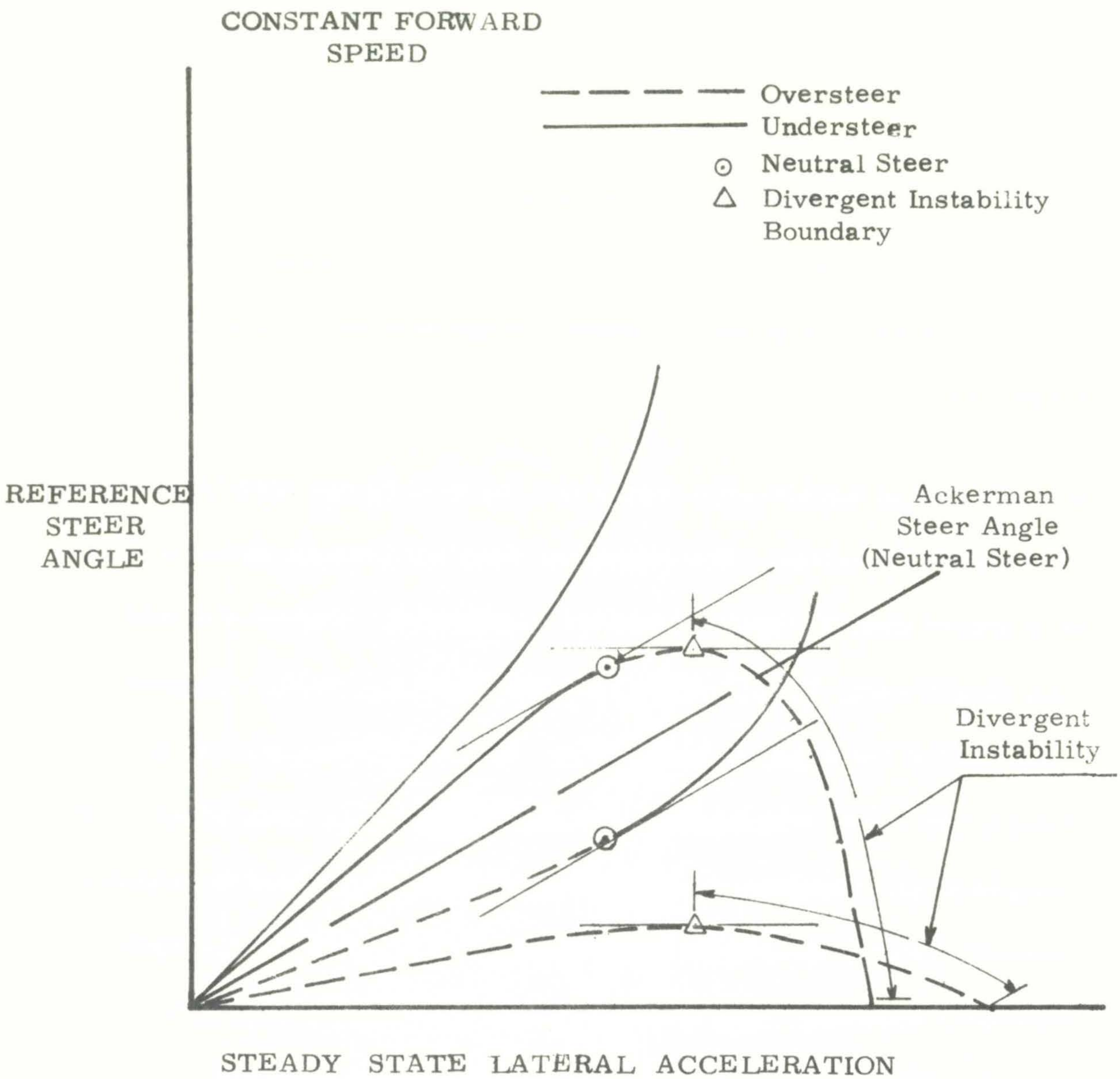


Fig. 4 - Steer Properties

SAE Handbook Supplement, Vehicle Dynamics Terminology, SAE J670b

Illustration No. 5

The information reviewed established that under various loading conditions and tire pressures some other vehicles, domestic and foreign, also have transitions from understeer to oversteer.

It is concluded that the Corvairs transition from understeer through neutral steer to oversteer does not result in abnormal potential for loss of control.

c. Beyond Limit of Control

As previously discussed (page 19), the films and data reviewed clearly show that during sustained lateral accelerations above 0.6g the Corvair is not controllable. The data indicate further that a transient lateral acceleration above 0.6g can be experienced by a skilled driver without loss of control.

In describing vehicle dynamics beyond the limit of control, it can be stated that an oversteering vehicle will normally decrease its radius of curvature at an increasing rate (that is spin-out) above its limit of control, dissipating its kinetic energy, whereas an understeering vehicle will endeavor to proceed in a straight path, dissipating its kinetic energy. There are pros and cons for both modes of breakaway. Depending on the circumstances, the modes may be equally hazardous.

d. Rollover

Given certain circumstances virtually every automobile can be made to roll over. In the Twelfth Stapp Car Crash Conference, Mr. John W. Garrett, ACIR, CAL, Inc. (Automotive Accident Crash Injury Research, Cornell Aeronautical Laboratory, Inc.) in his report, "A Study of Rollover in Rural United States Automobile Accidents," concluded that the rollover frequency decreases as weight and tread width increase and car height decreases. Mr. Garrett's findings indicate that the Corvair and lighter American cars rolled over more frequently than heavier cars, whereas the popular four passenger lighter imports (Volkswagen and Renault) were involved in a higher proportion of rollovers than the Corvair. (See Illustrations Nos. 6 and 7).

Although data were obtained by Mr. Garrett from Utah and New Mexico in his study, the New Mexico data were not utilized in the analysis because these data did not include driver age. The Utah data were obtained during the period from September 1966 to August 1967 and involved 8,749 vehicles. Data, when standardized for driver age and traveling speed, indicate that the Corvair was involved in a lower percentage of rollover accidents than other light domestic cars.

While all Corvair models from 1960 through 1967 were included in the study, an estimate from Mr. Garrett indicates that at least 80 percent were 1963 and earlier models. Thus, the results primarily reflect the behavior of models of concern to this analysis. The other vehicles investigated included models up through 1968, as referred to in Illustration No. 6. A principal rollover is defined as an accident in which the major vehicle damage is associated with the rollover, although collision may also have occurred.

(EXTRACT)

Classification of Car Groups[a] According to Year and Make

Weight	Tread Width	Height	Vehicle
1	1	2	All Volkswagen, Renault
2	2	4	Corvair 60 to 67
3	3	4	Falcon 60-65/ Comet 60-65/ Chevy II 62-68/ Dart 62-67/ Tempest 61-63/ Lancer 61-62/ Valiant 60-67/ Buick Special 61-63/ F85 61-63/ Mustang (all years)/ Javelin, Cougar, Camaro, Firebird, American (all years)
....			
....			
....			

[a] Car groups based on weight, tread width, and height of vehicle. Data obtained from the annual Automotive News Almanac, Review and Reference Edition.

Illustration No. 6

(Proceedings of the 12th Stapp Car Crash Conference October 1968, page 68)

(EXTRACT)

Frequency of Principal Rollover (Utah) %

Vehicle Group	Driver Age, years							Crude Rate	Standardized[a] Rate	n
	to 14	15-19	20-29	30-39	40-49	50-59	60+			
112	40.00	26.60	21.33	6.82	26.32	10.00	4.29	21.24	21.36	339
224	____[b]	13.56	7.14	18.52	7.69	____	____	10.19	9.10	206
334	50.00	8.65	9.91	3.81	10.00	16.39	6.82	9.23	9.19	780
...										
										5888

[a]Standardardized on Driver Age

[b]____ = no principal rollover among observed cases.

Frequency of Principal Rollover (Utah) %

Vehicle Group	Traveling Speed, mph				Crude Rate	Standardized[a] Rate	n
	to 19	20-39	40-59	60+			
112	____[b]	2.90	25.19	46.25	22.57	20.20	319
224	____	2.08	10.81	22.64	10.88	9.51	193
334	____	3.03	13.67	27.23	13.11	11.81	702
...							
							5355

[a]Standardized on Traveling speed.

[b]____ = no principal rollover among observed cases.

Note: Rollover rates were standardized separately on traveling speed and age of driver because it is known that these variables are associated with both vehicle type and rollover frequency. The method of standardization is described in Appendix 7, Technical Report, "A Study of Volkswagen Accidents in the U.S.A.", (CAL Report No. VJ-1823-R32) by J. W. Garrett and A. Stern, Cornell Aeronautical Laboratory, Inc., November 1968.

Illustration No. 7
(Proceedings of the 12th Stapp Car Crash Conference, October 1968, pages 69 and 70)

The principal rollover rate in percent of accidents investigated, standardized for driver age, is compared below:

	Principal Rollover Standardized Rate %
Volkswagen and Renault (Group 112)	21.36
Corvair (Group 224)	9.10
Light Conventional Domestic Cars (Group 334)	9.19

When standardized for traveling speed, the principal rollover rate in percent in accidents investigated was as follows:

	Principal Rollover Standardized Rate %
Volkswagen and Renault (Group 112)	20.20
Corvair (Group 224)	9.51
Light Conventional Domestic Cars (Group 334)	11.81

Mr. Garrett stated in his report that relatively few cars overturned when traveling speeds were below 40 mph. In general, rollover frequency was highest among young drivers in small cars and decreased as driver age and car size increased. In the Utah data, about 75 percent of the drivers of Volkswagens and Renaults (Group 112) and of Corvairs (Group 224) were under 30 years of age, and about 65 percent of the drivers in the category that includes many of the sports-type cars, light conventional domestic, (Group 334) were under 30 years of age.

Mr. Garrett said in his report that ". . . in the Utah data the majority of the Volkswagen and Corvair cars pre-dated major modification in the suspension system. Thus, the findings largely reflect the behavior of those models manufactured before the suspension system changes were made."

Another study made by ACIR, CAL, Inc., "A Study of Volkswagen Accidents in the United States," dated November 1968, indicates that, when corrected for driver age, the Corvair and lighter American cars rolled over more frequently than heavier American cars, and the popular four passenger lighter imports (Volkswagen, Renault, Foreign Sedans) were involved in a higher percentage of rollovers than light American cars as a class. (See Illustration No. 8).

All the vehicles investigated in this study were 1966 or earlier models and again, as in the Utah data, at least 80 percent of the Corvairs were 1963 or earlier models, based on an estimate provided by Mr. Garrett. The principal rollover rate, without prior collision in this case, was as follows:

	Principal Rollover Rate Standardized for Driver Age %
Volkswagen	28.0
Renault	38.6
Foreign Sedans	20.8
Corvair	14.8
Light	10.9

These data indicate the Corvair was involved in a slightly higher percentage of rollover accidents than other contemporary light weight domestic automobiles.

(EXTRACT)

Percent Distribution of Accident Type Standardized by Driver Age

Car Group	Accident Type: Prin. Rollover* Without Coll.	Accident Type: Prin. Rollover* With Coll.	Secondary Rollover**
Volkswagen	28.0	12.6	4.4
Renault	38.6	16.8	6.8
Foreign Sedan	20.8	9.4	5.9
Corvair	14.8	10.5	2.8
Light	10.9	7.4	4.2
Intermediate	9.9	8.0	3.2
Heavy	7.5	6.7	1.6

* A principal rollover (PRO) is defined as an accident in which both collision and overturn of the car may occur, but major car damage is associated with the rollover.

** A secondary rollover is defined as an accident in which both collision and overturn of the car occur, but major car damage is associated with the collision.

Illustration No. 8

(CAL REPORT NO. VJ-1823-R32, A STUDY OF VOLKSWAGEN ACCIDENTS IN THE UNITED STATES, NOVEMBER 1968, PAGE 16)

In addition to examination of the ACIR, CAL, Inc., rollover data, the analysis included discussion of a University of North Carolina Highway Research Center report, Driver Injury in Automobile Accidents Involving Certain Car Models, with the author, Dr. B. J. Campbell. Purpose of discussion was to examine the possible relatedness of Dr. Campbell's data to the analysis of 1960-1963 Corvair handling and stability. Of the six variables used by Dr. Campbell for his study, the "Type of Accident" variable which contains the category "Car Ran Off the Roadway" is the one that relates most closely to the area of interest. This category includes all vehicles that ran off the roadway, for whatever reason, such as blowouts, fell asleep at the wheel, excessive speed, etc., before striking any object. It includes vehicles that went off the road and struck a tree, as well as those that went off the road without striking anything. Off highway rollovers are included in the category.

The data presented by Dr. Campbell for the Corvair indicated a reduction in the percentage of total accidents in the "Car Ran Off the Roadway" category from the level of model years 1965 through 1968. It was noted that these percentage shifts match the model years when changes were made in the Corvair, and this apparent relationship is logical. The significance of the magnitude of change in the data is uncertain, particularly in view of unexplained changes in the same data for other vehicles, such as the Chevy II and Valiant about which there is no knowledge of any pertinent changes in the vehicle during the related periods.

Due to differences in method of classifying accident data between Dr. Campbell's "North Carolina" study and the Cornell Aeronautical Laboratory, Inc., studies, it is not possible to correlate Dr. Campbell's data with the data already presented. To make Dr. Campbell's data comparable, it would be necessary to return to the accident reports and establish the categories "Principal Rollover Without Collision" and "Principal Rollover With Collision." Data then would have to be standardized for driver age and vehicle speed by classification of vehicle.

During the review of the numerous films of engineering and special tests, it was observed that many attempts involving extreme maneuvers designed to cause rollover were made by expert drivers before rollover actually occurred. In addition to the films involving extreme maneuvers designed to induce rollover, many of the others observed were for the purpose of demonstrating and evaluating vehicle handling characteristics involving the limits of control, as well as understeer and oversteer characteristics.

Frame-by-frame analysis of films supplied clearly established that wheel rim contact with the pavement is not the precipitating cause of Corvair rollover, but occurs in the course of rollover. Similarly, it has been established that while a moderate amount of positive camber and jacking at the rear wheels exists prior to rollover of the Corvair, tuckunder is not observed until the vehicle is well into a rollover mode. Tuckunder, therefore, is considered not to be a major contributor to Corvair rollovers.

4. Analysis of Documents Commented on By Engineers Cited by Mr. Nader

a. NHTSA Comments on General Motors P. G. Reports 15699 and 17103

In Mr. Nader's letter of December 15, 1970, to Mr. Volpe (Appendix II), he cited two General Motors Proving Grounds reports--PG 15699 and PG 17103--which he asked the Department of Transportation to include in the investigation of the stability of the 1960-1963 Corvair. These two reports including the many supporting charts, photographs, and movie film had been received from General Motors three months previously. A thorough analysis had already been completed.

The General Motors tests, as explained in these reports, were conducted for the purpose of evaluating the roll stability characteristics of different suspension modifications on a 1962 and 1963 Corvair.

Ten different sets of test conditions with various modifications were evaluated in PG 15699 and eight test conditions with various modifications in PG 17103.

To conduct the tests and protect the driver the windshield and rear glass were removed, a set of roll bars installed, rear seat removed, and the vehicle interior padded.

The vehicles were equipped with accelerometers and potentiometers to measure the accelerations and motions resulting from the tests. A camera was mounted on the vehicles to record suspension motions.

The vehicles were driven by a professional test driver at increasing speed increments using rapid steering, maximum throttle and torque inputs designed to test the various suspension modifications to the point of rollover or until it was difficult to produce a more violent maneuver.

In summary, because of the nature and severity of these development tests which were not representative of the practical driving environment, these tests should not reasonably be interpreted to conclude that 1960-1963 Corvair is susceptible to rollover at low speeds on a flat surface in the normal driving environment.

b. NHTSA Analysis of Comments by Messrs. Smith, Fonda, and Sergay

Mr. Nader had solicited three engineers, Messrs. Smith, Fonda, and Sergay to analyze the reports for him. His letter to Mr. Volpe included responses to some specific questions that he had asked the engineers.

Some of the questions asked of Messrs. Smith, Fonda, and Sergay were the same, others were similar. When possible a comparison of their answers was made. The answers these men gave for one particular question many times conflicted with their own answers provided for other questions. Also the answers that Messrs. Fonda and Sergay gave conflicted in some cases with those of Mr. Smith.

In the first question the men were asked: "If you were a design engineer and saw PG 17103 or PG 15699 results on a prototype vehicle being considered for production, would you recommend the car for production without modification?" All three men stated that they would not recommend any of the configurations for production because of the vehicle performance as it related to the rollover criterion, but later they all recommended modifications that were included in these reports.

Mr. Nader asked Messrs. Fonda and Sergay the question: "Are any of these test runs representative of the Corvairs which were actually produced and sold in 1960-63?" Their response was, "The vehicle of run 120 of PG 17103 appears in all (emphasis added) respects as being a vehicle representative of 1963 production Corvairs. . . ."

The vehicle used in run number 120 of PG 17103 was a 1962 Corvair with 1963 production shock absorbers. It had been used for 64 runs in PG 15699 and PG 17103 and had been rolled over 10 times before run number 120. The tenth rollover (run number 117) was a severe one. The vehicle had a set of roll bars installed, the windshield and back glass had all been removed, the rear and front wheel openings were cut out, the rear seat removed and the body had been deformed in the previous tests. The center of gravity had been shifted upward and rearward as a result of these modifications to the vehicle. The conditions described above show that the vehicle was in a test development configuration that was not representative of a 1962 or 1963 production Corvair.

A question was asked if the rollover and stability behavior of the 1960-1963 Corvair differed from the behavior of other American sedans and from foreign cars sold in the United States. Since no foreign vehicles were involved in these tests, the men had no comments as it related to the foreign vehicles. Only one other vehicle, a standard Chevrolet, was used in one of the tests (PG 15699). Since only one other vehicle was used it would appear to be invalid for anyone to be able to extrapolate the results of that one vehicle to apply to all other vehicles from these two tests.

Messrs. Fonda and Sergay stated in answer to their question number 3 that a vehicle ". . . must slide instead of rolling over on a flat road surface, with any combination of driver actions. . . ."

The data and films analyzed by NHTSA in this study clearly indicate that other American vehicles can also be made to rollover on flat surfaces. As in the case of the Corvair, a considerable amount of effort is required to achieve rollover and it is difficult to repeat.

The actual rollover experience that Mr. Garrett reported (see Illustration No. 8) in his rollover reports indicated that the heavier, wider, American sedans were involved in fewer rollover accidents when corrected for driver age than the smaller, lighter sedans but all classes were involved in rollover accidents.

When the men were asked to comment as to their estimates as to the cost to modify the 1960-1963 Corvair to make them perform comparably to other American cars with rigid axles, that is, to make these vehicles skid or spin out rather than rollover, the answer by Messrs. Fonda and Sergay again conflicted with Mr. Smith's answer.

Messrs. Fonda and Sergay recommended the incorporation of hydraulic cutoff rear shocks at an estimated cost of $20 per car. This conflicts with Mr. Smith's estimate of $11 total for 4 springs, 2 rear shocks, a stabilizer bar and fittings, and two rebound straps.

The recommendation of the hydraulic rebound cutoff rear shocks by Messrs. Fonda and Sergay is inconsistent with their previous answers to their question number 3. The hydraulic rebound limiting cutoff shock absorber they recommended from run number 73 of PG 15699 was even longer than the 1963 production shock absorber which they said they would not recommend for production for the 1963 model. (The answer to their question number 3.) Also, run number 71 of PG 15699 which resulted in a rollover had exactly the same configuration as run number 73, except the rebound travel in run number 71 was limited by an additional one-half inch. There were many rollovers in PG 17103 in which rebound was restricted even more than in run number 73.

It appears that Mr. Smith in his recommendation was suggesting a package similar to the RPO 696. The configuration in PG 15699 that was similar to the RPO package did not prevent a rollover. Also the rebound straps used in the RPO package did not restrict the rebound camber angle any further than the 1963 or 1964 production hydraulic rebound cutoff shock absorbers.

The rebound could not be restricted further than that of the 1963 production vehicles because there would not be sufficient wheelhouse clearance to remove the wheel and tire assembly.

The information contained in the PG reports and films do not represent conditions that would be experienced in the practical driving environment. The maneuvers that the test driver used were maximum throttle-extreme steering inputs designed to produce rollover. This type of driving is not representative of the practical driving environment although it is used in research and development.

The testing performed by NHTSA at the Texas Transportation Institute under the fully loaded conditions recommended by Mr. Sellers (a Nader associate) demonstrated that the 1963 Corvair would spin out on a high coefficient of friction surface in violent maneuvers designed to induce rollover.

On the subject of the effect of vehicle degradation on vehicle rollover, Messrs. Fonda and Sergay contradicted Mr. Smith. Messrs. Fonda and Sergay did not feel that the degradation of the suspension components would effect the rollover characteristics of the 1960-1963 Corvair. Mr. Smith said he thought it would.

It must be pointed out, however, a failure of one component can lead to a catastrophic failure of the entire system of any vehicle and in no way is limited to the Corvair as Mr. Smith stated in his answer related to degradation.

The probability of injury to occupants of a vehicle spinning out of control on a highway or rolling over off the road is a matter of conjecture. Both types of accidents can be equally hazardous depending on the particular circumstances, such as contact with another vehicle or object.

Analysis was made of some of the estimates by Messrs. Fonda and Sergay. They stated that there were 600,000 1960-1963 Corvairs on the road at the time of their calculations. This figure was approximately 50 percent higher than the 407, 922 R. L. Polk registeration figures reported six months earlier (July 1970). They then estimated that there would be about 100, 000 1960-1963 Corvairs in use in 14 years. Current registeration trends indicate that this estimate would more likely be about 5, 000 remaining. Their other estimates about vehicle life expectancy and potential accidents and injuries were based on these figures and consequently also reflected these discrepencies.

In summary, the conclusions and inferences by Mr. Nader's engineers do not appear warranted, because the vehicles used in these tests were in various states of test modifications and the nature and severity of these development tests were not representative of the practical driving environment.

c. Analysis of 1960 Falcon-Corvair Comparison Film

The National Highway Traffic Safety Administration became aware of the existence of Ford Motor Company information concerning the 1960-1963 Corvair handling qualities in June 1971 when a copy of a letter was received from Mr. Harley Copp (a Ford Motor Company executive) written to Senator Warren G. Magnuson, Chairman of the Senate Commerce Committee.

An Information Request dated June 15, 1971, was sent to the Ford Motor Company asking for all pertinent information relating to the information supplied by Mr. Copp. Ford Motor Company answered the NHTSA request on June 28, 1971, with a follow-up on July 29, 1972, and supplied test reports and other relevant information including a film entitled, "1960 Falcon-Corvair Handling Comparison."

A detailed examination was made by NHTSA of the film in conjunction with the analysis made by Mr. Copp. This was initiated prior to the public release of this information by Mr. Ralph Nader:

The NHTSA analysis of the film is as follows:

> A special projector was used in this analysis which had a frame counter with variable speed in forward and reverse motion. Each frame could be reviewed one at a time or in other desired sequences. A stop watch was also used

while analyzing the film to assist in establishing the speed of the vehicles. A layout of the test facility where the "Comparison" was performed was obtained from Ford Motor Company. (See Illustration No. 9.) This layout was used to assist in establishing the paths of the vehicles and in calculating the vehicle's speed.

The test was conducted so that the Falcon was always the lead car when the two cars were driven in the same scene. It was the conclusion of the analysts that this gave the Falcon a distinct advantage in the driving maneuvers on the test track.

There was no apparent instrumentation or inside cameras used, therefore, the drivers could not be monitored in their steering, throttle, or brake activities. The drivers did not use any visible crash helmets or other safety equipment; apparently rollovers or accidents of this nature were not anticipated.

There were skid marks and dirt on the track at several points, where the driver ultimately left the road, which were there prior to the filming. This indicated that some practice runs may have been performed before the filming.

