A three-man advisory panel was engaged by the National Highway Traffic Safety Administration to independently and objectively evaluate all of the information presented to them concerning the handling and stability performance of the 1960-1963 Corvair and to give their candid approach taken by the Government in its evaluation of this performance.

This report contains the results of several meetings between the panel and the Government. The significant handling and stability characteristics of the 1960-1963 are discussed by the panel. The panel completed a report on January 25, 1972, with conclusions and recommendations. Additional information that was disclosed at a later date was evaluated by the panel and an addendum to the report was prepared on June 6, 1972. The panel concluded that "The research performed for NHTSA relating to the handling and stability of the Corvair was adequate in scope and depth, basically sound in design, and professional in its performance."
PANEL EVALUATION OF
NHTSA APPROACH TO THE
1960-1963 CORVAIR HANDLING AND STABILITY
SUBMITTED BY
GENERAL TESTING LABORATORIES, INC.
CONTRACT NO. NHTSA-2-2306

JANUARY 25, 1972

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Date: February 9, 1972

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Date: February 9, 1972

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Date: 2/18/72
The opinions, recommendations and conclusions expressed herein are solely those of the panel members and are not intended to reflect the opinions of the writer or General Testing Laboratories in any way.
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I. INTRODUCTION

On 15 September 1971 Mr. Edwin L. Resler, Jr. from Cornell University; Mr. Paul H. Wright from Georgia Institute of Technology, and Mr. Ray W. Caldwell of the Autodynamics Corporation were engaged by the National Highway Traffic Safety Administration of the Department of Transportation to participate as members of a three-man advisory panel to evaluate the NHTSA study of the 1960-1963 Corvair handling and stability characteristics. General Testing Laboratories was requested to report the findings of the panel and to assist in the coordination of the meetings and activities of the panel with the NHTSA.

The tasks of the panel included the following:

1. Review all correspondence between Ralph Nader and his associates and officials of the D.O.T.

2. Review and examine the General Motors Corporation documents and films supplied to the D.O.T.

3. Review an NHTSA Analysis of Corvair handling and stability.

4. Review and examine the NHTSA films and a report of tests conducted at Texas A&M University.

5. Review related literature on vehicle handling and stability.

6. Arrive at joint panel findings, conclusions and recommendations about past and future NHTSA programs for evaluation of the 1960-1963 Corvair handling and stability.

The initial meeting of the panel was held at D.O.T. on September 15, 1971 with the following persons present:

J. H. Clark, Jr. - D.O.T.
M. J. Lilley - D.O.T.
E. Wittich - D.O.T.
E. French - D.O.T.
P. H. Wright - Georgia Institute of Technology
E. L. Resler, Jr. - Cornell University
R. W. Caldwell - Autodynamics Corporation
H. E. Holt - General Testing Laboratories - Recorder
The panel members were informed in the opening remarks by Joe Clark that they were not being asked to endorse the Corvair, the position of the General Motors Corporation, the charges by Ralph Nader, or the Department of Transportation. Rather, they were requested to evaluate all of the information presented to them and give their candid opinions and views on the approach taken by the D.O.T. Two additional panel meetings were subsequently held, one at General Testing Laboratories on 27 September 1971, and at D.O.T. on 15 December 1971.

On 12 April 1972 the panel was reconvened at D.O.T. at the request of NHTSA to evaluate additional information concerning the Corvair understeer-oversteer transition and its possible consequences in the 1960-1963 Corvair. On 2 and 3 June 1972 another panel meeting was called to review and finalize the report. This report includes an addendum at the end in which the transition is defined and its implications to the Corvair are discussed.

II. SUMMARY

In the mid-1960's Ralph Nader charged that the 1960-through-1963 Chevrolet Corvairs handled in an unstable manner and had a propensity for overturning. He further asserted that this condition was caused by a design defect which constituted a safety hazard and that it should be corrected by General Motors Corporation. He has maintained this position to the present time.

The panel, in evaluating the information presented to it, considered whether these charges were valid by comparison of the characteristics of vehicles available to the public during the period from 1960 to 1963. From this perspective, it is the opinion of the panel that the Corvair quantitatively meets or exceeds the standards set by contemporary cars in stability tests, cornering tests and roll-over tests. For this reason, the panel concluded that the 1960-1963 Corvair does not have a safety defect and is not more unstable or more likely to roll over than contemporary automobiles.