RIDE AND HANDLING ROADS

LANE	LEGEND
1	SHAKE ROAD – BROKEN AND PATCHED CONCRETE – WHEEL RIGHT CURVE
2	TRANSVERSE TAR STRIPS – STREETCAR TRACKS
3	CHUCK HOLES – WASHBOARD ROADS – DISPLACED SLABS
4 & 5	PITCH, TWIST AND SHAKE ROADS AND SQUARE-EDGED POTHOLES
6 & 7	RAILROAD CROSSING – CROWNED STREET INTERSECTION – ADJUSTABLE RAMP AND REFERENCE LANE
8	HIGH CROWN ROAD – ENTRANCE TO HANDLING ROAD

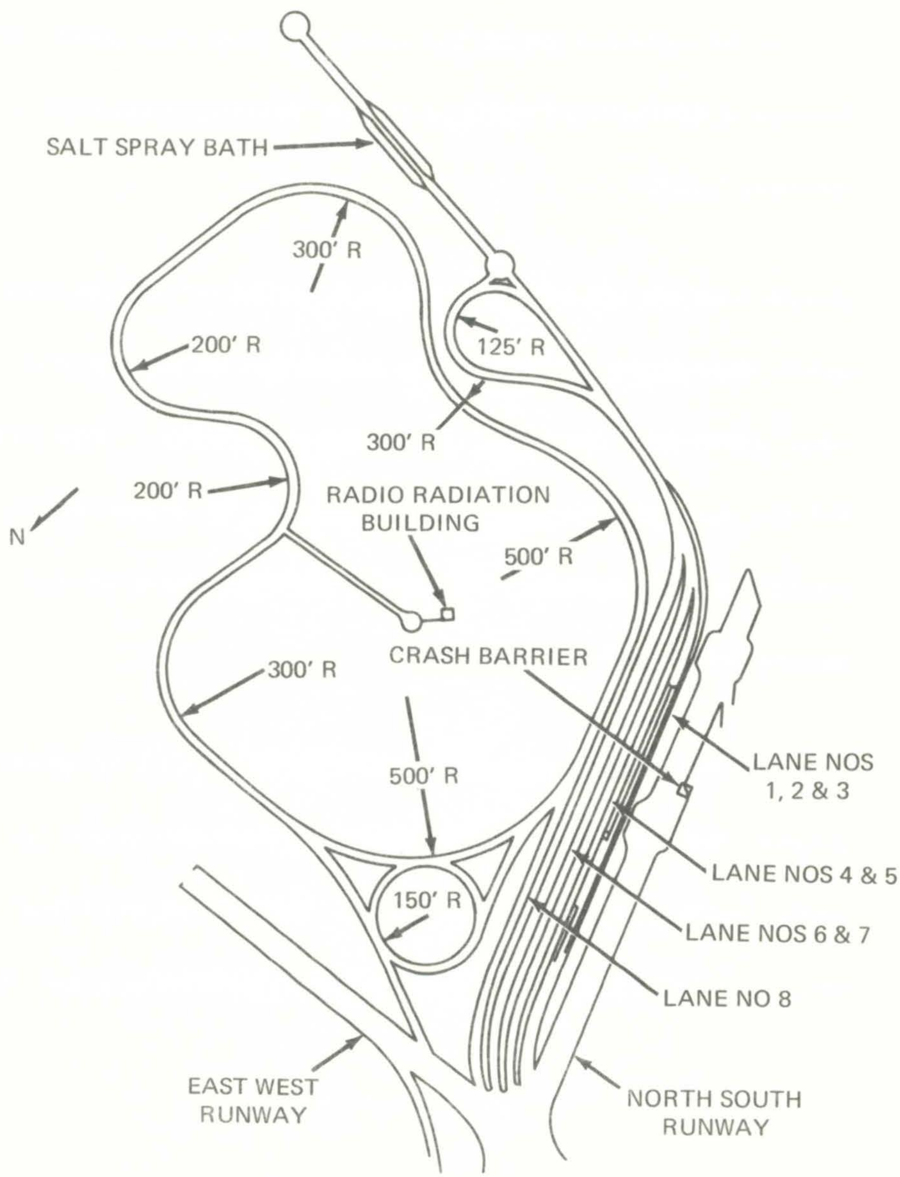


ILLUSTRATION NO. 9

Only on a few occasions could the driver's steering actions be seen. Also there was no indication of the physical condition of the vehicles.

It was interesting to note that the driver generally got the car to skid in about the same location, at a point where he was in front of the camera. The driver also got the Corvair to go straight off the circular test track both forward and backward in the same spot.

Test Entitled Phase I, Comparative Breakaway Tests

Test No. 1, Manufacturer's Recommended Pressures

During this phase the vehicles traveled in the outside of the outer lane of the circular track which had a center radius of 150 feet. The lanes were 12 foot wide and the center of the outside lane had 156 foot radius. Therefore, the center of the vehicles were on a 156-plus foot radius path. (See Illustration No. 10.)

At the start of Phase I, Test No. 1, the vehicles made about one and one-half revolutions of the circular track. The number of frames for a complete revolution were determined. A stop watch was used to measure the time it took to make one revolution. The point where this is done is shown in Illustration No. 11. The average speed for the complete lap was calculated to be 35 mph., using 156 feet as the radius of travel on the circular track the lateral acceleration was calculated to be 0. 52g. The calculations are considerably higher than the values of 30 mph. and 0. 4g given by Mr. Copp.

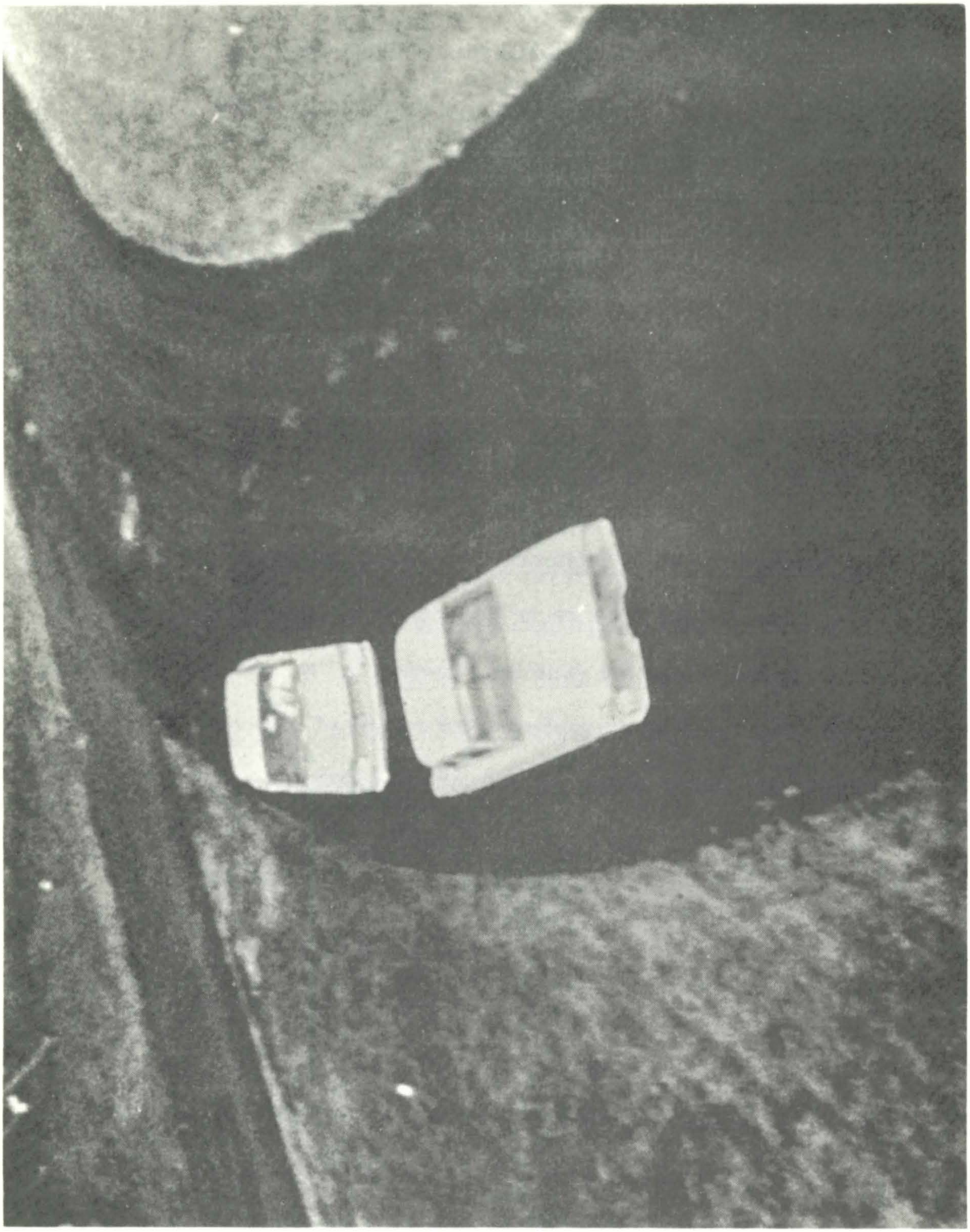


Illustration No. 10
Path of Vehicles in Outside Lane of Circular Test Track

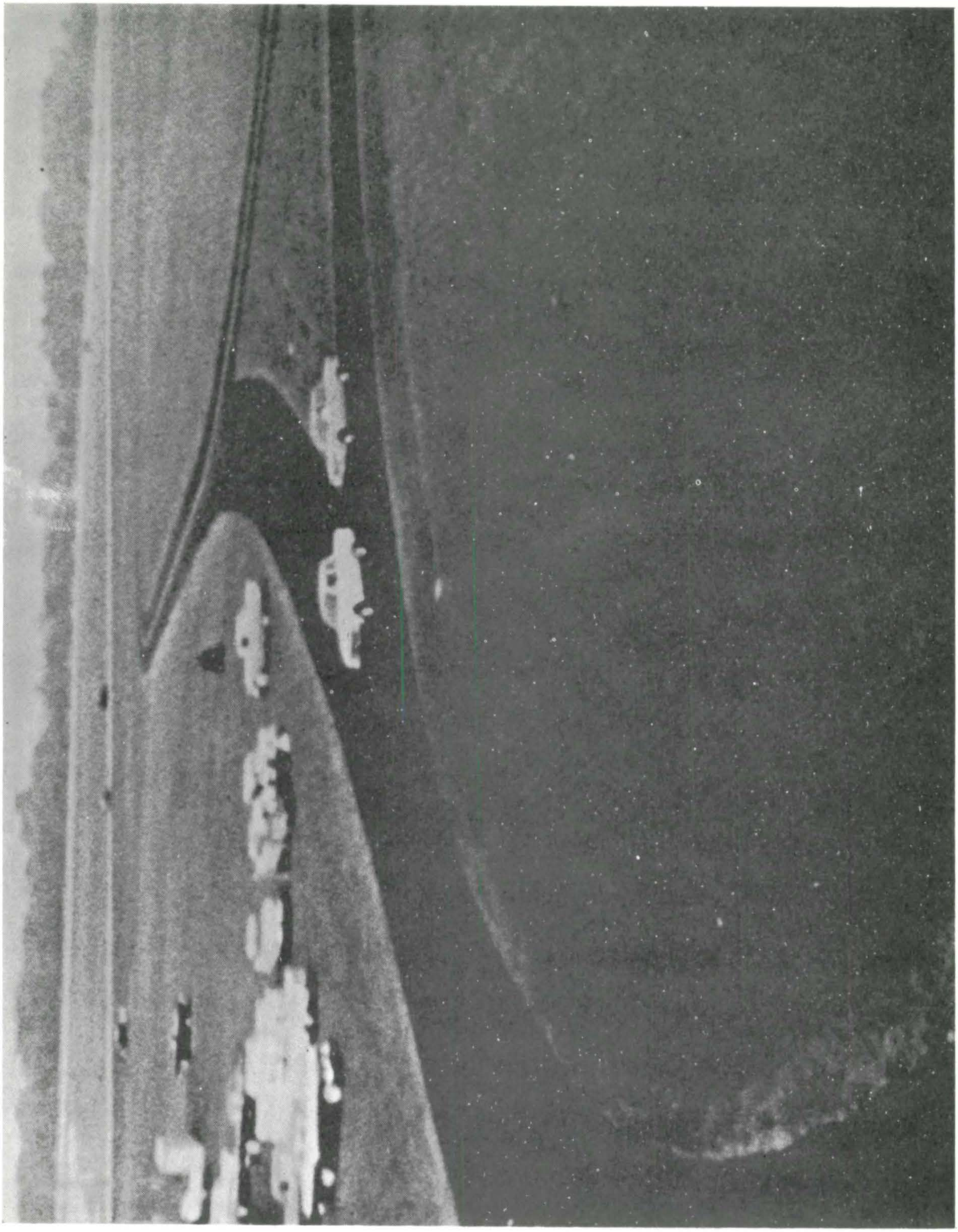


Illustration No. 11
Circular Test Track Reference Point for Speed and Lateral Acceleration Calculations

Since there were no cameras or other data recording instruments inside the car to monitor the actions of the operator as he was driving the vehicle, it was difficult to establish the reasons for the car's reactions. Because of the driver's obvious steering wheel movements which seemed to induce vehicle reactions which can be seen in Phase II section of the film, the driver's actions appear inappropriate.

For Phase I, Test No. 2 of the "Comparative Breakaway Tests," with the Falcon tires inflated to the manufacturer's recommended pressures and the Corvair tires inflated to non-recommended pressure of 26 psi front and rear, the speeds and lateral acceleration were calculated. Again the vehicles were on the outer lane of the test track. Using the same reference point as in Test No. 1, counting the frames for one complete revolution and recording the time, the average speed was calculated to be approximately 37 mph. and the lateral acceleration to be 0.57g. This is also much higher than the 30 mph. and 0.4g quoted by Mr. Copp. As in Phase I, Test 1 of the film no cameras or recording instruments were in the car to monitor the driver's actions and the reasons for the vehicle's ultimate maneuver could not be determined.

A point to note is that Mr. Copp rated the Corvair higher with the non-recommended 26 psi front and rear tire pressures than with the manufacturer's recommended tire pressures used in Test No. 1 which were inconsistent with his analysis.

Test Entitled Phase II, Highway Cornering Test

The NHTSA also calculated the approximate speed and lateral acceleration for the Phase II - Highway Cornering Test which took place on an "S" curve. Each curve section was an arc of approximately 140° with a 200 foot radius connected by a straight section of 100 feet in between the arcs and 82 foot straight section at the end, according to the Ford information.

During Phase II, 'Test No. 1 the manufacturer's recommended tire pressures were used by both vehicles - Falcon 24 psi front and rear, Corvair 15 psi front and 26 psi rear. The speed and lateral acceleration of the vehicles during this portion of the film were more difficult to estimate. However, near the end of the second turn as the vehicles passed in front of the camera the speed and lateral acceleration were estimated, with the aid of the frame counter, to be about 38 mph. and 0. 5g respectively. Here again the values are higher than those calculated by Mr. Copp.

In all the scenes the vehicles negotiate the first of the two curves with no difficulty. As the vehicles come to the end of the second curve with no apparent problems the driver of the Corvair can clearly be seen turning the steering wheel to the inside of the radius of the curve, for no logical reason, just as the vehicle passes the camera. At this point in time the vehicle starts to skid. (See Illustration Nos. 12, 13, and 14.) The driver of the Corvair can be seen making similar steering inputs in the runs of Phase II, Test No. 1.

Phase II, Test No. 2, is conducted with the Falcon tires inflated to recommended pressures of 24 psi front and rear. The Corvair is run with non-recommended pressures of 26 psi front and rear.

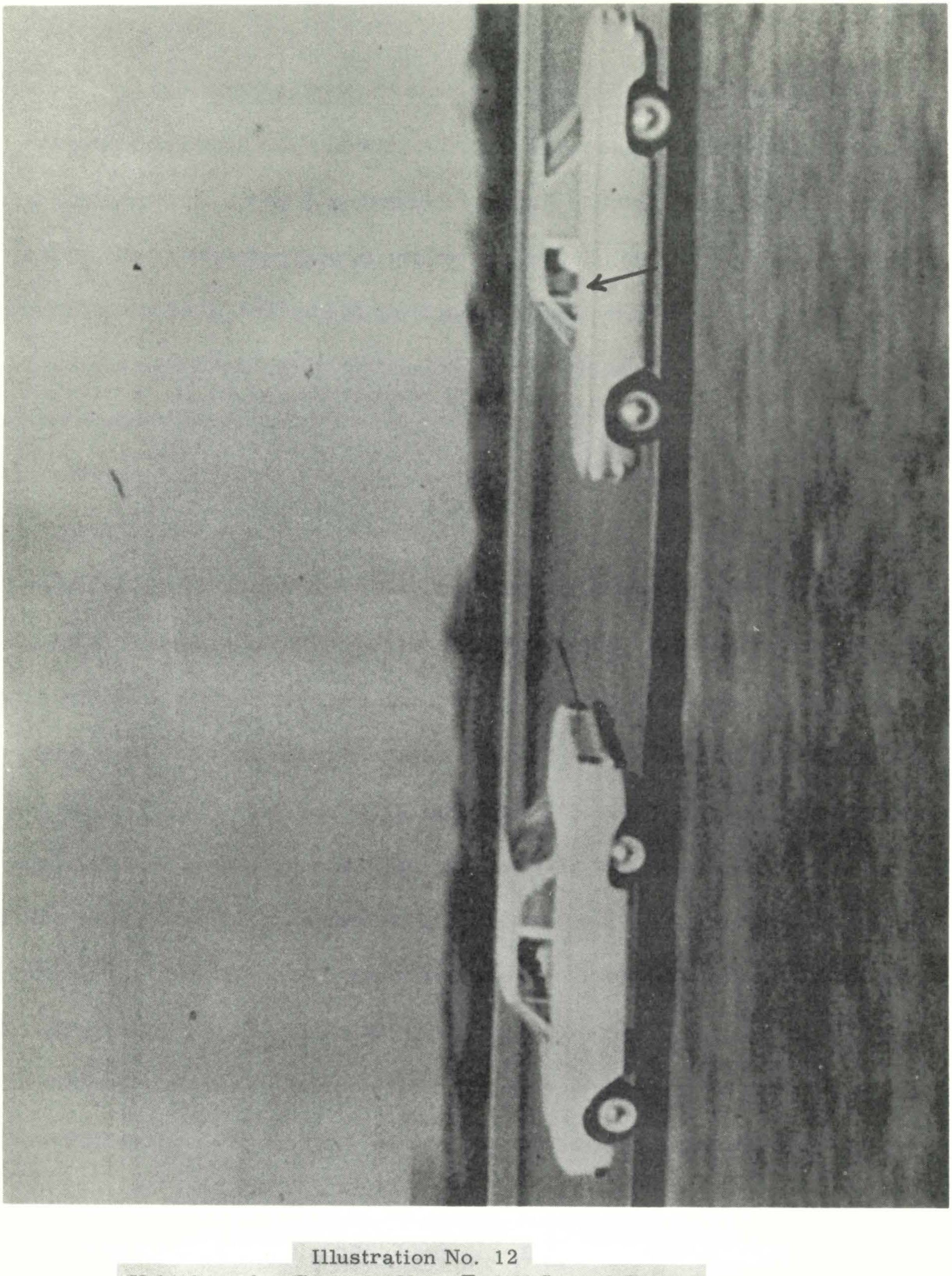


Illustration No. 12
Vehicle under Control--Near End of Second Curve

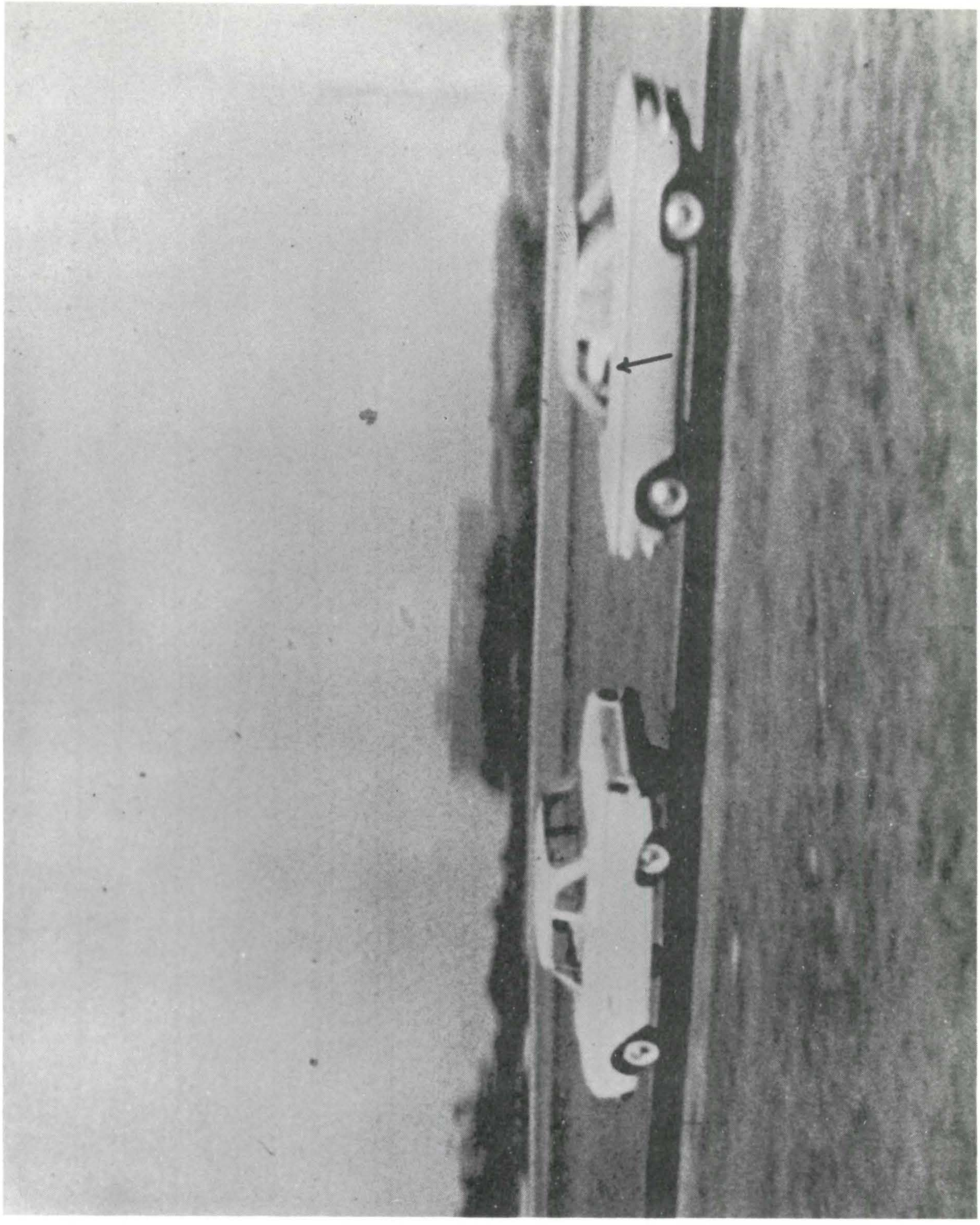


Illustration No. 13
Driver Giving Additional Steering Input--Near End of Second Curve

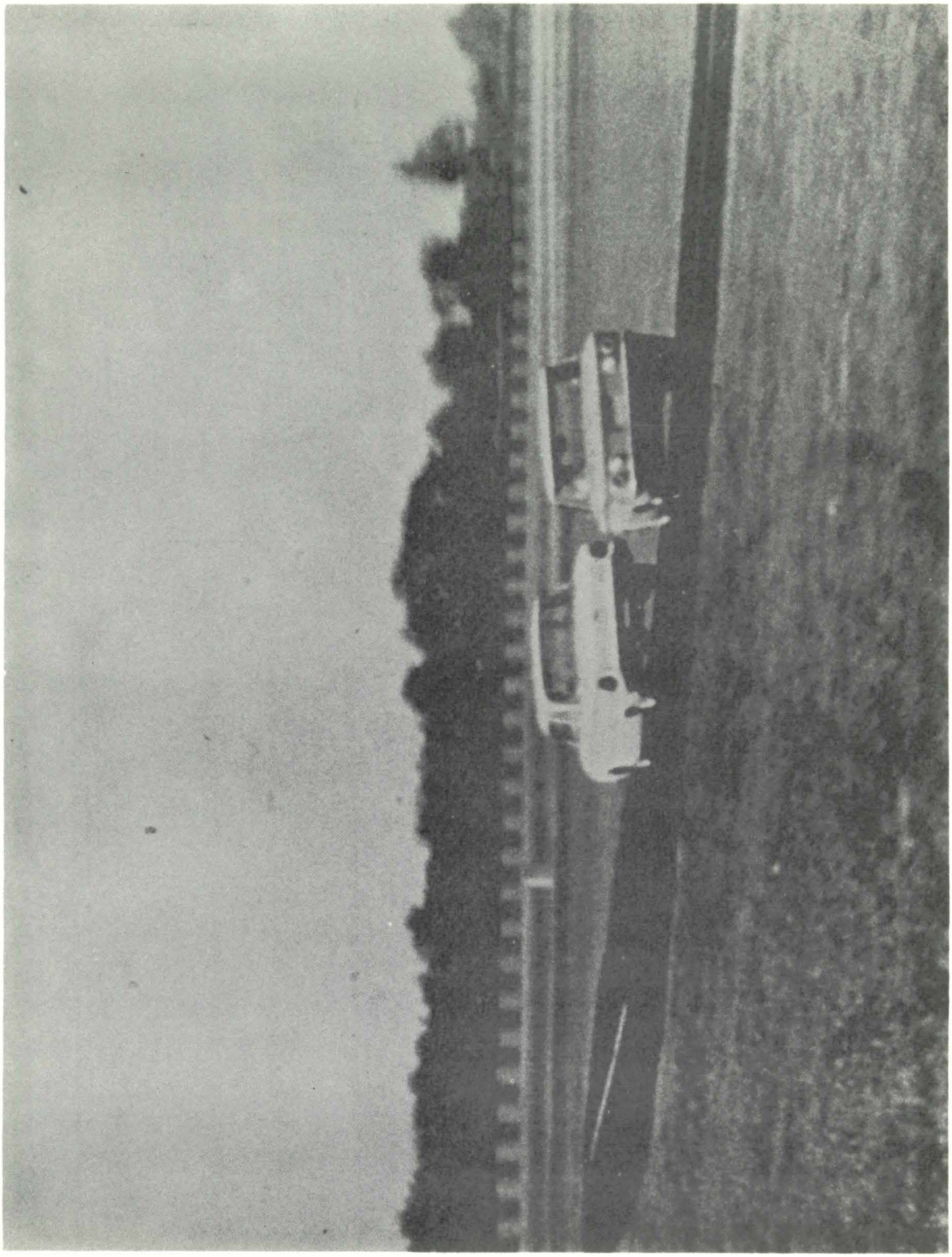


Illustration No. 14
Vehicle Responding to Additional Steering Input--End of Second Curve

This series starts out with the Corvair doing a solo run. The driver takes the first curve without any difficulty. As he comes into the second curve he is either going too fast, or he gives the vehicle too much steering input which causes it to spin off the road on the inside. It was noted that the driver was not wearing a crash helmet, so he must not have been concerned about overturning. It should be noted that the same results could have been obtained with the factory recommended tire pressures by driving at similar speeds and steering the vehicle in a like manner.

The second scene of this section of film is similar to Phase II, Test No. 1, with the Corvair following the Falcon around the first curve, then as they go around the second curve the driver of the Corvair appears to take the curve further to the outside and then turn it sharper to get behind the Falcon. This causes him to almost go off the road on the inside. In correcting for this, the back end of the vehicle slides and the driver then goes off the road on the left side.

The last scene of this series starts with the Corvair at a considerable distance behind the Falcon. By the end of the first 200 foot radius curve the Corvair had caught up with the Falcon. The driver of the Corvair again appears to take the second 200 foot radius curve further to the outside and as he comes past the camera he can be seen putting in a little extra steering and the Corvair is then driven off the curve on the inside.

It was noted that the drivers of the Corvair and Falcon always made it around the first curve without any difficulty. It was not until the Corvair almost completed the second 200 foot radius curve and was in front of the camera that for no apparent reason the driver appeared to make an unnecessary steering input which caused the vehicle to skid off the road.

Mr. Copp's implication that the limit of control of the 1960-1963 Corvair is about 0.4g is not consistent with the NHTSA calculation from the Ford film. It also does not agree with other data provided by Dr. Manos, the Ford Motor Company, or statements which were presented and accepted by representatives of all the major automotive manufacturers during the 1966 Michigan State Senate Hearing, nor the NHTSA testing. All these sources concur that the limit of control of the 1960-1963 Corvair as being about 0.6g sustained lateral acceleration.

It is concluded that the film and Mr. Copps' analysis is not a valid evaluation of the handling characteristics of a 1960 Corvair.

C. Input-Response Test Program

1. Purpose

The purpose of this test program was to compare the handling and stability characteristics of the 1960-1963 Corvair with selected small passenger cars manufactured between 1960 and 1967.

2. Scope

The scope of this test program was to carry out comparative Input-Response tests involving five separate maneuvers on all of the selected vehicles.

3. Background

When the decision to conduct handling and stability tests was made by the National Highway Traffic Safety Administration, one of the requirements was that NHTSA personnel would conduct the tests, with technical support from an independent research agency. The Texas Transportation Institute (TTI), Texas A&M Research Foundation, was selected as the prime contractor.

There are basically two types of tests for vehicle handling performance: (a) Input-Response and (b) Task Performance. Of these two, Input-Response was selected by NHTSA for comparative tests.

As the primary developer of the Input-Response testing methods, the Highway Safety Research Institute (HSRI) of the University of Michigan (U of M) was contacted and consulted during the intial phases of this program. The vehicle handling test procedures employed in this program were defined by NHTSA although they were closely related to methods previously developed and used at the HSRI.

Five tests were chosen with the intent of providing a basis for comparing the handling characteristics of the six vehicles included in the program. These vehicles were a 1962 Falcon, 1962 Volkswagen, 1963 Corvair, 1963 Renault, 1960 Valiant, and a 1967 Corvair.

The tests were designed to incorporate steering maneuvers, steering plus braking maneuvers, and steering maneuvers on a rough surface. These are briefly described as follows:

Steady Turn Braking, Smooth Road

This test consisted of braking the vehicle which was in a steady-state turn of 0.3 g's (lateral to vehicle) at 30 mph. Successive runs were made modifying the brake line pressure as necessary so that conditions from impending one wheel lock-up (no wheels locked), one wheel, two wheel, three wheel and four wheel lock-up were achieved, if possible. The type of maneuver in this test simulates the maneuver required in an emergency situation in which a vehicle being driven through a curve must be brought to to a stop with little or no deviation from its intended path The purpose of this test was to determine vehicle path deviation from a nominal circular trajectory, as the level of deceleration was increased toward its limit value.

Steady Turn, Rough Road

In this test the vehicle was stabilized in a 0.3g steady-state turn at 30 mph, before encountering a series of bumps. Three types of bumps were laid out with 30 mph designed frequencies of 9, 11, and 14 Hertz, which approximated the natural range of frequencies of the suspension systems of the vehicles being used in the tests. This test simulated a vehicle cornering at fairly high lateral acceleration and encountering a series of bumps or other unexpected road obstructions in the road.

Step Steer

This test consisted of suddenly applying a steering input to a vehicle traveling in a straight line at 30 mph The test was repeated with progressively increased steering inputs to the point of maximum input.

This maneuver represents a "J" turn.

Reverse Steer Input

In this maneuver the vehicle was put in a 40 mph steady-state turn at 0.3g and at 0.4g followed by a sudden steering input applied in the opposite direction. The test was repeated with progressively larger reverse steering inputs to the point of maximum steering wheel displacement (lock). This maneuver represents a modified "J" turn.

Drastic Steer, Drastic Brake

This test utilized a first generation automatic controller (developed by HSRI) in lieu of a driver. The performance of the maneuver depended on the critical timing of events based on measured response parameters as well as on programmed inputs of such a nature that they could not be provided by a driver. The sequence of inputs was that which HSRI concluded was most apt to place a vehicle in a rollover mode. Vehicle speeds from 40 mph through 60 mph in increments of 10 mph were used except when limited by the top speed of the vehicle. Runs at 30 mph were also made if outrigger contact occurred at 40 mph to determine if contact would be made at that lower speed. With the vehicle proceeding on a straight path at a predetermined speed, the throttle was released simultaneously with the application of a half-sine steering input of predetermined amplitude increasing up to 400 degrees which was the limit of the control equipment. The duration of the input was one second.

A brake input sufficient to cause lock-up of all wheels was introduced at a point in time when the vehicle's yaw rate response was approximately at its peak. After 0.5 seconds maximum four wheel lock-up, the brakes were released. By varying the magnitude and timing of inputs described above, an effort was made to induce rollover in each vehicle tested.

4. Vehicles and Facilities

The vehicles used in the test program were given a comprehensive inspection and repaired to bring them up to an acceptable level of mechanical condition and safety. Each vehicle was brought up to the manufacturer's specifications in accordance with its individual service manuals The replacement and spare parts used were the original manufacturer's supply and were obtained through the local dealers, with the exception of the Renault parts. There was no local Renault dealer, and necessary parts, in this case, were obtained through a regional warehouse. The tires used in the test program were as close to the original O. E. M. specifications (size, manufacturer, tread design, and materials) as possible. The correct tire sizes in the present-day line and materials were found for all the cars except the Renault. A source for the 5.00 x 15 or 5.10 x 15 tires for the Renault was not found by the time testing of the Renault was to start; therefore, it was necessary to use 5.60 x 15 tires on the Renault, which were available.

After each vehicle had been mechanically prepared and instrumented, weight was added so that each wheel was loaded statically to match the manufacturer's maximum recommended weight with passengers and luggagé. The fifth wheel, used to measure vehicle speed, was in the down position for each measurement of vehicle weight.

Vehicle wheel alignment was adjusted to the manufacturer's recommendations at curb weight after the mechanical preparation. In each case, wheel alignment was again measured in the fully loaded condition and "base line" measurements were determined for this condition. Alignment then was checked and reset as necessary to the "base line" values throughout the testing of each vehicle.

The outrigger pad heights were set to represent a "rollover" if they made contact with the roadway surface during a maneuver. Vehicle brakes were burnished following the S.A.E. Recommended Practice J843C.

The tires used in the program were all given a 200 mile break-in prior to being used for testing. The tread depth was measured and recorded after the break-in. The tire pressures were set to the vehicle manufacturer's recommendations (cold) for all tests except one -- Steady Turn, Rough Road. (This exception will be explained later in the report.)

Tires were replaced when, or before, any point was worn to 80% of the "after break-in" average tread depth (20% maximum wear). Several of the test maneuvers produced severe tire sidewall wear. Constant monitoring of the sidewalls was required, in addition to monitoring of the tread depth, to assure that test data were not biased by worn tires.

The road surface grade of the test areas was level within 1%. The average skid number for the road surface was 79 at 30 mph and 80 at 60 mph. The ambient temperatures and wind velocity were monitored during testing with portable on-site equipment.

5. Comparison of Test Data

Steady Turn Braking, Smooth Road

The values of the "Average Maximum Yaw Rate Deviation" (Δr) and "Heading Angle Deviation" ($\Delta\psi$) versus the number of wheels locked were two of the four plots* generated for this particular maneuver These plots also contain the "Average Longitudinal Deceleration" ($\Delta \bar{A}x$) and are presented as one of the vehicle comparisons. Although various combinations of wheel lock-up or impending wheel lock-up were tried during the tests, it was not possible to achieve the same condition of wheel lock-up or impending wheel lock-up in every vehicle because of braking system differences.

The condition of impending one wheel lock-up (No wheels locked) was viewed as being most representative of "real life" and was attainable in all but the 1967 Corvair. The safety feature of the dual system master cylinder of the 1967 Corvair, when combined with the pressure modulator system used for pressure control, caused minimum of two wheels to lock in this vehicle.

The "Average Maximum Yaw Rate Deviation" and the "Average Longitudinal Deceleration" for impending one wheel lock-up

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*The other two plots were Maximum Yaw Rate Deviation" (Δr) versus "Average Longitudinal Deceleration ($\bar{A}x$) and "Heading Angle Deviation ($\Delta\psi$) versus $\bar{A}x$.

in the 1963 Corvair fell between the values for the Falcon and Valiant. (See Illustration No. 15) The "Average Heading Angle Deviation" for the 1963 Corvair and Valiant were nearly the same, with the Falcon closer to the Zero Deviation Line. All three of these vehicles were on the "Spin" side of the Zero Deviation Line. (See Illustration No. 16)

The Volkswagen and the Renault had about the same "Average Heading Angle Deviation" and "Average Maximum Yaw Rate Deviation" but they were on the "plow" side of the Zero Deviation Line.* The "Average Longitudinal Deceleration" of the 1963 Corvair was between the Volkswagen and the Valiant values and the Renault and Falcon values.

The "Average Maximum Yaw Rate Deviation" and "Average Heading Angle Deviation" plots with the four wheel lock-up condition resulted in the 1963 Corvair being between the Falcon and the Valiant. The values for the Volkswagen and the 1967 Corvair were less than the three aforementioned vehicles, with

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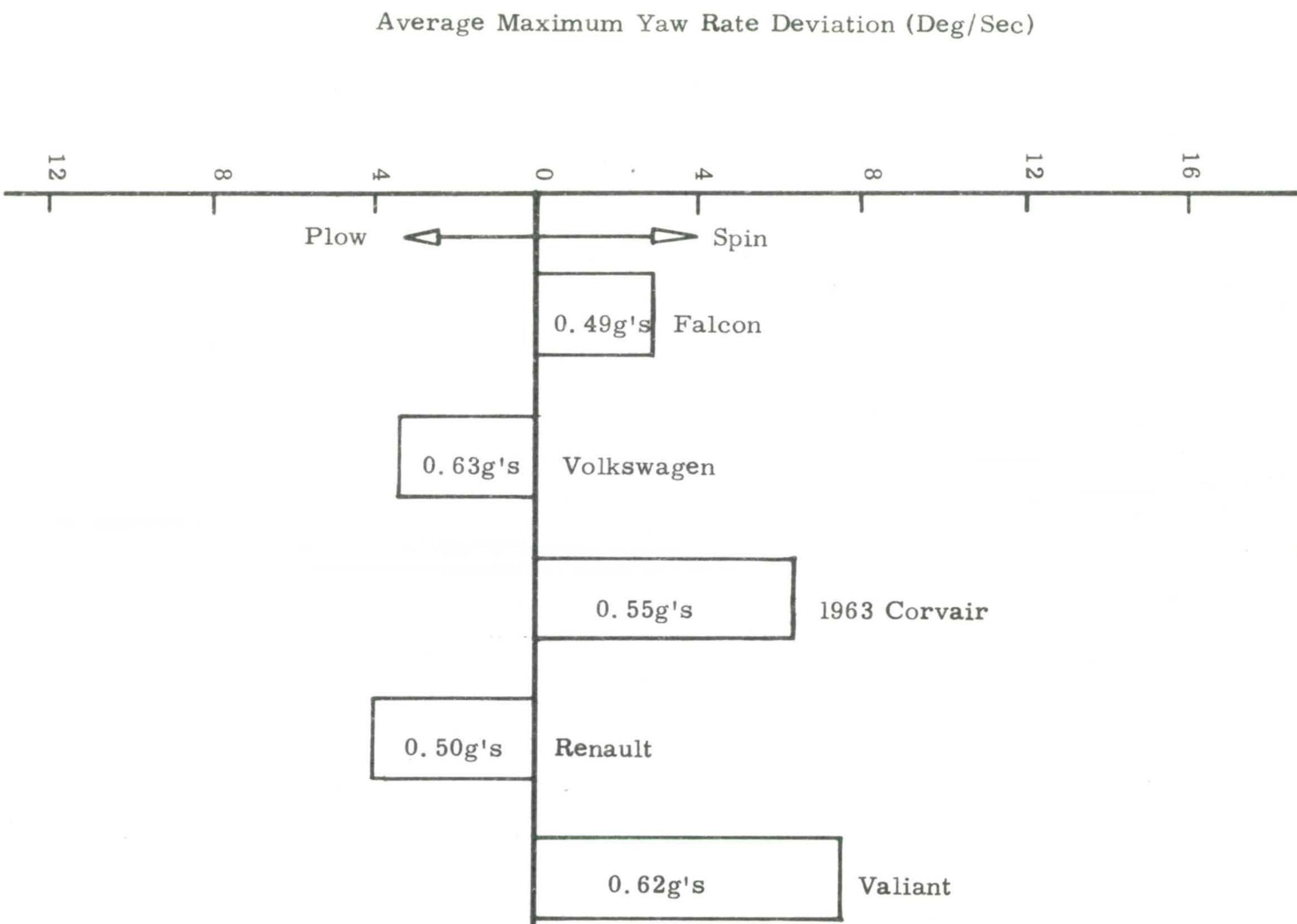
*The terms "spin" and "plow", as used throughout this report, only indicate the mode in which body side slip occurs, and they do not suggest loss of control of the automobile. "Spin" simply describes a situation in which side forces have probably saturated on both rear tires during a turning maneuver, causing an increase in yaw rate. Conversely, "plow" indicates a probable saturation of side forces on both front tires, causing a decrease in yaw rate.

STEADY TURN BRAKING, SMOOTH ROAD

IMPENDING ONE WHEEL LOCKUP
WITH NO WHEELS LOCKED
(Right Turn)



1967 Corvair -
For this test, because of the dual master cylinder and the design of the pressure modulator system, impending one wheel (no wheels locked) lock-up was not achieved.

Illustration No. 15

STEADY TURN BRAKING, SMOOTH ROAD

IMPENDING ONE WHEEL LOCKUP
WITH NO WHEELS LOCKED
(Right Turn)

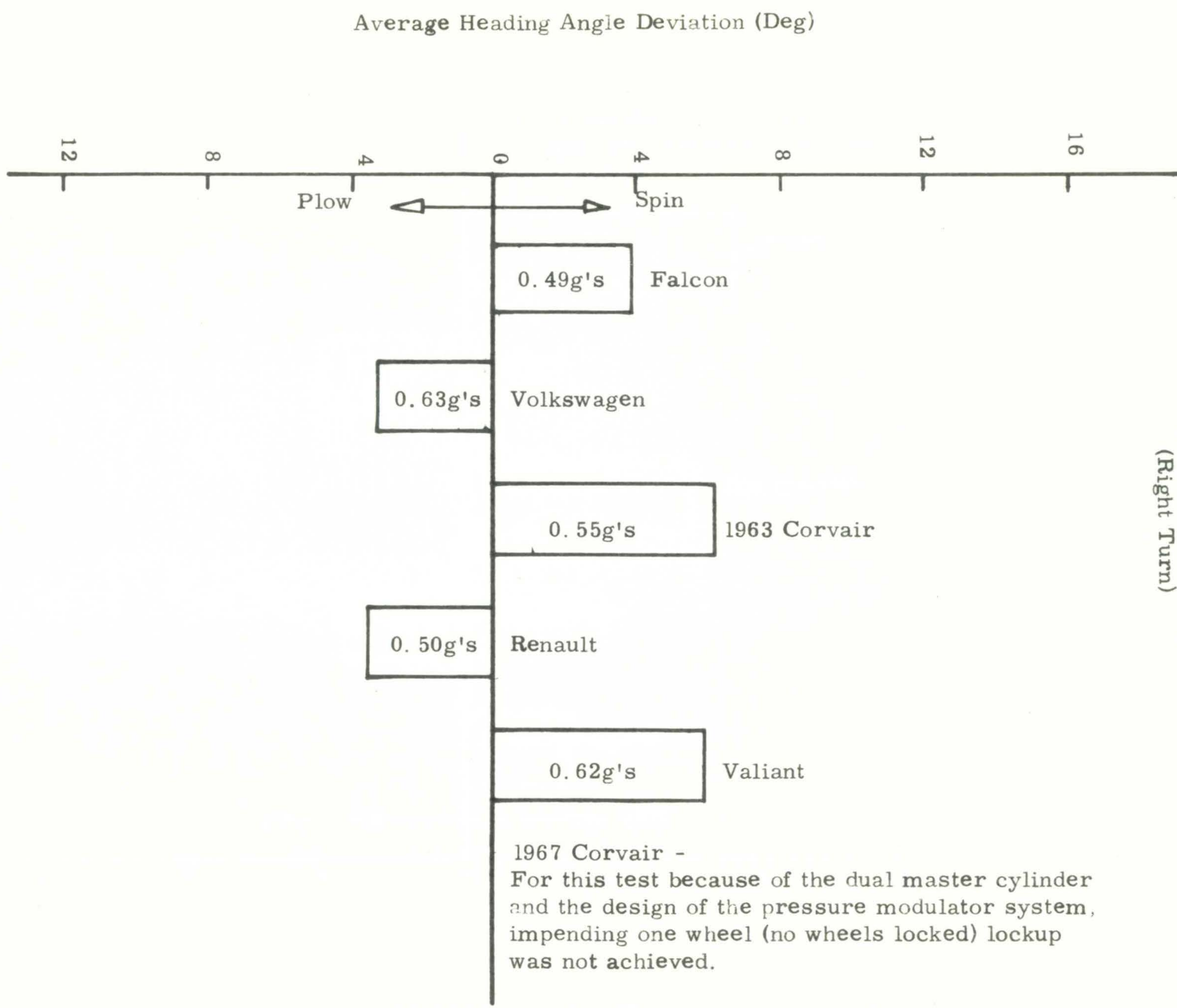


Illustration No. 16

the 1967 Corvair having the lowest deviations. (See Illustration Nos. 17, 18) In this maneuver, the Renault could not be evaluated because of the design of the brakes not permitting rear wheel lockup.