Information furnished to D.O.T. by General Motors including movies, written reports and a summary of the handling characteristics of the 1960-through-1963 Corvair is accurate in the opinion of the panel. However, while General Motors describes the change from an initial understeer condition to final oversteer in the controllable range of the vehicle as being a gentle transition, its effects could cause some drivers to lose control of their vehicles under certain circumstances. This transition does appear gentle when depicted graphically with the "stability margin" plotted versus lateral acceleration. This curve is, however, independent of time and therefore the transition from understeer to oversteer through the neutral steer

*The "stability margin" is defined as the distance between the vehicle center of gravity and the instantaneous neutral steer center, measured in percent of wheelbase.
condition, which occurs at approximately 0.4 g lateral acceleration, does not infer in any way, the time available to the driver to adjust to the change in steering characteristics. The film data indicates, however, that the Corvair can change from understeer to oversteer in a very short period of time when the car is involved in a turning situation under emergency conditions. This characteristic is the only significant feature of the Corvair which could account for the Corvair handling stability controversy.

The D.O.T. evaluated the same information that was presented to the panel. Although they summarily concluded that the 1960-through-1963 Corvair did compare favorably with other contemporary cars from the points of view of handling stability, cornering forces and forces necessary to roll it over, they then conducted a series of their own tests which served to corroborate the above review of information and test data. D.O.T. therefore concluded that the 1960-through-1963 Corvair did not have a safety defect. Although the importance of the rapid transition from understeer to oversteer in the controllable range was recognized, it was not emphasized and it could not be investigated in terms of driver response since the tests conducted by D.O.T. were of the input-response type.

Also, although a thorough attempt was made by D.O.T. to collect Corvair accident data, an evaluation of the Corvair accident frequency was limited because of the small amount of actual accident information which exists.

The panel, after evaluating all of the above information, decided that: (1) the handling characteristics of the 1960-through-1963 Corvair had been appropriately and sufficiently defined; (2) not enough data is available in the area of actual frequency of accidents to allow a valid determination to be made as to whether the Corvair has been involved in more accidents than contemporary cars; and (3) the only real issue appeared to be whether or not the average driver can cope with a rapid change from understeer to oversteer during a period of stress.

Although the Corvair, with its rear weight bias and swing axle rear suspension is somewhat different from contemporary American automobiles, it is similar in both design and handling to some contemporary foreign cars. The lack of accident statistics makes it impossible to determine whether or not there is a real accident cause and effect relationship between the handling characteristics of the Corvair and the actual driving situation. Unfortunately, and this is true of all other vehicles as well, there are no test methods presently available which would allow a complete and quantitative evaluation to be made of Corvair driver interface with vehicle handling characteristics such as a rapid understeer-oversteer transition.
The panel therefore makes the following recommendations: (1) that a notice be issued by the D.O.T. stating that there is a handling characteristic peculiar to the Corvair which is the possible occurrence of a rapid transition from understeer to oversteer within the range of driver controllability. Owners and drivers of 1960-through-1963 Corvairs should be cautioned to familiarize themselves with this particular characteristic so that they will not be caught unaware, (2) that the recommended tire pressures should be strictly adhered to because changes in the recommended pressures can result in the understeer-oversteer transition to occur at even lower lateral accelerations, (3) that the D.O.T. should perform the research necessary to develop minimum handling requirements for all cars so any unusual handling characteristic will not occur in a manner that poses possible safety hazards to the driver. Until such time, vehicle manufacturers whose vehicles possess unusual handling characteristics, should inform owners of them and their consequences as accurately as possible.

The panel also feels that the tests to date have sufficiently described the characteristics of the Corvair handling and stability and further testing along these lines is unnecessary. The 1960-through-1963 Corvair is now a minimum of eight years old and retrofitting would in many cases be ineffective in view of the present condition of vehicles of that vintage. In light of the vast amount of information gathered and the sound manner in which D.O.T. has performed their research on the Corvair, the panel further recommends that D.O.T. should now direct their efforts toward other problems which have greater importance to present traffic safety.

III. COMMENTS ON ASSERTIONS BY RALPH NADER, et al

In the opinion of the panel, Ralph Nader, et al sensed there was a difference between the Corvair and contemporary American cars of the 1960-through-1963 period. He expressed his feelings in terms that the Corvair handled in an unstable manner and also had a propensity to overturn. This has been the basis for his assertions that the Corvair design constitutes a safety defect.