STEADY TURN BRAKING - SMOOTH ROAD

Four Wheel Lock-up
(Right Turn)

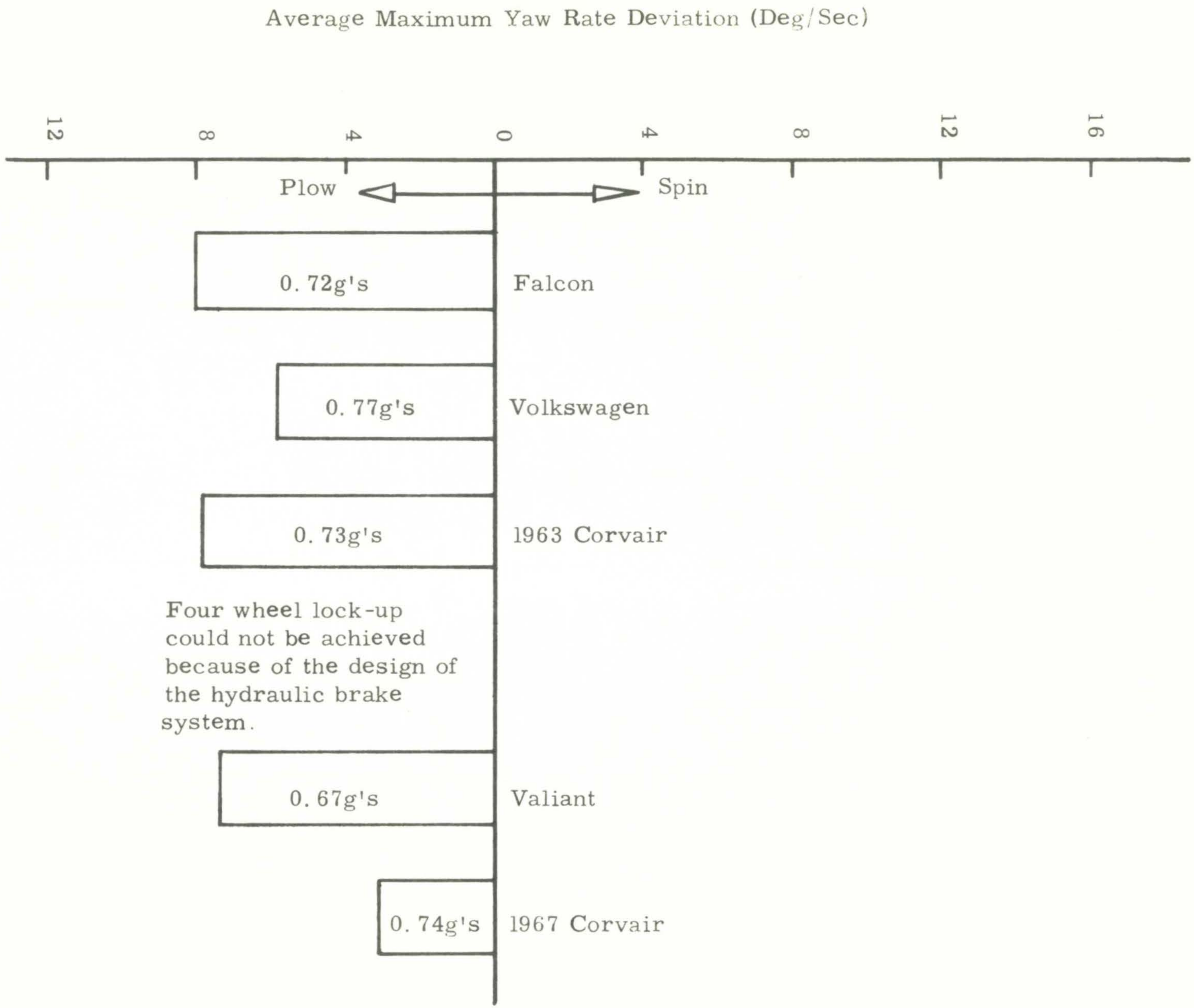


Illustration No. 17

STEADY TURN BRAKING - SMOOTH ROAD

Four Wheel Lock-Up
(Right Turn)

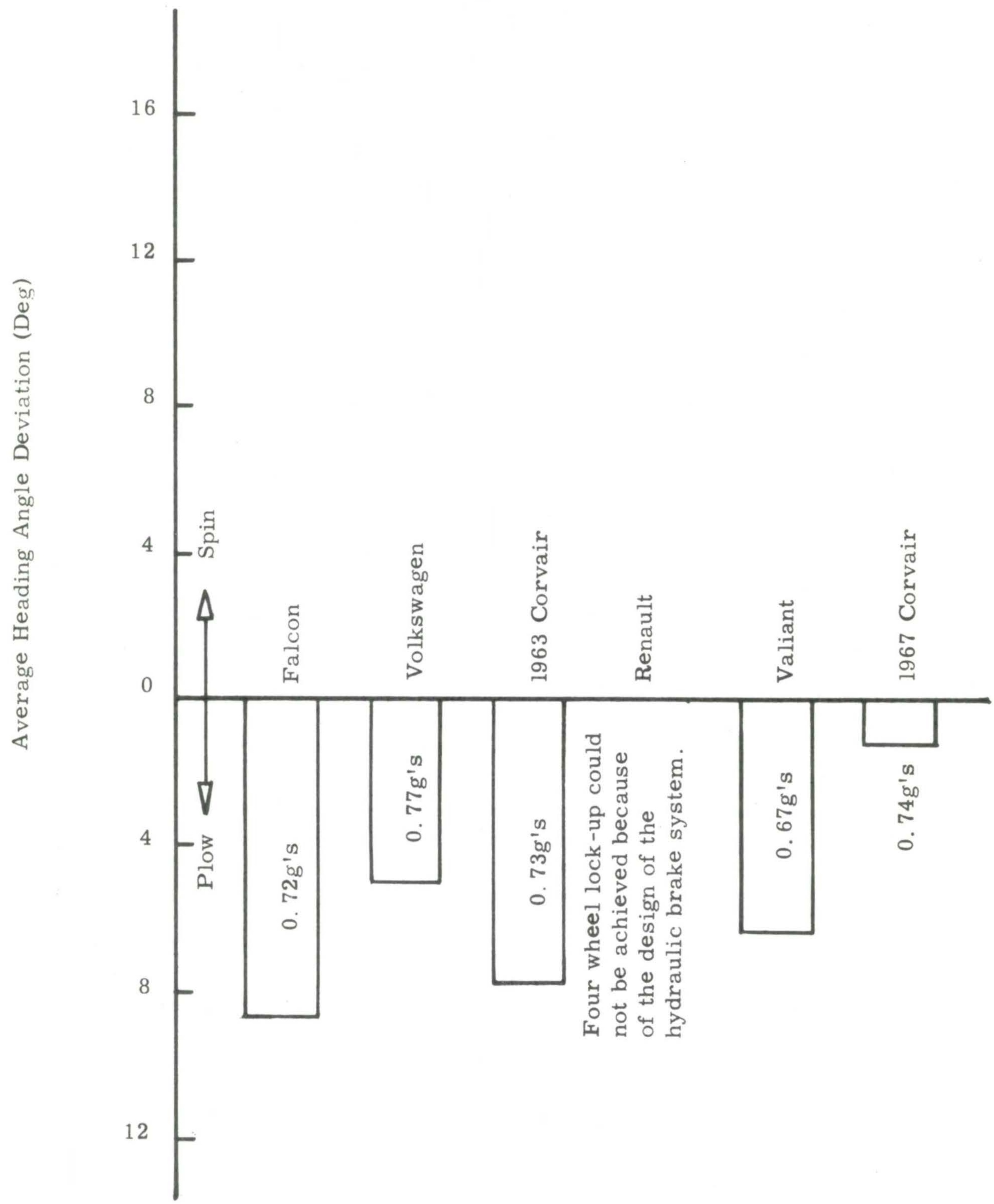


Illustration No. 18

Steady Turn, Rough Road

This test was conducted at two tire pressures--the manufacturer's recommended pressures and non-recommended pressures. The non-recommended pressures used for all except two vehicles (the 1962 Falcon and 1963 Renault) were obtained from data developed by the Davidson Laboratory, Stevens Institute of Technology and published in "Pressure and Load Characteristics of Small Passenger Car Tires," May 1971. The Falcon was tested prior to the availability of data from this report. A tire pressure higher than that recommended by the manufacturer was selected for it. No data were available in the report for the Renault; therefore, pressures were selected that reflected the tire pressure data in the report for the Volkswagen.

In this test the vehicle was placed in a 0.3g steady-state turn at 30 mph before traversing three separate series of bumps with 9, 11, and 14 hertz frequencies.

The plots generated by this maneuver were "Normalized Decrease in Lateral Acceleration" ($\Delta Ay/Ayo$) versus "Hertz" and "Normalized Change in Yaw Rate" ($\Delta r/r_o$) versus "Hertz".

On the "Normalized Decrease in Lateral Acceleration" plot a vehicle with no loss in roadholding would have $\Delta Ay/Ao = 0$, whereas a vehicle with a complete loss of control would have $\Delta Ay/Ao = 1.0$.

The "Normalized Decrease in Lateral Acceleration: plot of the series conducted at the manufacturer's recommended tire pressure resulted in the 1963 Corvair having the lowest value (close to zero) for both the 9 and 11 hertz bumps. The Volkswagen and the 1963 Corvair were lowest for the 14 hertz bumps. (See Illustration No. 19) The same series conducted at the non-recommended pressures showed the 1963 Corvair with the lowest value at 9 hertz At 11 hertz the 1963 Corvair was in the middle with the Falcon and Renault above it, the Volkswagen and Valiant below it and the 1967 Corvair was about the same as the 1963 Corvair. At 14 hertz the 1963 Corvair had the highest value. (See Illustration No. 20)

The "Normalized Change in Yaw Rate" was plotted so that the resulting value of ($\Delta r/r_o$) was plotted as a positive quantity for Δr greater than r_o and as a negative quantity for Δr less than r_o.

The "Normalized Change in Yaw Rate" plot of the initial vehicle responses for the series conducted at the manufacturer's recommended pressures showed the 1963 Corvair having the lowest values (closest to Zero) for 9, 11, and 14 hertz (See Illustration No. 21) The same plot for the series conducted at the <u>non</u>-recommended pressures showed the 1963 Corvair with the lowest

STEADY TURN - ROUGH ROAD

(WITH MANUFACTURER'S RECOMMENDED TIRE PRESSURES)

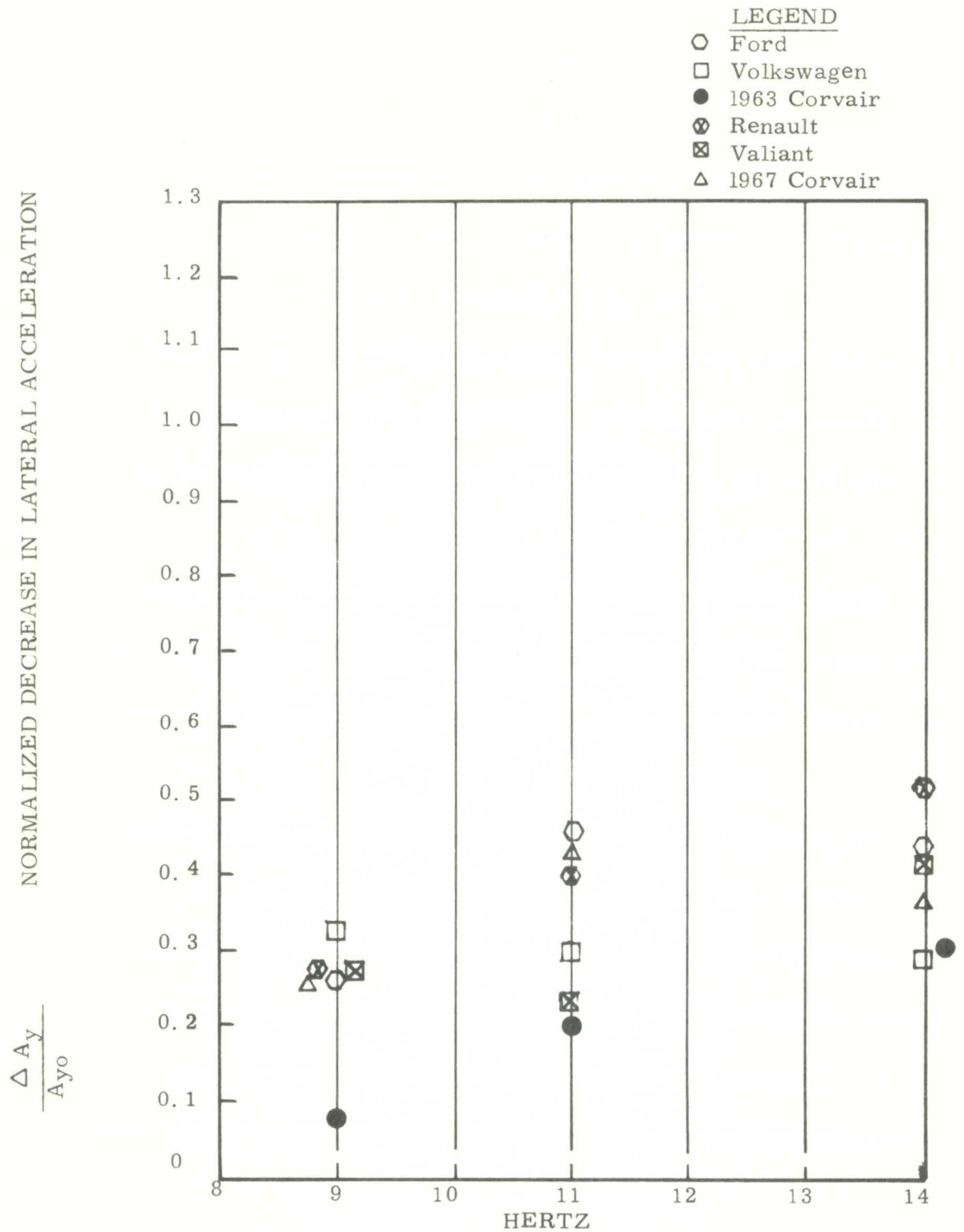


Illustration No. 19

STEADY TURN - ROUGH ROAD

(WITH NON-RECOMMENDED TIRE PRESSURES)

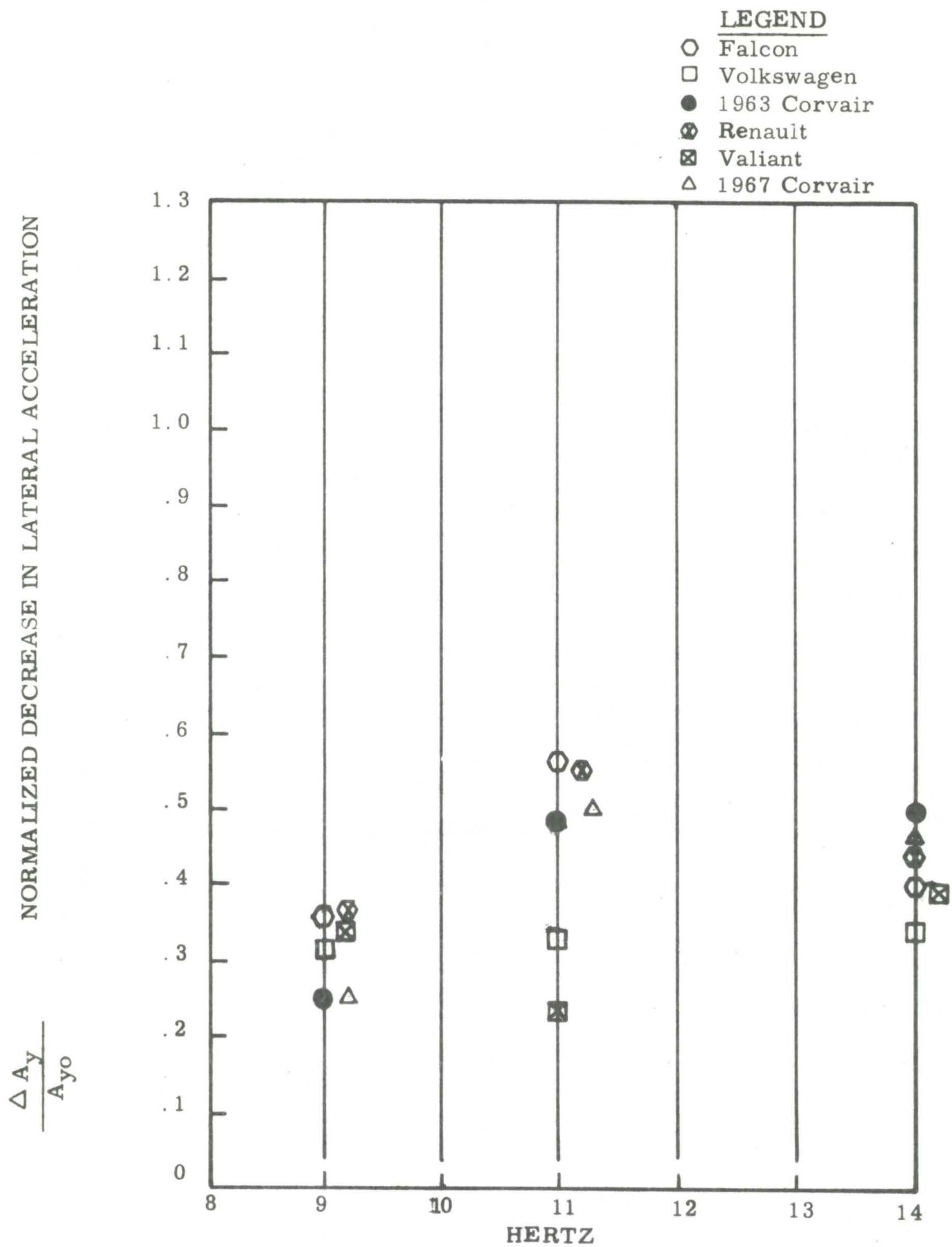


Illustration No. 20

STEADY TURN - ROUGH ROAD
INITIAL RESPONSE
(WITH MANUFACTURERS RECOMMENDED TIRE PRESSURES)

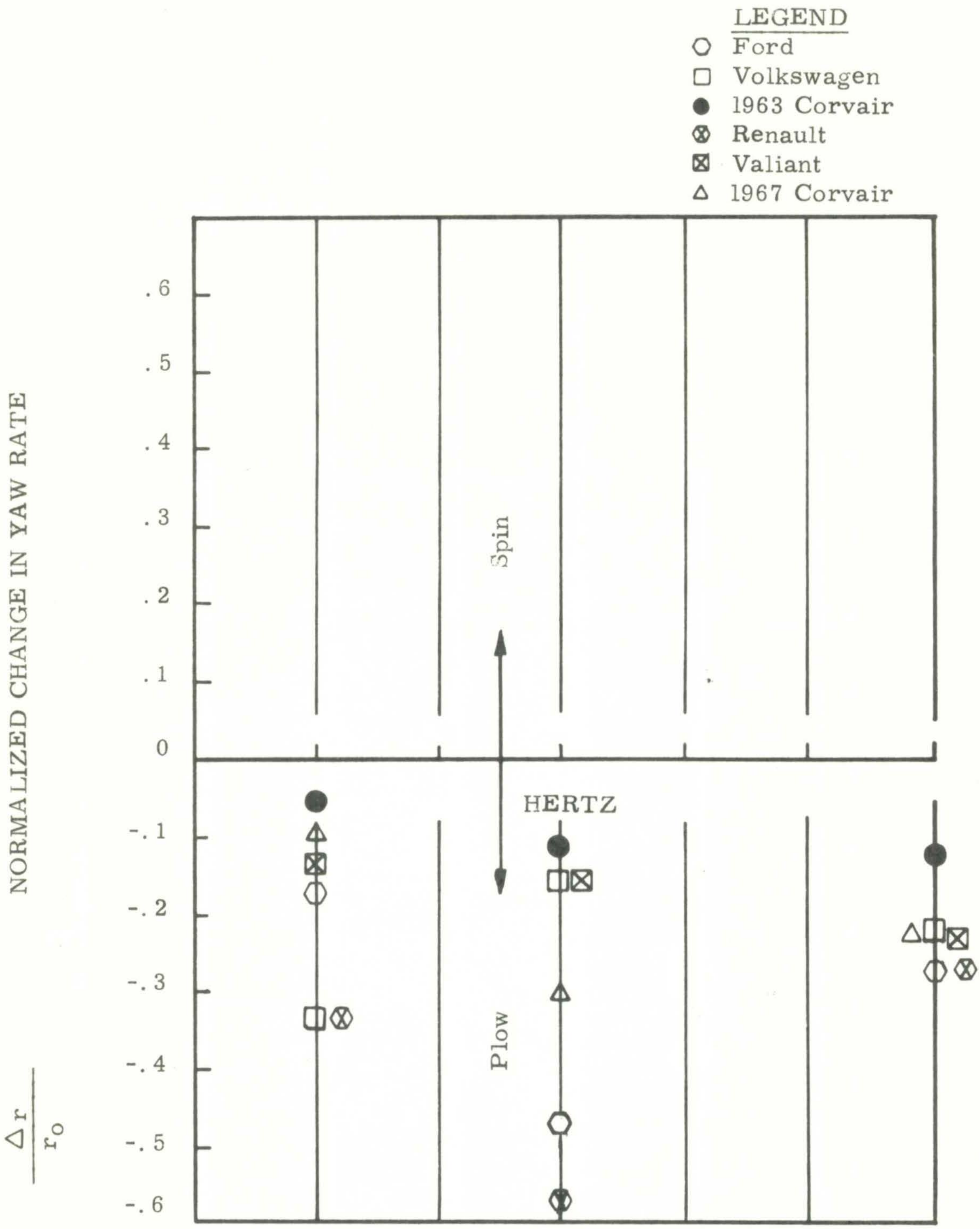


Illustration No. 21

value (closest to zero) for the 9 hertz bumps. It (1963 Corvair) was about the same as the Valiant and Volkswagen, which were the lowest (closest to zero) for the 11 hertz bumps and about the same as the Volkswagen, which was the lowest (closest to zero) for the 14 hertz bumps. (See Illustration No. 22)

STEADY TURN - ROUGH ROAD
INITIAL RESPONSE
(WITH NON-RECOMMENDED TIRE PRESSURES)

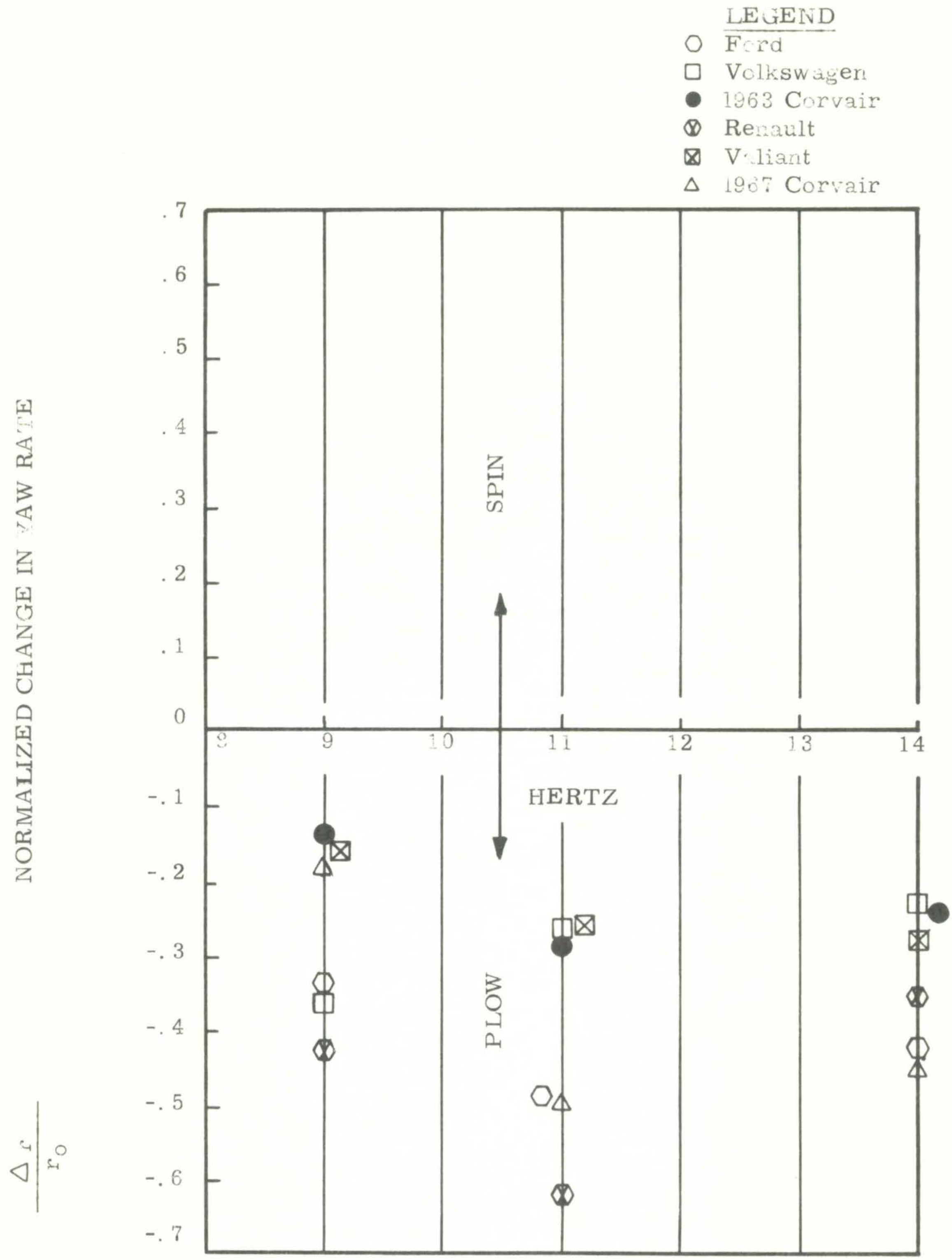


Illustration No. 22

Step Steer

This test had no initial steady state turn, but began with the vehicle achieving a steady velocity of 30 mph straight ahead, at which time a predetermined steering input was suddenly applied and held constant. This maneuver represented a "J" turn. The vehicles were subjected to incremental increases in steering input up to and including the maximum steering wheel displacement.

Lateral acceleration (Ay), Yaw rate (r) and Velocity (V) were all recorded during this maneuver. When the vehicle held the path perfectly, i.e., no body side slip and no time lag between steering input and response for any given run, the values of Ay, V and r at any particular time during the maneuver obeyed the relationship, Ay = rV. Therefore, the data were plotted as "Peak Lateral Acceleration" (Ayp) versus the "Yaw Rate, Velocity Product (r'pV'p), where both r'p and V'p corresponded in time to the occurrence of Ayp.

Superimposed on this plot is the "no side slip" or "perfect path holding" line described by the equation Ay = rV. A data point falling to the right of the "no side slip" line suggests that the vehicle was losing its path in a "spin" mode, a data point to the left is an apparent "plow" situation, and a point near or on the line is considered to be ideal. In addition, a line is drawn across the plot at 0.6g lateral acceleration. This line represents the approximate "Limit of Control" for the vehicles tested, except for the 1967 Corvair which has a higher limit of control of about 0.7g. Maneuvers that generate lateral acceleration greater than the "limit" value generally would result in the vehicle being uncontrollable. Therefore, values above the 0.6g "limit of control line" would generally be in the uncontrollable area except in the case of the 1967 Corvair.

The 1963 Corvair data points fell very close to the "no slip line" throughout the vehicle's controllable range and compared favorably with the plots for the other vehicles tested. (See Illustration No. 23)

In addition to the above, a plot of "Peak Lateral Acceleration" versus "Steering Wheel Angle" (δ sw) was developed.

The data points for the 1963 Corvair for this Plot fell between the Falcon, Valiant, and 1967 Corvair on one side, and the Volkswagen and Renault on the other side. (See Illustration No. 24)

The "Peak Lateral Acceleration" versus "Steering Wheel Angle" plot was also "normalized" to neutralize the effect of the differences in steering ratio for the cars tested. Up to the "Limit of Control", all the plotted lines for the vehicles fell in a tight band. (See Illustration No. 25) Beyond the limit of

STEP STEER

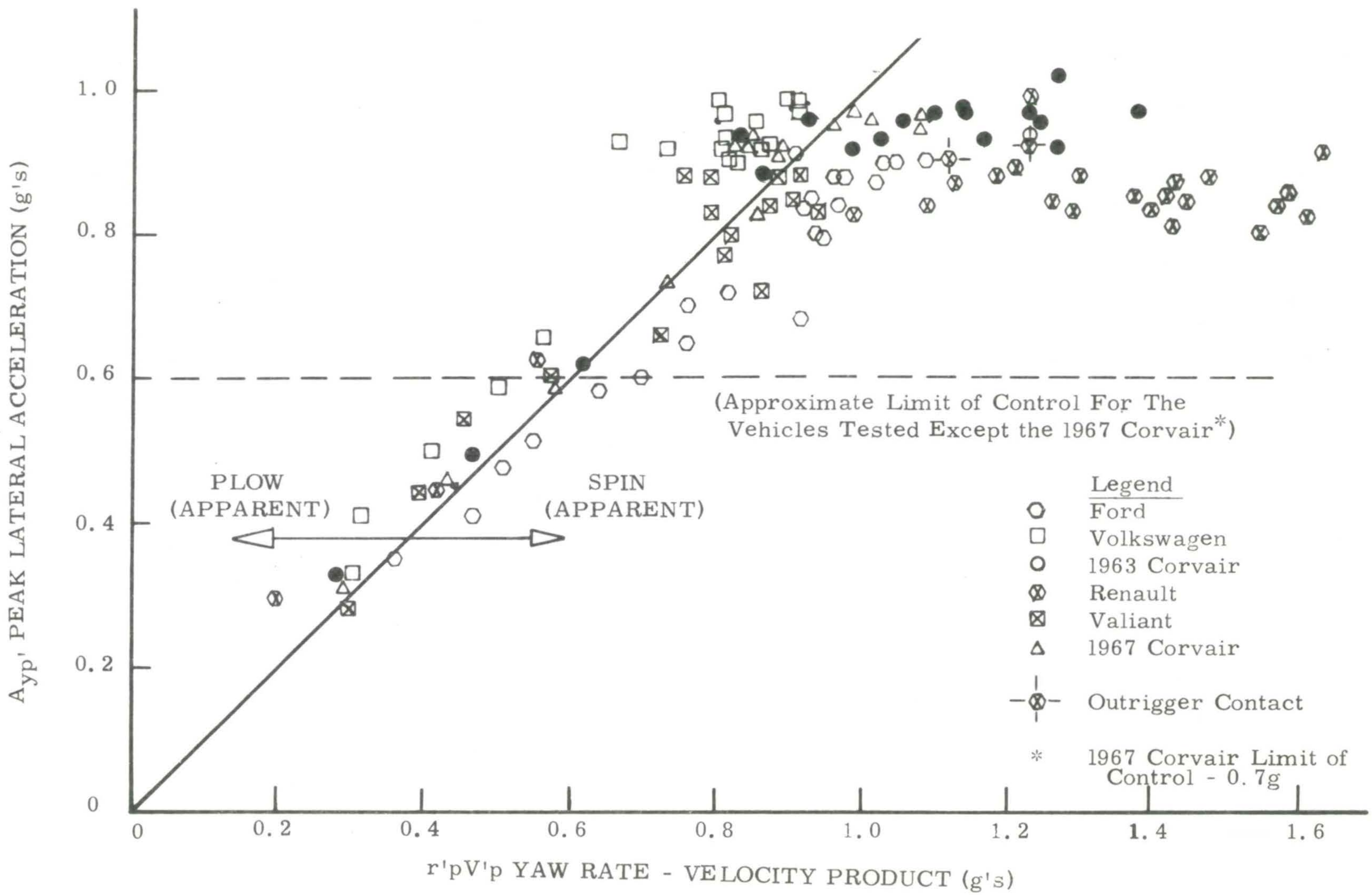


Illustration No. 23

STEP STEER

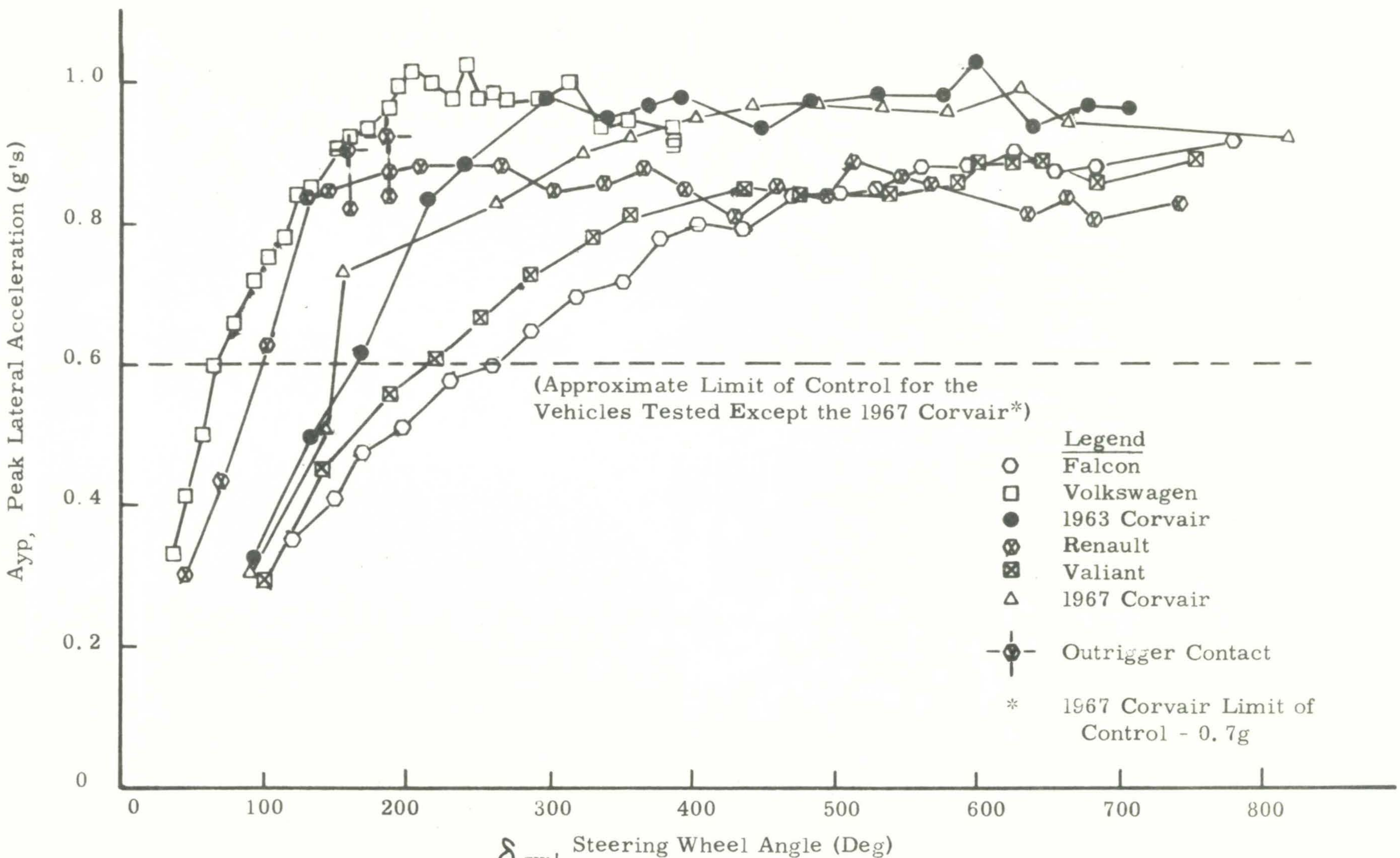


Illustration No. 24

STEP STEER

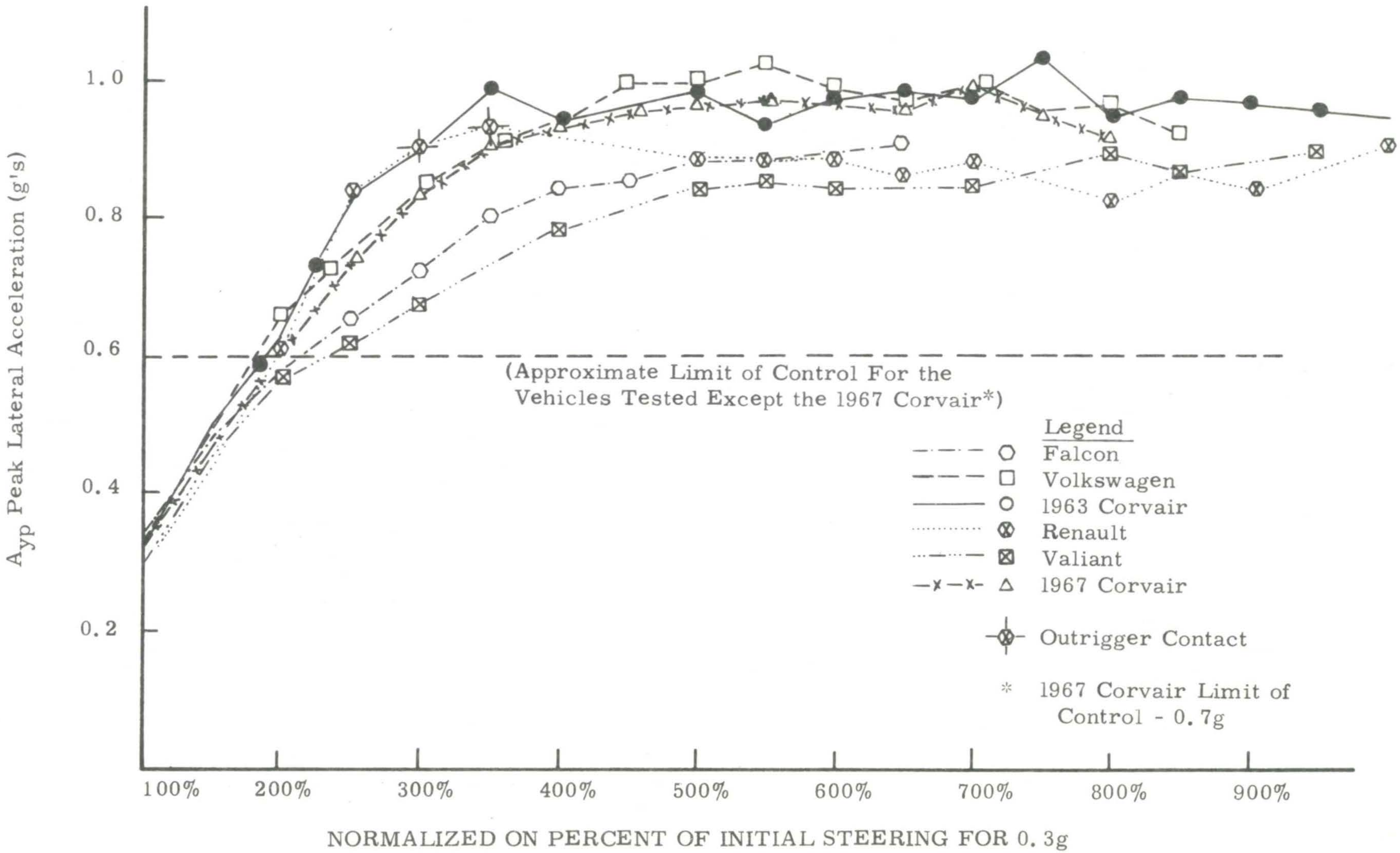


Illustration No. 25

control, the 1963 Corvair along with the Volkswagen, Renault and the 1967 Corvair, produced higher lateral acceleration "G" forces than the Falcon or Valiant.

A point of interest in this Step Steer Test was that during two of the maneuvers involving the Renault, outrigger contact was made. Although the maneuvers that produced the outrigger contacts were repeated immediately after the necessary inspections and adjustments were made to the vehicle and were also repeated again the next day, the outrigger contact did not occur again for the repeated maneuvers or for more severe maneuvers.

Reverse Steer

This test was conducted at 40 mph. After attaining a velocity of 40 mph, the steering wheel was turned against a preset stop so that the vehicle would achieve a steady-state turn. The magnitude of the input steer was adjusted to obtain a constant lateral acceleration of 0.3 g's for one test condition and 0.4 g's for another. After several seconds in the steady-state condition, the steering wheel of the vehicle was rapidly turned in the opposite direction against a second preset stop. This maneuver represented a modified "J" turn. The single input variable in this test was the magnitude of the reverse steer.

The plots generated for this maneuver were "Peak Lateral Acceleration" (Ayp) versus "Yaw Rate Velocity Product" (r'p V'p) and "Peak Lateral Acceleration" versus "Reverse Steer Input" (δsw) for both the 0.3g and 0.4g steady-state conditions. In addition, the "Peak Lateral Acceleration" versus "Steering Wheel Angle" plot were "normalized" to neutralize the effects of the different steering ratios.

On the "Peak Lateral Acceleration" versus "Yaw Rate-Velocity Product" plot for the 0.3g condition the two points of the 1963 Corvair that were near or below the Limit of Control fell right on the "no side slip line". (See Illustration No. 26) On the "Peak Lateral Acceleration" versus "Reverse Steer Input" plot,

REVERSE STEER

Initial Left Turn Stabilized Input - 0.3g

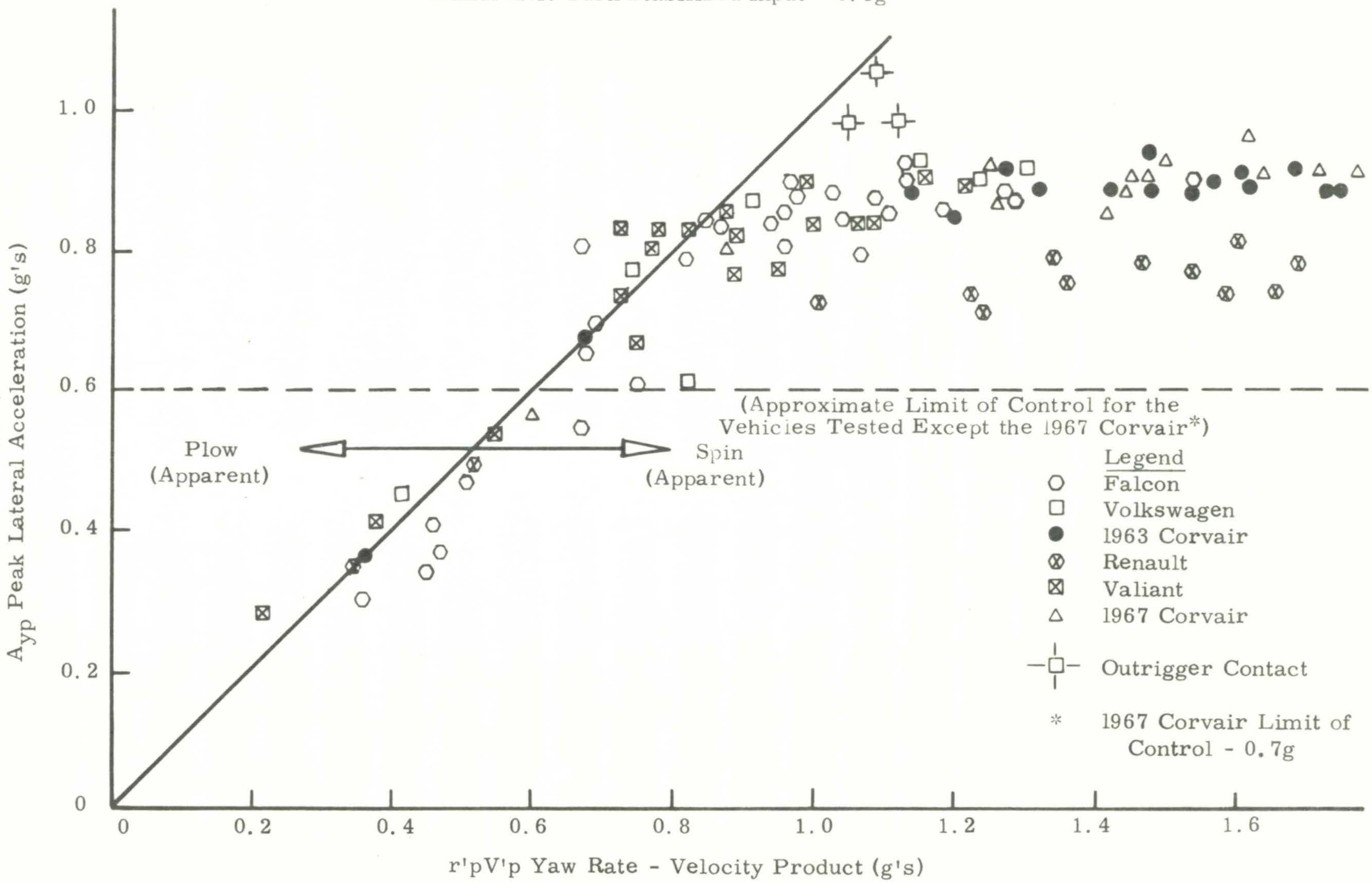


Illustration No. 26

the 1963 Corvair data fell between the Falcon-Valiant and the Volkswagen-Renault points and were almost the same as the 1967 Corvair. (See Illustration No. 27) When the "Reverse Steer Angle" was "normalized" on the percent of initial left turn steering degrees for 0. 3g and plotted against "Peak Lateral Acceleration" the 1963 Corvair fell between the 1967 Corvair, which was the highest, and the other vehicles tested. (See Illustration No. 28)

A significant point of interest during this test was that the Volkswagen made outrigger contact three times. (See Illustration Nos. 26, 27, 28) After the third outrigger contact, the test was terminated for fear of damaging the vehicle for the remaining tests and the limited supply of wheels on hand. During each outrigger contact, the outside wheels would get bent or scrapped.

On the "Peak Lateral Acceleration" versus "Yaw Rate-Velocity Product" plot for the 0. 4g condition, the 1963 Corvair only had one point below the "Limit of Control Line" and it was slightly to the right of a similar point for the Falcon. They were both on the "spin" side of the "no side slip line". See Illustration No. 29)

On the "Peak Lateral Acceleration" versus "Reverse Steer Input" for the 0. 4g condition, the data points for the 1963

REVERSE STEER

Initial Left Turn Stabilized Input 0.3g

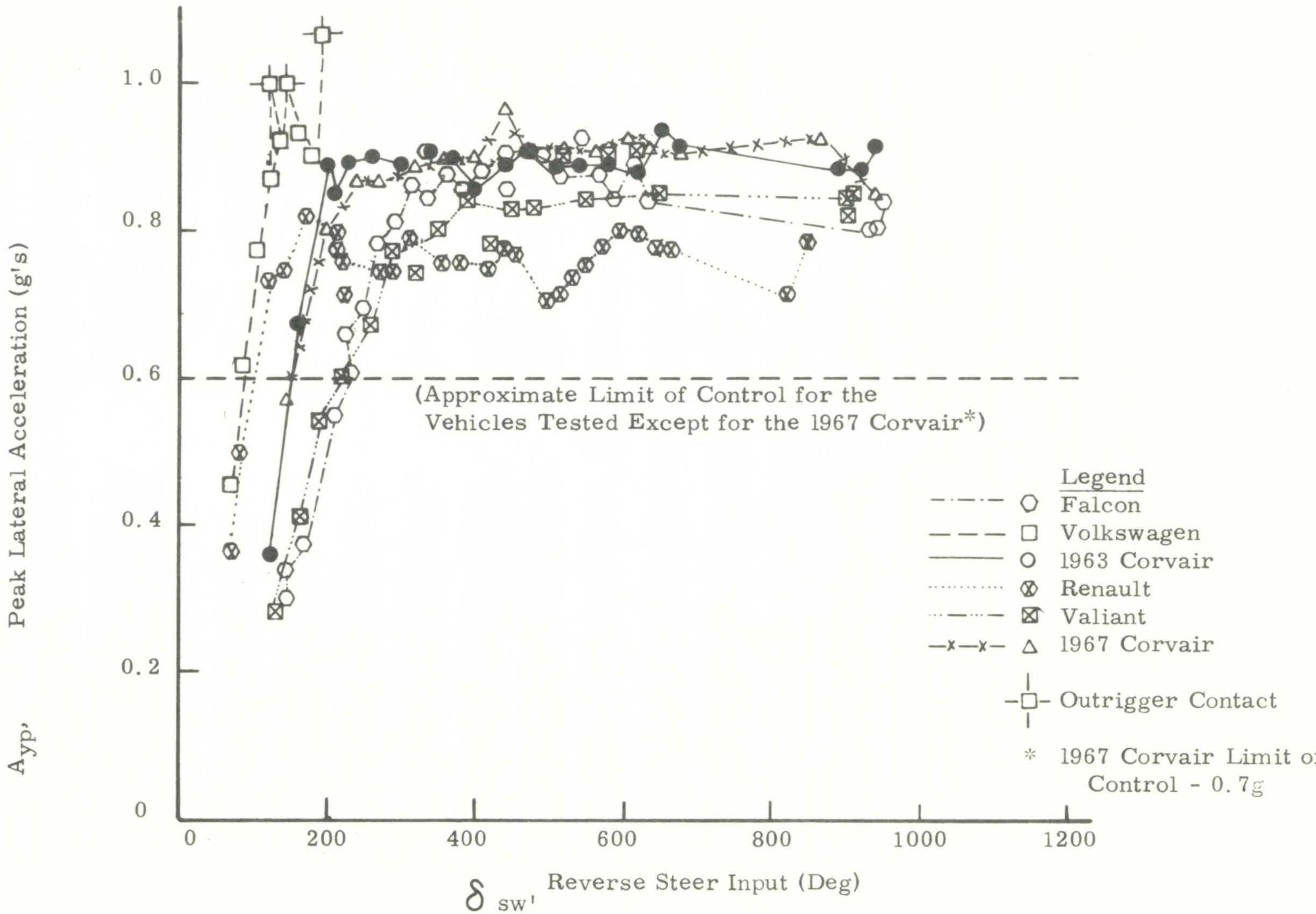


Illustration No. 27

REVERSE STEER

Peak g's In The Right Turn As a Percent of Steering Degrees Required
For The 0.3g Lateral Acceleration For The Initial Left Turn Stabilized Input