The tests and investigations by General Motors Corporation, by the D.O.T., and finally the evaluation of this information by the panel indicate that there is no evidence to support the contention that the Corvair will roll over more easily than contemporary vehicles. Films of tests designed to determine overturning susceptibility of the Corvair show that it is possible to turn the car over on a flat surface if energy is stored in the suspension and then released, as in a "modified J turn." But attempted roll-overs were very difficult to accomplish. In order to roll the Corvair over, a lateral force equal to .95 of its weight must be supplied at the center of gravity. This compares with a 1.0 g side force.
usually necessary to accomplish roll-over for other cars and is in accord with accepted practice. Significantly, in the Texas A&M input response tests, there were no roll-overs (outrigger contacts) for the Corvair in any of the tests, but the 1962 Volkswagen showed a marked tendency to overturn in the reverse steer and drastic steer-dramatic brake tests. The D.O.T. input response tests all verify the results of driver controlled tests conducted by General Motors.

The limit of control for the 1960-through-1963 Corvair is a lateral acceleration of about 0.6 g, a value equal to or greater than maximum lateral accelerations for other vehicles of comparable weight and size manufactured during that period. Also, when operated below the steering transition, the Corvair handles generally better than contemporary cars.

What is different about the 1960-through-1963 Corvair is the characteristic transition from understeer to oversteer which occurs at a lateral acceleration of 0.4 g to 0.5 g. Occurring as it does at lateral accelerations seldom experienced by the average driver, this transition presents the driver with a change in handling control characteristics which may be difficult to cope with when it occurs quickly. It has been determined that the vast majority of drivers will not knowingly and voluntarily operate their car so as to experience lateral accelerations above about 0.3 g, and this level is generally tolerated only at speeds less than twenty miles per hour. It would appear therefore that the average and prudent driver would encounter the rapid understeer-oversteer transition in the Corvair only in emergency situations in which the vehicle is already in imminent danger of going out of control. In this case, a driver facing the unexpected transition could make the wrong steering response and contribute to the occurrence of a crash or worsen its consequences. One can only decide whether or not the transition is a gradual one when the time frame within which a transition occurs is known. In the General Motors films it was observed that the lateral acceleration might go from 0.3 g to 0.6 g in a quarter to a half second depending on the attitude and speed of the vehicle. While the overall effects of this phenomenon cannot be determined with certainty from the data presented, it appears to the panel that it could be detrimental to traffic safety. However, in the opinion of the panel, it is not a matter of faulty design but rather, it is a characteristic of car handling which should be discussed in broader terms, namely, whether or not future cars should be designed so as to have handling transitions which occur low in the controllable range.

The available data do not allow a complete evaluation of the Corvair with various tire pressures, but routine estimates indicate that the control characteristics of the Corvair can be altered significantly if the recommended differential tire pressure is not maintained. Changes in tire
pressure differential can cause the oversteer characteristics to be changed with a possible consequence being that the transition from understeer to oversteer will be shifted to a lateral acceleration value of less than 0.4 g. However, this differential in inflation pressures is not unusual even in current automobiles such as some station wagons and other foreign automobiles.

IV. COMMENTS ON GENERAL MOTORS DATA

Although General Motors' initial steps relative to early charges made by Ralph Nader appeared to be somewhat abortive, they subsequently furnished to D.O.T. upon request a large amount of very candid information which made it possible to evaluate the actual characteristics of the 1960-through-1963 Corvair. The movies which depicted the Corvair entering various radius circles at various speeds, and the movies of the car on the test track plus the movies of contemporary cars under the same maneuvers allowed both D.O.T. and the panel to accurately get a quantitative depiction of the 1960-through-1963 Corvair. The General Motors summary of the characteristics of the Corvair seems complete and accurate. Although General Motors describes the understeer-oversteer transition as a gradual, gentle change, and the conclusions drawn are somewhat biased in their favor, the information appears to be factual and it was very helpful to both D.O.T. and the panel.

V. COMMENTS ON THE D.O.T. CORVAIR EVALUATION

The D.O.T. has made an honest and effective evaluation of the 1960-through-1963 Corvair. The report of 31 December 1970, which was not issued, is clear, concise, appropriately depicts the Corvair characteristics and, with one exception, should be sufficient to evaluate any charges concerning the Corvair design. That exception is again the discussion of the importance of the understeer-oversteer transition. Although the possibility of its rapid occurrence is discussed, it occurs at 0.4 g to 0.5 g lateral acceleration which is within the range of controllability and this is the reason for its significance.