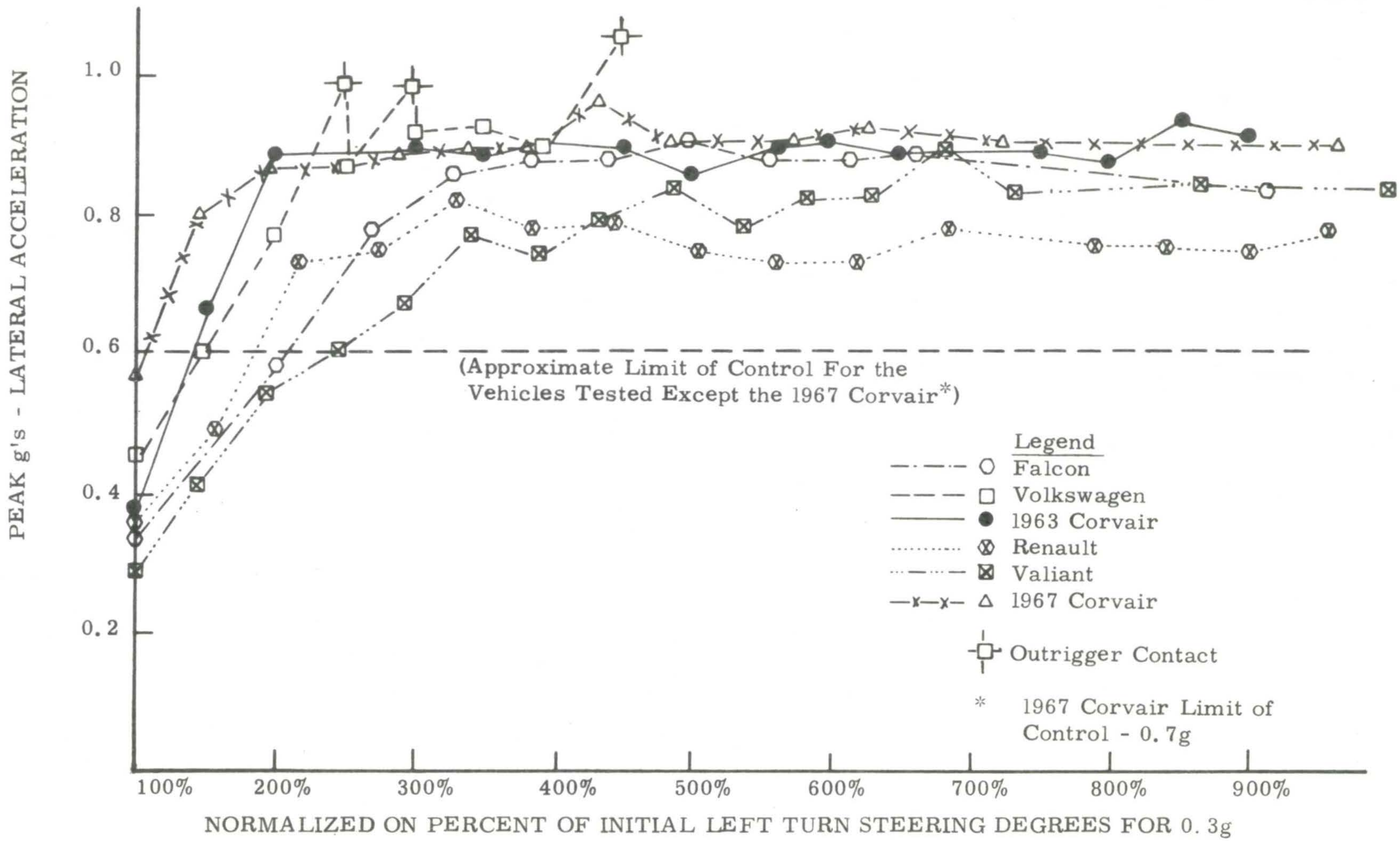


Illustration No. 28

REVERSE STEER

Initial Left Turn Stabilized Input - 0.4g

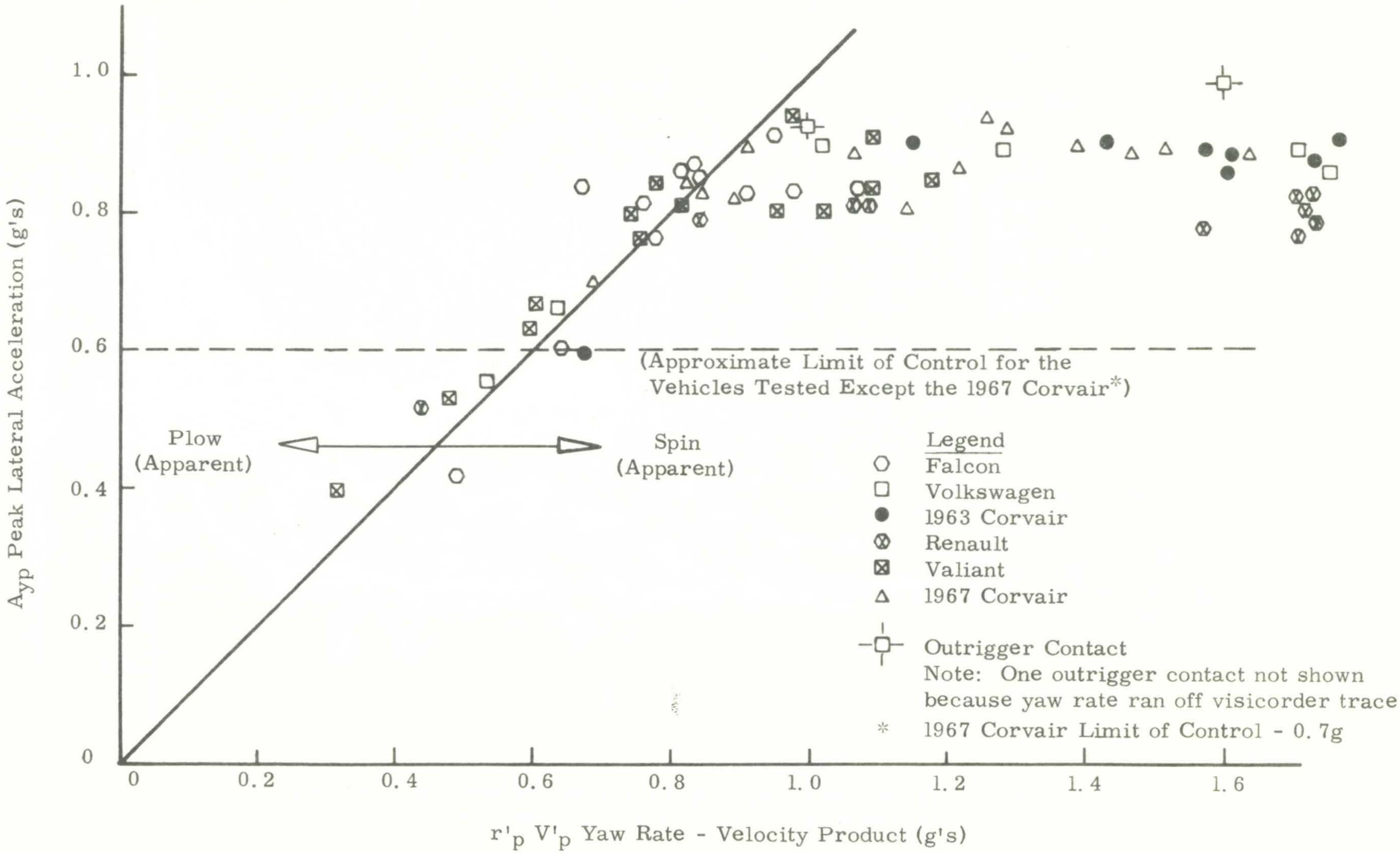


Illustration No. 29

Corvair fell between the Volkswagen and Renault on one side and the 1967 Corvair, Falcon, and Valiant on the other side. (See Illustration No. 30) When the "Peak Lateral Acceleration" was plotted versus the "normalized steering inputs", the data points for the 1963 Corvair fell between the 1967 Corvair, which were the highest, and the other vehicles. (See Illustration No. 31)

Again, a significant point of interest during this test was that the Volkswagen made outrigger contact three times. (See Illustration Nos. 29, 30, 31) Although the last outrigger contact was made at the full steering stop, the regular stepped increases between the second outrigger contact to full steering stop were not made for fear of damaging the vehicle for the remaining test and because of the limited supply of wheels available.

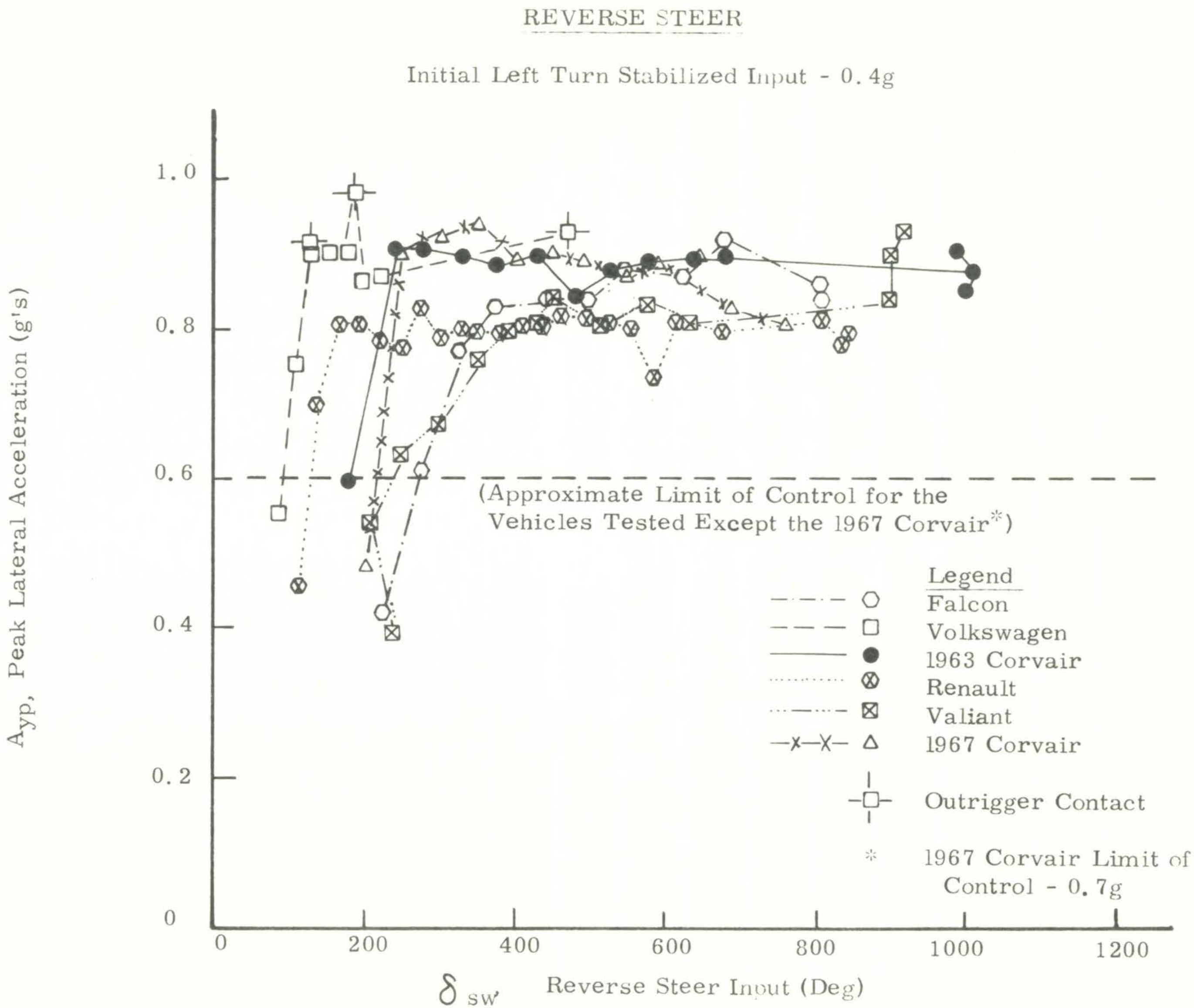


Illustration No. **30**

REVERSE STEER

Peak g's In The Right Turn as a Percent of Steering Degrees Required
For 0.4g Lateral Acceleration For The Initial Left Turn Stabilized Input

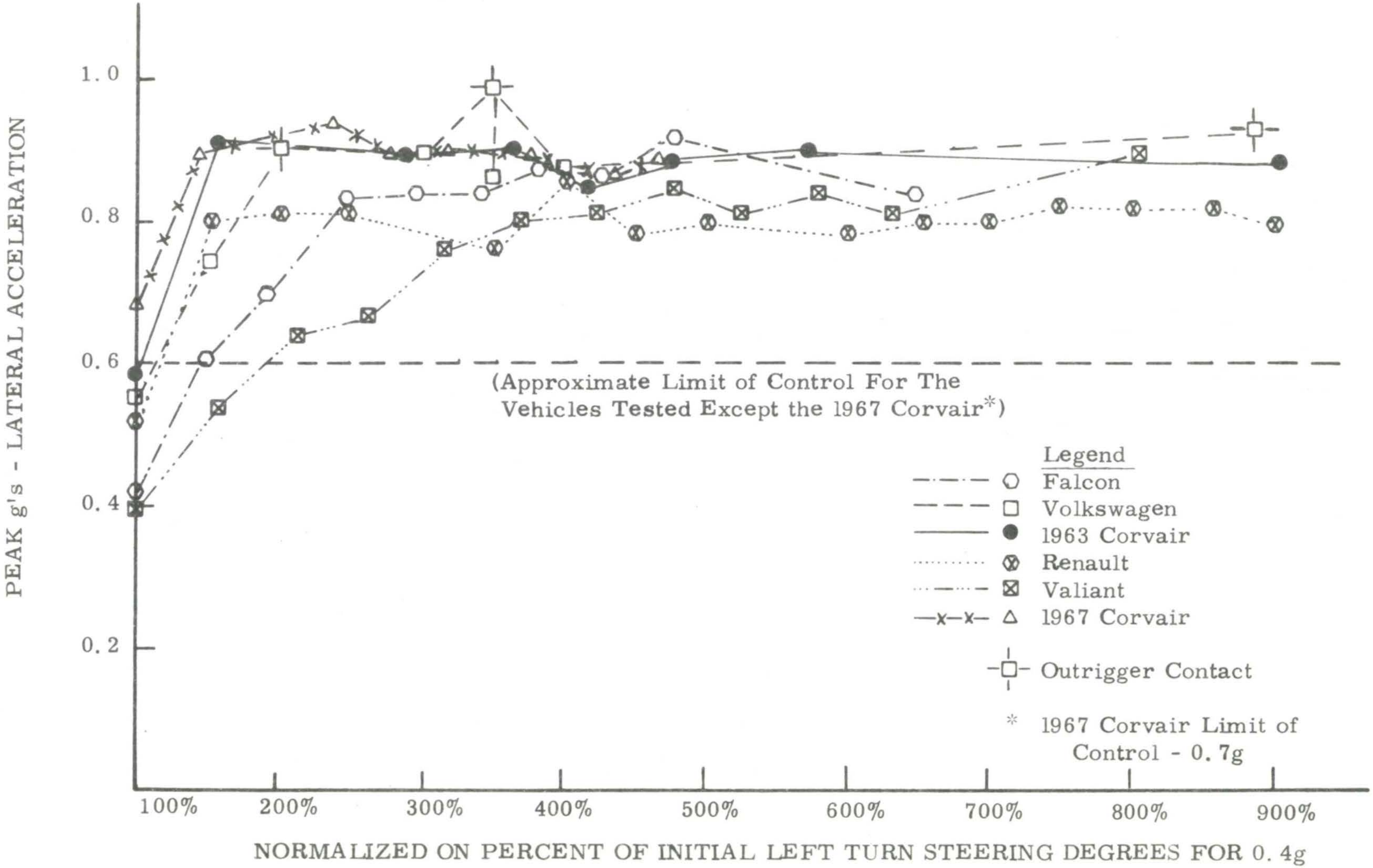


Illustration No. 31

Drastic Steer - Drastic Brake

The object of this test was to determine if outrigger contact, which represented vehicle rollover, would occur during this very severe maneuver. The maneuvers were conducted starting at 40 mph and increased to 60 mph in 10 mph increments or until outrigger contact was made. If outrigger contact was made at 40 mph, the maneuver was tried at 30 mph to determine if the outrigger contact would occur at this lower speed.

The speed attainable for the smaller engine vehicles (Renault and Volkswagen) was limited. The maximum speed range that the Renault could be operated at was 40 mph and the maximum for the Volkswagen was 50 mph.

The test requirements of four wheel lock-up could not be accomplished for the Renault because the hydraulic system was designed so that rear wheel lock-up would not occur. Also the automatic controller equipment configuration and location requirement resulted in the front axle being overloaded about 60 pounds.

Because the maximum speed range that the Renault was capable of achieving was only 40 mph, the four wheels could not be locked, and the front axle was overloaded, it was concluded it would be not appropriate to compare the Renault with the other vehicles for this maneuver.

The Volkswagen was the only vehicle that had outrigger contact during the Drastic Steer-Drastic Brake maneuver. It had outrigger contact at the 40 mph and 50 mph speeds. (See Illustration No. 32) There was no outrigger contact at 30 mph. Although the test guidelines did not require that tests further be conducted at a higher speed after contact was made at 40 mph, the test maneuver was also conducted at 50 mph in the interest of determining what steering input might induce outrigger contact at the higher speed.

DRASTIC STEER - DRASTIC BRAKE

Speed MPH	Steer Input (deg)	Outrigger Contact: Falcon	1963 Corvair	Renault	Valiant	1967 Corvair	Volks-Wagen	Comments
30	400						NO	
40	70						NO	
40	100		NO					
40	120			NO				
40	130						NO	
40	155			NO				
40	160						NO	
40	190			NO				
40	200	NO	NO		NO	NO	NO	
40	225			NO			NO	
40	250						YES	No outrigger contact occurred on repeat run
40	260			NO				
40	275						NO	
40	300	NO	NO	NO	NO	NO	NO	
40	325						NO	
40	350			NO	NO	NO	YES	No outrigger contact occurred on repeat run
40	375						YES	Outrigger contact on the two repeat runs
40	400	NO	NO	NO	NO	NO		
50	100		NO					
50	175						NO	
50	200	NO	NO		NO	NO	NO	
50	225						NO	
50	250				NO	NO	NO	
50	275						YES	Outrigger contact on first repeat run. No contact occurred on the second repeat run.
50	300	NO	NO		NO		NO	
50	325						YES	Outrigger contact on first repeat run. No second repeat run because of breakdown of controller.
50	350		NO		NO	NO		
50	400	NO	NO		NO	NO		
60	200	NO	NO		NO	NO		
60	300	NO	NO		NO	NO		
60	350		NO		NO	NO		
60	400	NO	NO		NO	NO		

Illustration No. 32

IV. CONCLUSIONS

During the course of this investigation, large quantities of information concerning the 1960-1963 Corvair were reviewed by NHTSA engineers. This information included extensive data obtained from General Motors, input from Mr. Nader and his associates, numerous technical and consumer publications concerning vehicle handling, sworn testimony from several court proceedings, comparison vehicle testing by Ford Motor Company, and NHTSA vehicle test data.

After careful and deliberate analysis of the information, the following conclusions are made:

1. The 1960-1963 Corvair understeers in the same manner as conventional passenger cars up to about 0.4g lateral acceleration.

2. The transition from understeer, through neutral steer, to moderate oversteer occurs in a range from about 0.4g to 0.5g, lateral acceleration. This transition does not result in abnormal potential for loss of control.

3. The limit of control for the 1960-1963 Corvair is 0.6g sustained lateral acceleration, which is comparable to contemporary solid rear axle, front engine domestic vehicles.

4. The 1960-1963 Corvair was found to have no critical speed.

5. The limited accident data available indicates that the rollover rate of the 1960-1963 Corvair is comparable to other light domestic cars. One accident study shows the Corvair to have a higher percentage of rollover accidents, while another indicates it to be slightly lower.

6. The Corvair compared favorably with the other contemporary vehicles used in the following NHTSA Input Response Tests:

   Steady Turn Braking, Smooth Road simulating the maneuver required in an emergency situation, bringing the vehicle to a stop on a curve with little or no deviation from its intended path.

   Steady Turn, Rough Road simulating a vehicle cornering at high lateral acceleration and encountering a series of bumps or road obstructions.

   Step Steer simulating a "J" turn.

   Reverse Steer Input simulating a modified "J" turn.

   Drastic Steer, Drastic Brake This test was mechanically controlled test without a driver and was the one which Highway Safety Research Institute had concluded was most apt to place a vehicle in the rollover mode.

For many of the tests the plotted data indicated that the Corvair performance fell between the Valiant and Falcon on one side and the Volkswagen and Renault on the other side. Outrigger contact (representing vehicle rollover) did not occur in any of the comparative tests for the Corvair, Falcon or Valiant. Outrigger contact was made by the Volkswagen and the Renault in some of the comparative tests.

7. The comments by Messrs. Smith, Fonda, and Sergay about the General Motors Proving Ground reports PG 15699 and PG 17103 and the analysis by Mr. Copp of a Ford Motor Company film, "1960 Falcon-Corvair Handling Comparison" do not provide any valid data for a determination that the handling and stability of the 1960-1963 Corvair is unsafe.

It is concluded that the handling and stability performance of the 1960-1963 Corvair does not result in an abnormal potential for loss of control or rollover and that its handling and stability performance is at least as good as the performance of some contemporary vehicles both foreign and domestic.

V. LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

VI. DOCUMENTS ANALYZED

Note: The items recognized as manufacturers proprietory items are not included.

1. A policy on Geometric Design of Rural Highways, 1965, ASSHO.

2. Twelfth Stapp Car Crash Conference, 1968, S. A. E.

3. The University of N. C. Highway Research Center Driver Injury in Automobile Accidents Involving Certain Car Models, 1970, B. J. Campbell.

4. Study of Volkswagen Accidents in the U. S. A., 1968, Automobile Crash Injury Research, Cornell.

5. What Makes Cars Handle Part I and II, Jim Hall.

6. Road Test, Corvair, Autocar, January 6, 1961.

7. European Post War Cars, 1953, M. Olley.

8. Mechanics of Vehicles, J. J. Tarborek.

9. Vehicle Dynamics Terminology (J670a&b) S. A. E.

10. Suspension and Handling (Road and Track), Ron Wakefield.

11. A Study of Rollover in Rural U. S. A., Automobile Accidents, Cornell, J. W. Garrett, 1967.

12. Chevrolet Workshop Manuals for Corvair 1960 to 1968.

13. Unsafe at any Speed, 1966, R. Nader.

14. The Assasination of the Corvair, A. J. White.

15. Steering Diagnosis (In-use Vehicle Handling), Clayton.

16. Standard for Handling Characteristics of Automobiles, W. E. Mulliken, Jr. and F. Dell'Amico, Cornell Aeronautical Laboratory, Inc., July 1968.

17. A Study of the Relation between Forward Velocity and Lateral Acceleration in Curves During Normal Driving. (Extracted from Human Factors, 1968, 10(3) 255 - 258), Malcolm L. Richie, William K. McCoy and William L. Welde.

18. Lateral Forces on Vehicles During Driving (Extracted from Automobile Engineer, December 1967), J. G. Smith and J. E. Smith.

19. Traffic Engineering and Control (Extracted from International Road Safety and Traffic Review), J. Emmerson.

20. Vehicle Handling Test Procedures (Under FH 11-7297), Highway Safety Research Institute, University of Michigan, November 1970.

21. Magazine Articles Reviewed:

Consumers Reports,	Page	39,	Jan. 1960
Consumers Reports,	Page	195,	Apr. 1960
Consumers Reports,	Page	377,	Jul. 1960
Consumers Reports,	Page	191,	Apr. 1961
Consumers Reports,	Page	144,	Mar. 1961
Consumers Reports,	Page	46,	Jan. 1962
Consumers Reports,	Page	135,	Mar. 1962
Mechanix Illustrated,	Page	63,	Nov. 1959
Mechanix Illustrated,	Page	74,	Oct. 1962
Autocar (Road Test Report)	Page	29,	Jun. 1961
Road and Track	Page	28,	Nov. 1959
Autocar (Road Test Report)	Page	116,	Apr. 1962
Popular Mechanics,	Page	103,	Oct. 1959
Popular Mechanics,	Page	125,	Mar. 1960
Popular Science,	Page	108,	Oct. 1959
Popular Science,	Page	112,	Jan. 1960
Popular Science,	Page	77,	Apr. 1962
Popular Mechanics,	Page	106,	Sept. 1961
Popular Science	Page	84,	Oct. 1960

22. General Motors Corporation Data

ITEM I - A - 3

P. G. Report No. 11245, Tire Blowout Comparison at 60 mph., 1959 Chevrolet and 1960 Corvair

"Handling Characteristics of Automobiles" by Dr. T. Manos, Iowa Public Hearing on Automotive Safety

Deposition of Dr. T. Manos in Anderson vs. General Motors

List of Alleged Corvair Defects as Given by D. Harney, Plaintiffs' Attorney

Opening Statement on Behalf of the Plaintiffs by D. Harney in Collins vs. General Motors

M. I. R. A. Report - V. A. II
Closing Arguments, Collins v. s. GMC
Closing Arguments, Drummond v. s. GMC

ITEM II - B, CHEVROLET TEST REPORTS

T. W. O. 25004-13	T. W. O. 25014-47	T. W. O. 25513-14
T. W. O. 25013-59	T. W. O. 25014-51	T. W. O. 25564-37
T. W. O. 25014-46	T. W. O. 25508-4	T. W. O. 25585 (Ref. PG-13685)

ITEM II - C, PROVING GROUND REPORTS

P. G. -14737
P. G. -14752
P. G. -17118 (Ref. TWO 29111-10)
P. G. -17854
P. G. -19577
P. G. -15699
P. G. -17103

ITEM III - A - 1, DRUMMOND DECISION

ITEM III - A - 3, COMPLETE WINCHELL TRANSCRIPT

ITEM III - A - 4

Summary - Corvair Dimensions and Characteristics

Corvair Ownership List

S. A. E. Paper #140C

S. A. E. Paper #143D

Comments on ACIR, CAL. No. VJ-1823-R32

ITEM III - A - 5, LANSING PRESENTATION AND BACKGROUND INFORMATION

Letter and Copy of Statement by G. M. C. before Michigan Senate Highway Committee, February 21, 1966

Transcript of F. J. Winchell's Statement

F. J. Winchell's Exhibits

Michigan Senate Bill #766-773 and back-up material

Statements of the Other Witnesses Before the Michigan Senate Highway Committee, February 21, 1966

Rim to Ground Clearance Photographs

ITEM III - A - 6, EXCERPTS OF TESTIMONY

FILMS

A-50 Free Control

A-53 Normal and Hard Driving

A-64 Simulated Roadability Film

A-83 Fixed Steering Film - Corvair-in-Car

A-84 Fixed Steering Film - Corvair-outside

A-85 Fixed Steering Film - Falcon-in-Car

A-86 Fixed Steering Film - Falcon-outside

A-88 Skidpad Limit of Control - Corvair-in-Car

A-89 Skidpad Limit of Control - Corvair-outside

A-90 Skidpad Limit of Control - Falcon-in-Car

A-91 Skidpad Limit of Control - Falcon-outside

A-93 Film Showing the Effect of Ride Motions during Cornering - Corvair-in-Car

A-94 Film Showing the Effect of Ride Motions during Cornering - Corvair-outside

A-95 Film Showing the Effect of Ride Motions during Cornering Falcon-in-Car

A-96 Film Showing the Effect of Ride Motions during Cornering - Falcon-outside

A-98 Film Showing J-Turns with and without Braking - Corvair-in-Car

A-99 Film Showing J-Turns with and without Braking - Corvair-outside

B-1 Film Showing J-Turns with and without Braking - Falcon-in-Car

B-2 Film Showing J-Turns with and without Braking - Falcon-outside

B-8 Ride and Handling Road Film - Corvair-in-Car

B-9 Ride and Handling Road Film - Falcon-in-Car

B-10 Ride and Handling Road Film - Belair Chevy II-in-Car

B-12 Vehicle Evasive Performance - In-Car

B-13 Vehicle Evasive Performance - Outside view

B-29 Ramp Film - Corvair-outside

B-30 Critical Speed Film - Corvair-in-Car

Exhibit "N" - Film of Driving at the Drummond Accident Site (Suspension Camera)

Exhibit "M" - Film of Driving at the Drummond Accident Site (Inside Camera)

Exhibit #48 - O'Shea Pomona Film

ITEM I - A - 1, Model Car on Ramp Film

ITEM I - A - 3(j), Vehicle and Driver Performance Film

ITEM III - A - 4, Movie Pomona Rollover Attempts

ITEM III - A - 5, Movie #7 Normal and Hard Driving

ITEM III - A - 5, Movie #8 Simulated Roadability

ITEM III - A - 5, Movie #2 J-Turns

Film for PG 11106

Film for PG 11304

Film for PG 11285

Film for PG 15699

Film for PG 17103

Dynamic Roadability - Corvair - Views of Both Rear Wheels During Skid Pad Runs

Exhibit #74 - Part 1 and 2 - Rollover Test of the Shock Absorber Lower Mounting Bracket

Exhibit #75 - O'Shea - Manos Film

SLIDES

ITEM III - A - 5, Slides in F. J. Winchell Presentation - Lansing, Michigan, February 21, 1966 (Slides #1, 3, 4, 5, 6, 10, 11, 12/13, 14)

23. Ford Motor Company Data

Film - "1960 Falcon-Corvair Handling Comparison" and analysis by Harley Copp.

Intra Company Communication, Subject: Vehicle Response Characteristics of Test Vehicle GAP#1 dated November 8, 1968

APPENDIX I

Letter - Mr. Ralph Nader to Secretary of Transportation,

John A. Volpe, Dated September 4, 1970

September 4, 1970

Honorable John A. Volpe
Secretary of Transportation
Department of Transportation
Washington, D.C.

Dear Secretary Volpe:

For five years, nearly four of them under the auto safety law, the federal government has declined to become involved in the Corvair matter, notwithstanding the mass of evidence as to its hazards which has been externally collected and transmitted to the government. Now comes decisive evidence which reveals a labyrinthic and systemati intra-company collusion, involving high General Motors officials, to sequester and suppress company produced data and films proving the Corvair (1960-63 models) dangerously unstable. The Department of Transportation can no longer avoid confronting the GM-Corvair depravity and the daily carnage of innocent people injured or killed in these vehicles. Probably 600,000 of these Corvairs are still on the roads, driven increasingly by the young and the poor. Little can be done about past Corvair casualties, except as a spur to this dismaying refusal to act by the Department. Much can be done to prevent further crash-injuries and to understand additional, serious design defects affecting all Corvairs (1960-1969 models). But first it is necessary to understand the enormity of what General Motors officials have done to their customers (and passengers), the federal government, the courts and any American who trusted the testimony and assurances of the nation's largest industrial corporation. For in a word, GM manufactured and maintained a massive lie.

The company's credibility is not at stake here. Its credibility is shattered here. It can now be reliably asserted that GM proving ground tests and films back in 1962-63 conclusively proved the Corvair to be uniquely unstable with unprecedented rollover capability unlike any other American car. (Such characteristics were known by GM engineers when the Corvair was in its design stage back in the late Fifties. But the cautions of the more concerned were over-ridden by management which refused to adopt a much safer suspension system then available.) None of this information was ever offered or disclosed in response to court orders to produce such or any other requests from federal and state officials. On the contrary, in a consistent posture of suppression and prevarication, the company declared the Corvair as safe as any other car and asserted that any claims to its lack of safety were false.

Before the Senate Subcommittee on Executive Reorganization on March 22, 1966, James M. Roche, then President, General Motors Corp. read approvingly into the hearing record a statement by GM's Assistant General Counsel, Louis H. Bridenstine and a technical account by Mr. Frank Winchell, Chief Engineer for Research and Development of Chevrolet Motor Division, which will become principal exhibits of the falsehoods and distortion utilized by the company's spokesmen. Other GM officials, including Mr. Edward Cole, now the company president and long known as the "father of the Corvair" stated what GM's own tests said was <u>not</u> so about the vehicle's handling

Mr. Winchell's statement was replete with statements contradicted by GM's own, secret test data and films to which Mr. Winchell had access. For example, in words to be substantially repeated under oath before courts across the land, Mr. Winchell told the Michigan Senate Committee on Highways (February 21, 1966) that "The Corvair differs from other cars only in the arrangement of its components." and "Photographs of tire distortions with a car sliding sideways will show no significant difference between the proximity of the rim to the pavement of the Corvair and any other automobile." These statements were made by Mr. Winchell, now a special assistant to Mr. Cole, although they are contradicted by GM proving ground data and films which were completed between three and nearly four years earlier.

Despite repeated interrogatories and motions to produce in litigation involving crash victims, these data and films were secreted in a special category of "hot documents". For example, your Department should be interested in obtaining all the reports, memos and films growing out of PG Job No. 032127 beginning approximately April 11, 1962 and specifically including those portions dealing with Test run numbers 46-50, 58, 71, 75, 80, 86, 92, 99, 104; and arising out of PG Job No. 032307 beginning approximately Nov. 13, 1962 and specifically including those portions dealing with test run numbers 117, 120, 125, 126, 127-31, 134, 135-36. These films showing roll overs at speeds of 26 mph, 28 mph, and 30 mph would be enlightening repudiation of the shocking disparities articulated in courts and before legislative hearings by GM officials.

In the afore-mentioned Michigan testimony, Mr. Bridenstine, now GM's number two lawyer (after General Counsel Ross Malone) had the presumption of raising the Canons of Professional Ethics regarding the behavior of a Detroit attorney while he has been closely involved in keeping suppressed the test data and films by GM's own engineers showing the early Corvairs to be exceptionally facile roll over candidates. He maintained this stance against the regular crashes incident to Corvair rollovers week after week and against the court sanctioned interrogatories put to GM for this material. The canons may well be applied to Mr. Bridenstine's behavior.

Pertinent to this suppression of data damaging to the Corvair and the public statement and testimony that all was well with the vehicle is the company's tactics of attrition and judicial manipulation. In a major Corvair trial, GM's presentation misled the California judge, Bernard Jefferson, into writing a lengthy opinion concluding that the Corvair design was not unsafely designed. Having obtained such a decision, GM proceeded to transform it into a promotion and in an obscene gesture perhaps unheard of in corporate legal history, initiated its distribution to its Chevrolet dealers, state and federal legislators and other influential recipients including judges. Sizable settlements in Corvair litigation are associated with how close plaintiff's lawyer gets to the "hot documents" in his discovery motions. If GM's lawyers could not wear the plaintiff down by dilatory techniques, or flout the discovery orders with impunity, the company order from the top would be to 'purchase the case' with a settlement. Several settlements have exceeded the $100,000 level.

The afore-mentioned test data, together with other memoranda, letters, and corroborating personnel, show conclusively that:

GM officials knew they had a safety problem involving rollover and uncontrollability before the Corvair litigation started about 1963, and dabbled with a cheap prospective technical "fix" that flopped;

GM officials consciously refused to issue warnings or recall the vehicles;

GM officials launched a policy of falsely stating that the Corvair did not behave differently than any other American car and misled members of three branches of government at both state and federal levels;

GM officials demanded or condoned unethical behavior by its lawyers and engineers which had major repercussions on the frequency of Corvair crashes and casualties;

GM officials at the highest level were responsible for the preceding policies and spared no expense to perpetuate false defense strategies in the courts and suppression of GM's own tests adverse to the Corvair;

The gravity of the situation proceeds from the personal responsibility of the Chairman of the Board, Mr. Roche, and the President, Mr. Cole. For years, they have been on notice as to the problems of the Corvair; indeed Mr. Cole took a personal role in its design. For years, their legal duties to the public safety, not to mention their shareholders, should have required the disclosure of all company test data, regardless of its criticality, simply because American lives are involved. For years, they actively defended the Corvair and carefully avoided true disclosure. If in the annals of corporate irresponsibility this behavior is not grounds for resignation, then the monster of corporatism has overtaken the law. They should both resign.

The situation of Mr. Ross Malone, GM's General Counsel and former President of the American Bar Association is one of a need for prompt re-appraisal. Having joined the company nearly two years ago, he is the heir, rather than the shaper of most of the Corvair legal strategy. However, his duty is to require reversal of odious practices such as placing as many private, potential Corvair expert witnesses on a monthly retainer to monopolize this "market" around the country, or requiring attorney's with whom they settle to agree not to take anymore Corvair cases. More important, Mr. Malone must realize the grave impropriety of using his lawyers as a shield to hide lifesaving company test data and as a sword to defeat attempts to obtain such information under judicial procedures. One has only to read the newspapers' regular descriptions of sudden rollover Corvair crashes to realize that the proper legal advice to the corporate client is to promptly warn motorists and recall and fix the source of instability, not to camouflage the truth and mass the company's legal resources to overwhelm plaintiffs and tie up the courts. There is the added responsibility for corporate counsel to review all cases where interrogatories were not responded to truthfully and completely.

Hon. John A. Volpe   Sept. 4, 1970

A design defect that affects all Corvair models from 1960 to 1969 permits the seepage of combustion chamber gases into the passenger compartment along with the heated air. These gases include carbon monoxide. This is a very common complaint, as many letters to the National Highway Safety Bureau and General Motors show. GM has hundreds of these complaints. Privately, both present and former engineers for the company concede the defect, but the company policy officials continue to cover it up. In the opinion of specialists, this is a most serious hazard and has been known to overwhelm or sicken the driver. Further information known to GM is forthcoming for your consideration.

Clearly, the Department of Transportation has the authority to take action to protect motorists and passengers. It can require GM to send a notification of defect(s) to all Corvair owners. Although this year GM defeated a request by the National Highway Safety Bureau to obtain congressional authority to compel recalls, the requirement to notify usually involves a recall.

The Department should also request from Mr. Roche a complete report on the Corvair design and the company's secret test and film data and relevant memoranda. It must be emphasized that the materials and other associated facts will soon be released irrespective of whether or not he takes this opportunity to assert full corporate responsibility.

While to some, the cessation of Corvair production means the vehicle is history, the fact is that Corvairs are being driven every day hundreds of thousands of miles by hundreds of thousands of drivers under latent hazards that should be considered intolerable by your Department. Your counsel has exerted authority to require defect notification on pre-1966 vehicles in the Chevrolet truck wheel defect. This range of vehicle defects for the Corvair is much more serious in volume and severity. The preposterous pretext underlying National Highway Safety Bureau inaction regarding the Corvair--namely that there is civil litigation pending--borders on malfeasance in office. Civil litigation should never block enforcement of the law.

How corporations react to crises of their own making is increasingly tending toward cataclysmic potential for many citizens, as companies become larger and their technology more complexly fraught with hazards. General Motors, thanks to outside pressures and inquiries, no longer receives uncritical deference to its alleged knowhow that was its unearned increment from society. Too many facts have been unloosed among the public in recent years about the company's suppression of pollution control technology, its profligate expenditures on profitable trivia and wasteful corporate ego trips to the detriment of attention to safety, durability, ease of repair and efficiency in vehicle operation. At the present time, GM lobbyists and lawyers are all over Washington pursuing callous drives to seriously weaken the air pollution legislation and to delay the installation of the air bag, or similar system, in motor vehicles so thousands of lives could be saved in crashes. Their collusion with other auto companies in these efforts, particularly the pollution lobbying, makes a mockery out of the consent decree which they signed last year with the Antitrust Division of the Justice Department.

Further revelations about Corvair collusion and suppression, known and condoned at the highest GM levels, will open new public understandings of the extent to which this company will go to shield its defective vehicles even from its own self-indictment of them.

I look forward to your response.

Sincerely yours,

Ralph Nader

Ralph Nader

APPENDIX II

Letter - Mr. Ralph Nader to Secretary of Transportation,

John A. Volpe, Dated December 15, 1970

December 15, 1970

Honorable John Volpe
Secretary of Transportation
Washington, D.C. 20591

Dear Mr. Secretary:

Since my letter to you dated September 4, 1970, disclosures and evaluations are now available, such as PG Reports 17103 and 15699, which intensify the need and justification for prompt remedial action by the Department of Transportation concerning the hazards of the 1960-63 Corvair.

Since that date and the announcement shortly thereafter of the Department's decision to conduct a preliminary examination of Corvair instability in order to decide whether ornot to initiate a formal investigation, we have received corroborative information from dozens of people knowledgeable about the manufacture and safety performance of the Corvair. This information has been made available to the National Highway Safety Bureau to the extent possible without adversely affecting the jobs or standing of our sources, and we have also suggested other pertinent information which we believe should be obtained by the Bureau in order for them to objectively evaluate the problem. In toto, the information now available to the Department (presuming it has now been solicited and evaluated) reveals a great disparity between the actual rollover propensity of the Corvair and both the promises that GM has given its customers and the public, and the representations in the 1966 testimony of Mr. James Roche, then President of GM, before the United States Senate.

The emergence of all of this new evidence demonstrates the grave peril facing millions of people as long as the early Corvairs continue on the highway without a retrofit. However, the issue here is even larger. If the Department of Transportation fails to act in this case on the basis of such theories as the one that other vehicles, like the Volkswagen, also exhibit a propensity to rollover, its erroneous rationale would represent an insidious precedent in the safety arena. It would also represent a sanctioning of the most open, notorious and continual misrepresentations by General Motors.

As an aid to the interpretation of the mass of materials (much of its irrelevant) which has been submitted to the Bureau by GM, and in an effort to lay bare the nature of the engineering problem which creates the hazards in the Corvair, and to determine how easily the Corvair defect can be corrected at low cost, I asked three qualified engineers, who are experts in vehicle handling, a number of questions pertinent to Corvair instability/rollover. Their detailed answers are attached for review and analysis by the National Highway Safety Bureau.

In short, I asked these engineers, based on their knowledge, expertise and analysis of the two long-suppressed GM proving ground reports, PG 17103 and PG 15699, for their comments on the origin and nature of Corvair rollover and instability; the minimum types of evidence which an engineer would need, in the light of the findings of these two General Motors PG reports, to find that the 1960-63 Corvairs are <u>not</u> defective; whether degradation with age affects the Corvair problem; whether the vehicle should be recalled; and the feasibility and cost of fixing the vehicle.

In summary, they have concluded that the 1960-63 Corvair is inherently susceptible to rollover when it is traveling at low speeds on a flat surface, and therefore it should be recalled and repaired by General Motors.

Specifically, Mr. Fonda and Mr. Sergay stated:

"A conclusion that the 1960-63 Corvairs are not defective would require either a successful, credible and authoritative experimental contradiction of the two PG tests, or a credible demonstration that the criterion of no rollover on a flat road surface is overly conservative and unnecessary for assuring consumer safety.

"While we know of no such tests and obviously cannot state the results of tests not yet performed or published, we predict that further testing would only confirm the results of PG 15699 and PG 17103 and our interpretation thereof."

Since the engineers which General Motors has commissioned to discuss this matter with the Bureau officials are on partisan corporate missions, it would be advisable for the Bureau officials to contact the three engineers whose statements are attached for further exploration of their views.

I urge you to take note of the compelling estimate made by two of the engineers of the magnitude of the danger involved should the Department decide not to require defect notifications and should General Motors decide not to recall and retrofit these vehicles. Their estimates are based on the number of law suits filed against General Motors because of Corvair instability/rollover crashes. As far as I know this information is far more comprehensive than that available for any other model vehicle. In their opinion, very conservatively, the continuing danger inherent in this vehicle will, or will not, exact its fatal toll on at least 1,000 Americans plus a larger number of injuries, depending upon the Department's decision in this matter.

Please let me know if the Department has any disagreement or need for clarification of the attached statements.

While this letter is concerned with Corvair rollover and instability, I must again urge you to act immediately on the heater defect in all model years of the Corvair. The evidence of this defect leaves not the slightest doubt that millions of Corvair occupants are being exposed to injurious amounts of carbon monoxide and other combustion gases as they drive in winter conditions with heaters fully operating. Any further delay by the Department on this issue cannot be justified.

Sincerely,

Ralph Nader

Ralph Nader

STATEMENT BY RALPH SMITH*

In Response to Questions by Ralph Nader about the Implications of General Motors Proving Ground Tests of Corvair Rollover Propensities.

Introductory Statement

The following are my answers to questions posed by Ralph Nader, offered to him without any remuneration or promise thereof. They reflect my views regarding the extent to which the GM rollover test results found in Proving Ground (PG) reports numbered PG 17103 and PG 15699, which I have studied, apply to the production Corvair suspension pre-1964. My comments are directed at the implications of these specific test data on the overturn propensities of the Corvair when subjected to driving maneuvers which are similar to those experienced in the J-turn. I would like to emphasize that although rollover tendencies may be aggravated by directional instability, the two phenomenon are distinct motion properties.

I believe it to be probable that if the Corvair is directionally unstable in practical turning motions, then this will, in practice, create control difficulties which promote rollover situations.

A directionally unstable rear-engined vehicle, however, is not necessarily prone to rollover even though the rear suspension is of the swing axle type. An example of the latter might be various models of the Abarth automobile.

Question 1

If you were a design engineer and saw PG 17103 and PG 15699 results on a prototype vehicle being considered for production, would you recommend the car for production without any modifications?

Answer

No. Unequivocally. The PG tests have established the unquestionable tendency for the Corvair suspension described as "production" to promote rollover tendencies. When I evaluate the "production" vehicle within the framework of these findings, I find that it is entirely plausible that the hazards it entails to a general motoring public are beyond the bounds of normal risk. Consequently, the Corvair suspension used in these tests requires careful redesign, with the objective being to eliminate the rollover propensity in the J-turn tests, before it could be released for production. I could not ignore this potential problem, or devise rationalizations for approval of the design, without violating the engineering canons of ethical practice.

*Aeronautical Engineer, University of Cincinnati, Ohio. Degree candidate for PhD. in engineering at Princeton University (June, 1971). Work experience during the last six years: Fundamental research studies in the mechanics and control of automobiles; theory of pneumatic tire mechanics; aircraft handling qualities and human dynamics; written numerous papers and reports on car/driving; expert on man/machine systems. 210 E. Montgomery, Hatboro, Pa. 201-782-1630.

Question 2

How does the rollover and stability behavior of the 1960-63 Corvair, as revealed by PG 17103 and PG 15699, differ, if at all, from the behavior of other American cars and from foreign cars sold in the United States?

Answer

The ratio of tread width to center of gravity height is somewhat greater for the Corvair than found in contemporary, American conventional sedans. This measurement would indicate to me as an engineer that the Corvair would be more resistant to overturn than the conventional sedan. However, PG Report 15699 establishes that when subjected to very similar maneuvers, the 1961 Chevrolet never overturned while the early model Corvair (even with modifications to decrease rollover tendency) overturned in nine out of ten tests. This unusual difference must be attributed to Corvair suspension irregularities. The substantial changes in sensitivity of the Corvair to modifications in the suspension system as these PG tests demonstrate reinforces this statement.

Tne conviction that the Corvair's susceptibility to rollver is inherent in the production vehicle components and design is verified by the test data which show that Corvair rollover in the J-turn experiements can at least in one case be eliminated by proper suspension modifications. These tests were conducted by General Motors in mid-1962. To the best of my knowledge no significant production line changes on Corvair suspension were made until the fall of 1963.

The typical automobile in service on American roads today does not have the jacking prone swing axle rear suspension of the pre-1964 Corvair, and, in J turn experiments, would be expected to exhibit behavior similar to the stability of the 1961 Chevrolet sedan tested in these PG reports, i.e., no rollover.

The two PG tests do not concern foreign vehicles. However, I would not expect a vehicle with a properly designed swing axle rear suspension to demonstrate rollover tendency on smooth roads. Rollover proneness is not in my view necessarily a property of the swing axle suspension. The GM tests, and my experience, lead me to conclude that the rollover problem entails complex nonlinear interactions between tires, suspension and chassis. Thus, each vehicle regardless of design similarities, must be evaluated separately.