The research performed for NHTSA relating to handling and stability of the Corvair was adequate in scope and depth, basically sound in design, and professional in its performance.
VI. RECOMMENDATIONS BY THE PANEL

In determining the advisability of further research, it is important to view the 1960-through-1963 Corvair problem and the overall accident problem in perspective. A total of 1,124,076 were manufactured during this period, of which approximately one-third are estimated to still be in use. This constitutes less than one-half of one percent of the registered vehicles in the United States. With the current magnitude and severity of other aspects of the traffic safety problem, no further testing relating specifically to the handling characteristics of the 1960-through-1963 Corvair is recommended.

The panel recommends that owners of 1960-through-1963 Corvairs be advised that these vehicles may exhibit unusual handling characteristics under conditions of hard cornering. They should be instructed that these handling characteristics do not arise when the vehicle is operated normally and prudently, but may be encountered in emergency situations such as exceeding posted safe speed limits for highway curves and expressway exit ramps. Owners should be further cautioned that these handling characteristics may be affected by failure to maintain the proper tire pressures as specified by the vehicle owner's manual.

Further research to provide a better understanding of vehicle handling characteristics and their interaction with the driver is strongly recommended. Efforts by D.O.T. to develop a set of test procedures to determine minimum acceptable safety vehicle handling performance levels should be continued. Contemporary design concepts, provided they exceed the minimum acceptable limits of safety, should not be criticized or suppressed only for being "different" from normal accepted current practice because any attempt to do so will result in the freezing of design requirements and will stifle creativity. Rather, manufacturers should be encouraged to be innovative in their approach to the solutions of current requirements so that the state-of-the-art will continue to be improved.

It is also recommended that a nationwide data collection network be developed to provide up-to-date statistically valid data relating to make, model and year of manufacture of vehicles involved in crashes. Such a system would provide early discovery of vehicle-related safety deficiencies and would point the way for in-depth vehicular safety studies, such as this one, to ascertain the need for vehicle recall campaigns.
REFERENCES
LETTERS

1. September 4, 1970 - Letter to Secretary Volpe, DOT, from Ralph Nader

2. September 11, 1970 - DOT News Release including:
   September 9, 1970 - Letter to Thomas A. Murphy, General Motors, from Rudolpho Diaz, DOT
   Undated - Letter to Ralph Nader from Secretary Volpe, DOT


5. December 15, 1970 - Letter to Secretary Volpe, DOT, from Ralph Nader

6. February 23, 1971 - Letter to Secretary Volpe, DOT, from Ralph Nader


DOT REPORTS


8. September 10, 1971 - "Input Response Tests of Selected Small Passenger Cars" by Texas A&M Research Foundation in cooperation with NHTSA
GM REPORTS

1. April, 1961 - "Corvair Steering" by Maurice Olley, GM Corporation


4. April, 1971 - Revisions to "Vehicle Handling Test Procedures" dated 4/8, 4/15, 4/26, and 5/14/71 by GM Handling and Stability Division

5. May, 1971 - "Proposed Vehicle Testing Procedure" by General Motors Corporation


SAE PAPERS AND PRESENTATIONS


2. March, 1960 - SAE Preprint of "Suspensions from the Ground Up" by C. M. Rubly, GMC, presented at SAE National Automobile Week Meeting, Detroit, Michigan

GENERAL REFERENCES

1. 1962 - "Accident Prevention" by R. N. Janoway in Passenger Car Design and Highway Safety


4. September 9, 1966 - Public Law 89-564, 89th Congress, S.3052


FILMS (Supplied by General Motors Corporation and DOT)

A-50 Free Control
A-53 Normal and Hard Driving
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

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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 III - A - 4, Movie Pomona & Willow Run Rollover Attempts
Exhibit #75 - O'Shea - Manos Film
Various DOT Films of Texas A&M Tests
Falcon versus Corvair - Ford Film
University of Michigan Test Film
RAY W. CALDWELL

B.S. in Mechanical Engineering, University of Wisconsin.
President of Autodynamics Corporation for past ten years.
Designed and developed a wide range of racing and specialty automobiles including FIA Group 7 road racing cars, Formula A, Formula Vee, Formula Super Vee and Formula Ford racing cars.
National SCCA driving championship in 1964 in a Formula Vee of own design.
Designed cars and managed professional racing team for SCCA Trans-American, Continental, and Canadian-American Championship series.
Holder of a commercial pilot's license with an instrument rating.
BIOGRAPHICAL SKETCHES OF PANEL MEMBERS
EDWIN L. RESLER, JR.