Question 3

What would you estimate in terms of cost to the manufacturer would be required to modify the rollover and stability behavior of the 1960-63 Corvair to make these Corvairs more comparable to other American cars?

Answer

The GM rollover tests in the two PG reports indicate that the Corvair's rollover problem could be reduced or eliminated at a cost to the manufacturer approximately equal to that of the costs of the heavy duty suspension package RPO 696 offered as an option for the 1962 model year Corvair. This includes: two new rear shock absorbers; new, stiffer, and shorter front and rear coil springs; two new rebound limiting straps; and a front stabilizer bar. A front-end alignment is also required with these modifications. As a "ballpark" figure I would estimate that the manufacturing costs for this package might be on the order of $10 to $15 (not counting alignment and installation costs or packaging and shipping at the dealer) broken down approximately as follows:

$2.00	Springs	$.50 each for 4
6.00	Rear Shocks	3.00 each for 2
2.00	Stabilizer bar and fittings	
1.00	Rebound-straps	$.50 each for 2

TOTAL $11.00

Retro-fitting of this package should offer the additional benefit of improved directional stability and handling. Retro-fitting could eliminate many of the driver control problems that arise in emergency situations and that lead to large, transient, lateral accelerations. Retro-fitting would also therefore have the attendant possibility for reduced rollover frequency with these cars.

Question 4

In light of the results of PG reports 17103 and 15699, what are the minimum types of evidence which should be evaluated by an engineer in order to substantiate a conclusion that the 1960-63 Corvair is not defective under the provisions of the National Traffic and Motor Vehicle Safety Act of 1966 (that is, that its rollover tendencies could not be defined as a defect in performance, construction, components or materials)?

Answer

The evidence I examined of Corvair rollover (contained in the PG test results) when considered within thecontext of the practical driving environment, is suggestive of a fundamental design deficiency. The J turn experiment can be accurately visualized as a simulation of what happens in an emergency situation caused by a driver's loss of full vehicle control because of vehicle instability at high lateral accelerations, or from intentional evasive action taken to avoid an impending accident. It is my belief that the Corvair is directionally unstable at higher lateral acceleration; thus, any rapid evasive maneuver during cornering conditions would be likely to produce a tail-first spin--that is, a spin where the rear wheels skid before the front wheels. The resulting effects of this tail spin are similar to those encountered in the J turn.

A thorough engineering evaluation designed to objectively examine questions raised here regarding Corvair rollover might seek statistical data which accurately establishes the comparative frequency with which Corvairs have been involved in single car accidents (vis-a-vis the "conventional" sedan) as an indication of existing stability and control difficulty. Such statistics should exclude post-1963 models and those equipped with suspension options, insofar as this is possible. I have never seen such data. Statistics representative of the vehicle population concerning the frequency of Corvair rollovers in both single and multi-car accidents might also be sought as an indication of the magnitude of the rollover problem.

My view, however, is that the J turn experiment is so representative of actual emergency situations encountered in highway driving that these data are generally valid. In my opinion it would be extremely difficult for GM to offer valid rationalizations to refute the rollover problem indicated by the two PG reports.

Question 5

Does degradation with age affect the Corvair rollover or stability problem because of degradation of parts or otherwise of the Corvair? Is there a known test to determine degradation of suspension geometry? Is this a fatigue problem?

Answer

Degradation of Corvair suspension components with age or use probably has significant effect on the car's rollover tendencies. Wear of shock absorbers in particular would increase the Corvair's susceptibility to rollover in rapid evasive maneuvers typical of driving emergencies. The GM rollover tests provide clear indication of this. Degradation of suspension bushings might worsen an already poor rollover performance by increasing suspension rebound limits. A conventional suspension system would not generally exhibit increased susceptibility to rollover due to such component wear.

There is no easy way to field test a vehicle for suspension degradation. This in my opinion provides a primary engineering criticism of the Corvair's design. That is, the car clearly has a rollover problem with nominal components which is probably worsened with suspension wear; yet, there is no practical expedient for evaluating the suspension performance.

Component fatigue is not the central problem for Corvair suspension design. However, the nature of the swing axle design is such that fatigue failure of one component can easily lead to catastrophic failure of the entire system. The same is not true for the conventional vehicle.

Question 6

Based on your engineering expertise and the newly revealed technical data in PG 17103 and 15599, do you believe that the 1960-63 Corvairs should now be recalled by the manufacturer and retrofitted to reduce rollover tendency?

Answer.

Yes.

STATEMENT BY ALBERT G. FONDA* AND DIMITRY SERGAY**

In Response to Questions From Ralph Nader about the Implications of General Motors Proving Ground Tests of Corvair Rollover Propensities

Introductory Statement

We have prepared this analysis in the public interest and therefore we have neither received nor expect to receive any compensation for this work. We have only received minor and partial reimbursement for our travel expenses.

We have studied the questions submitted to us by Mr. Ralph Nader and have reworded them slightly so as to completely and fully respond to the issues as we understand them. Our answers concern the extent to which the GM rollover test results found in Proving Ground (PG) reports numbered PG 17103 and PG 15699 apply to the early model Corvair production suspension and handling.

Question 1

If you were a design engineer and saw PG 17103 and PG 15699 test results on a prototype vehicle being considered for production, would you have recommended any of the reported test cars for production?

Answer

No. This opinion is offered with respect to only one criterion, that of rollover safety. The tests of PG 15699 and 17103, for purposes of our evaluation here, are directed only towards evaluation of rollover characteristics. Most of the Corvair vehicles tested were dangerously prone rollover. Of the safer vehicles, one had overhanging rear weights for test purposes only; the remaining two had modifications worthy of further consideration but were not ready for production decision.

Question 2

Are any of these test runs representative of the Corvairs which were actually produced and sold in 1960-63?

Answer

The vehicle of run 120 of PG 17103 appears in all respects as being a vehicle representative of 1963 production Corvairs. As far as we can

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*BME 1951 and MS 1954, Cornell University (with additional courses). Two years design research and teaching experience with agricultural machinery. Five years automotive dynamics and tire behavior research. Eleven years aircraft and space craft dynamics research. Eight years forensic engineering in automotive and mechanic product liability litigation (including consultant to automotive companies) plus highway crash barrier research. 481 Stacy Drive, King of Prussia, Pennsylvania. Area code 215-265-2453.

**BSME 1947, Wayne State University. Eleven years experience in products, plant, and manufacturing engineering in the automotive industry. Four years product engineer on automatic cannon. Eight years systems project engineer in space craft mission and vehicle design. Five years forensic engineering experience in automotive and machine tool product liability litigation. 427 Dorothy Drive, King of Prussia, Penn. 215-265-4452.

determine any differences between this test vehicle and the 1963 production Corvair were minor and would not have influenced test results. The same comments apply to the 1960-62 Corvair except that these earlier models did not have the rebound travel limited to 7 and one half degrees, but permitted 11° of rebound travel.

Question 3

Based on these test results, would you have recommended the 1963 Corvair for production?

Answer

No. The vehicle, to meet what we believe is a reasonable standard of safety, must slide instead of rollingover on a flat road surface, with any combination of driver actions. The vehicle of run 120, representative of the 1963 Corvair, rolled over quite readily. In this test run a single hard right turn at 28 mph "caused the car to roll over onto its roof."

Question 4

Based on these test results would you have recommended the 1960-62 Corvair for production?

Answer

No. The 1960-62 Corvair probably was even more prone to rollover than the 1963, and was equally unacceptable.

Question 5

Would you have recommended any of the modifications already considered in these tests, or combinations thereof, for further testing before production?

Answer

Yes. Based on the tests as far as they go, we would have recommended as a minimum, the incorporation of rear shock absorbers incorporating rebound limiting and hydraulic cutoff as used in test run 73 of PG 15699. We would have recommended thorough preproduction testing of additional modifications, singly and in combination, baring in mind the objective of maximizing safety and consistent vehicle behavior in owner driving situations. Such testing modifications would have included:

a) Transverse leaf spring

b) Lowered rear axle pivot points (or other factors accounting for the improved rollover behavior with the overhung rear weights occurring in runs 127 through 131 of PG 17103).

c) Front anti-roll bar.

We also believe that a combination of front roll bar and rebound limiting known as RPO 696 (offered by GM as an extra cost option) should have been included in the testing program. RPO 696 was not included in the tests reported in the two PG reports but may have been tested at another time by General Motors.

Question 6

Do the rollover tests in PG 17103 and 15699 show that the Corvair differs from the behavior of other American cars with rigid rear axle?

Answer

The rigid rear axle 1961 full size four-door Chevrolet sedan was tested for 10 runs with no rollovers occurring even though every effort was claimed to have been made to induce rollover while driving on a flat paved surface. This was done by turning the vehicle hard right, this being a J test. Sometimes this simple J turn was preceded by successive swerves to the left or right, this being a modified J turn test. Our considered opinion is that the rigid axle American car will skid rather than rollover when subjected to the J turn or to the modified J turn test . This is significant because these J turns subject the vehicle to one of the most severe maneuvers the driver can devise in order to determine which would occur: spin out or rollover. The results of this test enables the application of a simple yes or no criterion of rollover stability. The speed at which rollover occurs is of little significance. The crucial question is whether rollover occurs at all. In our opinion, it is far better to skid than to rollover under any foreseeable emergency circumstances.

Question 7

How does this behavior affect the safety of the driver or occupants?

Answer

Obviously, if a vehicle experiences a few horizontal turns as in a spin-out, this would cause no more trauma than an amusement park ride--providing there is room for a spin out--while a rollover on the other hand must necessarily cause severe damage to the vehicle and a high probability of severe injury to the occupants.

Question 8

Is there a difference between the 1960-63 Corvair and foreign vehicles in terms of rollover behavior?

Answer

These PG reports do not include tests of any foreign vehicles. Tests of rollover behavior are hazardous and expensive . We have not performed such tests nor are they reliably reported in the literature. To our knowledge GM has not made public any such tests it might have conducted. Therefore, no opinion is possible on this question.

Question 9

What is the estimate of the cost, to the manufacturer of modifying the rollover behavior of a 1960-1963 Corvair to make that vehicle perform comparably to other American cars with rigid rear axles, that is to make these vehicles skid or spin-out rather than roll over?

Answer

The minimum cost estimate is based on the answer to question no. 5 above, where we recommended incorporation of hydraulic cutoff rear shock absorbers in the proposed production vehicle. We estimate that the original cost to install these shocks as production components would have been less than $3.00 per car. The present day cost to retrofit the remaining cars with the same minimum fix is estimated to be approximately $20.00 today. The cost of testing the modified package which we recommended for verification of its suitability would be small when distributed over 600,000 cars. The limited test data contained in the two PG reports indicate that this would be a successful modification.

Question 10

In light of the results of PG reports 17103 and 15699, what are the minimum types of evidence which should be evaluated by an engineer in order to substantiate a conclusion that the 1960-63 Corvair is not defective under the provisions of the National Traffic and Motor Vehicle Safety Act of 1966 (that is, that its rollover tendencies could not be defined as a vehicle or equipment defect in performance, construction, components or materials)?

Answer

A conclusion that the 1960-63 Corvairs are not defective would require either a successful, credible and authoritative experimental contradiction of the two PG tests, or a credible demonstration that the criterion of no rollover on a flat road surface is overly conservative and unnecessary for assuring consumer safety.

While we know of no such tests and obviously cannot state the results of tests not yet performed or published, we predict that further testing would only confirm the results of PG 15699 and PG 17103 and our interpretation thereof.

An accepted principle of good product design is "fail safe." That is, if a failure does occur, a back up mode shall be available to the product user. Thus, if a car rolls over nothing except catastrophic destruction of the vehicle and probably death or serious injury to the occupants can occur. But if the car spins out of an emergency situation instead of rolling over, this "fail safe" performance characteristic at least offers the occupant the chance of no injury at all if there is room, as there often is on todays highways, for the spin to run its course. Furthermore, the very fact that the car's wheels are still on the pavement offers the driver at least the opportunity for him to attempt to regain control of the car if he can by pointing the front wheels in the skid direction. If successful, and again this depends on available area, then the car may be driven away from the near accident with ashen gray occupants the only result of the incident.

On the other hand, after the wheels leave the surface in the rollover, the driver can never regain control of his vehicle. That opportunity is denied him perhaps forever.

The chance for a safe spin out, the opportunity to regain control, and the reduction of injury if the upright spinning vehicle strikes an obstacle after dissipating some of its speed, are all provided in a vehicle that spins instead of rolls in an applicable emergency situation. Successful resistance to rollover on flat pavement is well within the state of the art for passenger cars, and has been for the last 20 years. Therefore, the criterion of spin out instead of rollover is valid and in its application to the Corvair has been too long delayed. In our opinion there is no convincing argument to the contrary.

Question 11

Does degradation of individual parts with age affect the rollover tendency of the Corvair?

Answer

Several types of degradation might occur. Tires and suspension bushings may deteriorate but their effects on rollover tendencies are unknown. The effect, if any, of shock absorber deterioration will be detrimental. Coil spring sag will reduce pivot point height and should therefore reduce the rollover tendency. In summary, we believe that the degradation of the various suspension components would probably have little net effect on the rollover characteristics of the Corvair.

Question 12

Based on your engineering expertise and the newly revealed technical data in PG 17103 and PG 15699, do you believed that the 1960-63 Corvairs should be recalled by the manufacturer and retrofitted to reduce rollover tendency?

Answer

Yes. The projected cost of this recall campaign is far less than the total projected future earnings of drivers and passengers otherwise fated to be killed or permanently incapacitated by rollover accidents as the current fleet of 1960-63 Corvairs runs out its useful life. This statement is based on accepted industry car use and life statistics. The fleet of 600,000 Corvairs in use today will number in the range of about 100,000 cars in 14 years. This level of usage will result in nearly 3,700,000 car years of driving from now until then. From this we may forecast the number of these cars which will cease their useful lives by a rollover accident resulting in death or loss of earning capacity.

To date a total of approximately 300 law suits have been filed against 1960-64 Corvairs where injured parties have alleged a defect in design or construction which led to an unnecessary loss of control or rollover or both. Of these, conservatively one half involved rollover. We would safely estimate that an absolute minimum of 1350 additional rollover accidents of equal severity have occurred since September 1959 involving this vehicle but were not suitable for court action because of such factors as contributory negligence, full coverage of losses by other negligent parties, lack of witnesses or other barriers or burdens. Our estimate of the total of rollover accidents is at least 1500. From established data we can show that these 1500 serious rollovers occurred in the course of 5,100,000 car years of use by the original 1,283,000 1960-63 and even including 196,000 1964 Corvairs, which is a rate of one serious rollover per 3150 car years (this is one accident per year among 3150 cars). Therefore, in the 3,700,000 car years remaining to the Corvair of this 1960-64 vintage now on the road, we would predict at least an additional 1087 rollovers resulting in serious injury or fatality.

If each of these projected future accidents causes, on the average, the loss to only one wage earner of half of this lifetime earnings and excluding any estimate as to property damage and medical expenses, the loss would be $160,000 for each of 1087 accidents, or a very minimal conservative total of $175 million. In contrast, the cost of the suggested recall and retrofit program is only $12 million at $20.00 per car.

Thus, the campaign has a benefit/cost ratio of about 14 to one, based on lost earning power alone, not to mention any allowance for medical expenses, property damage or human suffering by innocent parties. The accidents which will occur without the recall campaign are as certain as the turning of the earth.

APPENDIX III

Letter - Mr. Ralph Nader to Secretary of Transportation,

John A. Volpe, Dated February 23, 1971

February 23, 1971

Honorable John A. Volpe
Secretary of Transportation
Washington, D.C. 20591

Dear Secretary Volpe:

It has now been over five months since I sent you material concerning the relative instability of the 1960-63 Corvair automobile. Since the essence of my complaint was that the Corvair responds differently than all other American vehicles, and differently from rear engine vehicles such as the Volkswagen, I believe that the public is entitled to some substantial and quantifiable, if not precise, answers to these charges.

It is my belief that the National Highway Traffic Safety Administration has not yet conducted any tests of the Corvair which would reveal, as the suppressed General Motors Proving Ground reports reveal, the dangerously unique and quantitatively different response of the Corvair under transient or dynamic conditions compared to other vehicles. Without such test results (which are carefully avoided by the recent University of Michigan study [FH-11-7297] funded by the Department of Transportation) the Corvair's unique response has not been measured by the Department in comparison to other cars in terms of the lateral acceleration forces.

Of necessity, the issue of instability is one that must be answered by something other than a rationale which relies on the staged experimental tests by the party charged with manufacturing the defect. The government has accepted the principle that its own independent tests are necessary for ascertaining violations of food and drug regulations. Certainly the same principle applies here.

I would urge you strongly to act as quickly as possible to conduct the tests which are necessary to provide meaningful results which can serve the public. We know from the University of Michigan study that very sophisticated instrumentation has already been developed to test vehicle handling; moreover, other instrumentation such as for lateral acceleration is commonplace. In addition, so that there may be no burden, we will make available without charge a donated 1961 Corvair for your use in this regard.

The shocking fact that you are being asked by the NHTSA to issue a formal report stating that the 1960-63 Corvair has not been shown to be defective on the basis not of objective government tests but of armchair evaluation of General Motors public relations presentations and edited proving ground tests is another example in the long list of the Administration's special treatment of General Motors.

The plain fact is that this so-called inquiry into the Corvair has been carried out under NHTSA practices and procedures which are clearly incomplete and as such are incompetent by any engineering standard. Such incompetence is reflected in the absence of any vehicle handling standards over four years after the passage of the Auto Safety Law. No such standards have even been proposed, thus insuring the status quo well into the 1974-75 period.

Moreover, statements by three handling engineers critical of the Corvair were submitted to you with the subsequent recommendation that the Safety Administration cross-examine these experts. This was not done, nor was there a substantive response to their received statements.

You can perceive how these gaps in NHTSA competence and information are grossly irresponsible and unnecessary. Moreover, when the NHTSA then decides that no DOT testing is necessary to its evaluation of the Corvair, this amounts to engineering malpractice. It is time that the same standar of malpractice be applied to professionals inside government as can be done outside government.

Who in government is going to stand up for the victim of General Motor's negligence and obstinancy instead of taking the easy way of inaction or abdication? The struggle to bring accountability to General Motors over its design and handling of the Corvair cannot be treated so contemptuously that no Department tests are to be conducted. Must the courts be availed of to require adherence to the minimal levels of investigating quality for such an important decision? Must the U.S. Congress be asked to investigate this engineering arrogance?

I trust that before you make this decision, with its ramifications extending well beyond the instant subject matter as far as corporate deterrence is concerned, you will permit me an opportunity to meet with you. Thank you.

Sincerely,

Ralph Nader

Ralph Nader

APPENDIX IV

Letter - Mr. Gary B. Sellers, a Ralph Nader Associate, to Mr. Rodolfo A. Diaz, Acting Associate Director, Motor Vehicle Programs, National Highway Traffic Safety Administration, Dated March 17, 1971

Mr. Rodolfo A. Diaz
Acting Associate Director
Motor Vehicle Programs
National Highway Traffic Safety Administration
Department of Transportation
Washington, D.C. 20590

17 March 1971

Dear Mr. Diaz:

This is in response to Secretary Volpe's agreement of March 9, 1971 with Ralph Nader, involving the National Highway Traffic Safety Administration's proposed testing of the Corvair. Mr. Nader has asked me to follow up on this matter and to state that he shares Secretary Volpe's and Mr. Toms' belief that fair and objective tests of the performance of the 1960-63 Corvair can be achieved by your Administration and that such tests should reveal whether the Corvair has unique response characteristics in comparison to other American vehicles. To that end, and in the interest of expeditious action, we request that NHTSA adopt a sequence of procedures which assures that your Administration achieves its goals within the limited budget available. In general, we suggest that the testing on these vehicles begin under conditions where the critical variables (such as high coefficient of friction, equal tire pressures, heavy weight load, etc.) are at the most severe levels--those most likely to reveal the defects alleged--or the differentials in the margin of safety present. If under these conditions, the Corvair does not respond in a dangerous fashion, at variance with the public's expectation of response, then the public can be content that the defects revealed in the GM proving ground reports are anomolous or mistaken. If, however, the Corvair performs unpredictably and dangerously in comparison to other American cars of similar size, then you would be justified in finding it defective.

We stress American cars in the above sentence because this is the public standard of expectation which GM set for itself and the public in its public testimony under oath before the U.S. Senate, where GM said that 0.6g was the upper limit of control for all American passenger cars of that date (see page 1561 of Senate Hearings). The issue is to determine whether the vehicle is defective--not, as GM would prefer, to determine all the conditions under which it is not defective. Thus, testing which begins with all the variables at the least severe levels will be wasteful of the taxpayers' money and may also make a complete series testing unlikely for lack of funds. Starting with least severe tests would allow GM to assert after each that the vehicle is not representative of a production model.

Our more specific suggestions are:

1. That comparable vehicles tested include the 1960-63 Ford Falcon, the 1960-63 Plymouth Valiant, and the 1960-63 Corvair with the front stabilizer bar, and a 1965 or later model Corvair, and that each, as nearly as possible, have production suspension specifications and adequately operating components.

2. That the tests themselves begin with, and indeed confine themselves to, dynamic or transient maneuvers, such as the J-turn, or the hard hairpin turn, and S-turns, and other drastic accident avoidance maneuvers with braking in turns, and in movements from gravel to pavement. Since the GM data reveal, and our earlier presentation stresses, that most static tests (such as taking the Corvair at increased speeds around a fixed radius circle) document that the danger from an oversteering vehicle is that of going out of control end-for-end rather than straight ahead, we will accept these tests as not necessary to repeat.

3. That the above tests be conducted on the Corvair and other vehicles with equal tire pressures (26 lbs.) on all four tires. This is necessary since GM has stressed under oath that such variations from original specifications will make no significant difference, and indeed, that "even reversing the [prescribed] tire pressure differential is unrecognizable at 30-40 mph in a Corvair." (Senate Hearings, page 1561.) In any event, the original tire pressure recommendation for the Corvair, buried in the 1960-63 Owner's Guide, and merely stating the most minimal of information

in relation to front and rear pressure difference, has been eclipsed by repeated GM testimony as to how unimportant this was, and by the practice and expectation of today's owners or service station attendants on models of this early vintage.

4. That the skid number (effective coefficient of friction) of the surface used should be at the highest range found on the modern highway under dry conditions--since this surface will reveal the complete transitional response of the car most accurately.

5. That the vehicle also be tested with the maximum recommended load (such as the weight of four to six passengers), as might often be experienced on a Sunday drive. (Mrs. Collins had six people in her vehicle and luggage on the roof when her Corvair went out of control.)

6. That the car /be suitably equipped to measure acceleration and other relevant vehicle responses and that outriggers be provided to keep the vehicle from overturning.

As the above discussion indicates, the delineation of objective tests is certainly not a simple matter; however, since the above comments are not comprehensive, we believe that on-site observers offered by parties to this matter would greatly simplify and expedite the testing, resolve future technical interpretative questions (if asked to do so by NHTSA) and obviate unnecessary controversy at its conclusion. To that end, we will provide the services of Mr. Albert Fonda and Mr. Edward Heitzman, under any restrictions on their activities you deem appropriate, and we hope that you will allow GM also to have observers under similar conditions--since you have done so in the Kelsey Hayes wheel case, where a GM product was tested for another defect.

We believe the presence of observers is even more essential here, and would not constitute a burdensome precedent of any sort for NHTSA, because: (1) no objective standards for dynamic lateral stability testing have yet been set forth by the NHTSA; (2) because a passive observer allows total control of all procedures to be retained by you; (3) because the existence and revelation of the PG Reports in this case has placed the burden of proof on GM to rebut the results of their tests; and (4) certainly because the large cost of testing makes it impossible for the public to duplicate your essential work.

We also request that all vehicles be supervised at all times, 24 hours per day, and that maintenance personnel provide you with affidavits to that effect at the conclusion of the testing.

We would like the opportunity to comment on your final test procedures before they are submitted to the contractor.

Sincerely,

Gary B. Sellers

cc: Ralph Nader

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Mr. Albert Fonda
King of Prussia, Pennsylvania

GBS:lsd

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