Ph.D., Cornell University, 1951.
Director of Graduate School of Aerospace Engineering at Cornell for the past eight years.
Professor of Aerospace Engineering, Engineering Physics and Electrical Engineering at Cornell for the past fifteen years.
Fellow of American Institute of Aeronautics and Astronautics.
Member of Center for Radio Physics and Space Sciences, American Institute of Physics and American Physical Society.
Consultant to Avco-Everett Research Laboratory, Lansing Research Associates and Harry Diamond Laboratories.
PAUL H. WRIGHT

B.S. in Civil Engineering, University of Tennessee, 1953.
M.S., University of Tennessee, 1958.
Ph.D., Georgia Institute of Technology, 1964.
Associate Professor of Civil Engineering for past four years at Georgia Institute of Technology.
Presently, Project Director for multidisciplinary research team conducting in-depth investigations of traffic accidents.
Served as principal investigator on five Traffic and Highway Engineering research projects.
Two years experience in the development of new subdivision road specifications and establishment of a soil laboratory.
Three years in U.S. Navy Civil Engineer Corps.
Registered Professional Engineer in Georgia.
Member of American Society of Civil Engineers, Operations Research Society of America.
Member of Sigma Xi and Chi Epsilon honorary engineering societies.
Associate Member of Institute of Traffic Engineers.
ADDENDUM

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On 12 April 1972 the panel reconvened at D.O.T. The following persons were present:

Andrew Detrick - D.O.T.
M. J. Lilley - D.O.T.
E. Wittich - D.O.T.
E. French - D.O.T.
F. A. Berndt - D.O.T.
P. H. Wright - Georgia Institute of Technology
E. L. Resler - Cornell University
R. W. Caldwell - Autodynamics Corporation
H. E. Holt - General Testing Laboratories - Recorder

The panel was asked to examine and evaluate additional information which was obtained by NHTSA subsequent to the submission of the panel report dated 25 January 1972. The information presented included graphic data from General Motors, Ford, and MIRA which described in a more quantified manner the understeer-oversteer characteristics of the 1960-1963 Corvair and several other automobiles. These data from constant radius skid pad tests made it possible to plot steering wheel angle in degrees versus lateral acceleration in g's.

An additional meeting was called by the panel on 2 and 3 June 1972. At that time this addendum was drafted and approved by the panel members.

In an effort to assist in determining the significance of the understeer-oversteer transition with regard to Corvair stability and controllability, the panel submits the following definitions and charts.

The definitions of understeer, neutral steer and oversteer are important in order to eliminate any possible confusion in this discussion. These definitions, in general terms, are as follows:

If, when an automobile is on a constant radius circular path, an incremental speed increase requires additional turning toward the center of the circle to maintain the path, then the vehicle is in an understeering mode. If the incremental speed increase on the constant radius path requires no additional steering input, the vehicle is in a neutral steering mode. If the incremental speed increase on the constant radius path requires a steering input in a direction away from the center of the circle, then the vehicle is in an oversteering mode.
Divergent instability exists at a prescribed trim if any small temporary disturbance or control input causes an ever increasing vehicle response without oscillation. (See reference number 3 in the SAE Papers and Presentations.)

At the time of the Corvair's design this concept was well understood as verified by the following quotation by R. N. Janeway from page 48 of reference number 1 in the General References:

"Although other investigators had made a beginning in a mathematical approach of the dynamic stability problem, the Cornell Aeronautical Laboratory in recent years has carried out an extensive analytical and experimental program in this field. Five papers covering this work were compiled by the Institution of Mechanical Engineers in 1956. Of these,
the contributions of Leonard Segal and W. F. Milliken and D. W. Whitcomb are particularly pertinent to this discussion. Milliken and Whitcomb have derived an equation for critical speed beyond which the vehicle becomes unstable under steady state or transient conditions. Their equation proves that: (1) Instability can only occur under oversteering conditions, i.e., rear-wheel slip angle exceeds front-wheel slip angle requirement. (2) Instability occurs when the excess of rear slip angle over front slip angle becomes equal to the Ackerman steer angle.

Item (2) can be restated as the condition when the front-wheel steer angle has been reduced to zero (front and rear wheels are parallel)." Divergent instability may be illustrated by operation above the critical speed of an oversteer vehicle. Any input to the steering wheel will place the vehicle in a turn of ever decreasing radius unless the driver makes compensating motions of the wheel to maintain general equilibrium. This condition represents divergent instability. (See note 9 from reference number 3 in the SAE Papers and Presentations.)

Another definition employed by the panel to put a limit on the amount of oversteer or understeer desirable in a vehicle is that used by F. Winchell in reference number 8 in the General References, namely, the limit of control. This is demonstrated by the empirical ability of a driver to maintain a circular path about an approximately 100 foot radius skid pad for 3 complete laps. In some cars the driver loses control because of excessive oversteer and in other cars the driver loses control because of excessive understeer.

Control Sensitivity is defined as the change in steady state lateral acceleration per unit change in reference steer angle at a given trim. (See reference number 3 in the SAE Papers and Presentations.)

Two corollaries to this definition are as follows:

a. Infinite control sensitivity is the condition where any steering control input produces infinite vehicle response.

b. Zero control sensitivity is the condition where infinite steering control input produces no vehicle response.

These definitions serve to clarify the chart shown in Figure 2.
CONTROL AND STABILITY

UNSTABLE

DIVERGENT INSTABILITY BOUNDARY (CRITICAL SPEED)

OVERSTEER LIMIT OF CONTROL

OVERSTEER

1960-1963 CORVAIR

0g

UNDERSTEER

1960 FALCON & SOME OTHER 1960-1963 CARS

0g

UNDERSTEER LIMIT OF CONTROL

.6g

NEUTRAL STEER POINT

BAD

GOOD

FIGURE 2
Figure 2 is an attempt by the panel to depict the relationship to the above definitions of the 1960-1963 Corvair and other vehicles.

It should be noted that a typical oversteering car, while it may become unstable, occupies a superior position on the control sensitivity scale. An understeering vehicle which cannot become unstable in the same sense becomes uncontrollable when the control sensitivity is poor (the limit of control). The 1960-1963 Corvairs, which may operate in both the oversteer and understeer modes, tend to operate near the instability boundary at high lateral acceleration but are more controllable than typical understeering vehicles. Contemporary understeer vehicles are uncontrollable at the same lateral acceleration due to inferior control sensitivity. Thus there is a practical limit of control for both oversteer and understeer vehicles. (See Figure 2.)

The following comments may then be made from the above definitions, the information reviewed by the panel and from Figure 2.

The 1960-1963 Corvair, which is an initially understeering vehicle, changes from understeer to neutral steer at approximately .4 g lateral acceleration. At greater lateral acceleration this condition changes to oversteer which increases with the lateral acceleration until the vehicle is no longer under control of the driver above .6 g (limit of control). The time frame within which the transition occurs is a function of vehicle speed and trim, but the amount of steering wheel correction or steering change required to maintain a constant 108 foot radius is only about 50 degrees of steering wheel motion from .4 g to .6 g.

By comparison, a 1967 Chevrolet sedan and 1967 Chevrolet station wagon, both of which are understeering vehicles, require approximately 175 degrees of steering wheel movement, respectively, to maintain the same steady state conditions.

This means that the Corvair has greater control sensitivity than these vehicles as well as greater control sensitivity than contemporary vehicles. Note that all of these vehicles are operating at their limit of control.

Using these criteria with the Corvair in the oversteer condition, it is seen that at .6 g lateral acceleration the 1960-1963 Corvair is nearer the divergent instability boundary in the controllable range than any vehicle for which the panel has data.
Although the 1960-1963 Corvair does oversteer from .4 g to .6 g, it is not unstable and the control sensitivity is superior to that of contemporary vehicles in the sense that less steering input is required for a desired maneuver.

While it is true that only an oversteering car can be divergently unstable, oversteering does not necessarily imply instability. Indeed, the data supplied to the panel showed the Corvair to be stable in the range from 0 g to .6 g laterally.

In summary, these subsequent deliberations have only reinforced the panel's convictions stated on page 6 of the original report.

The panel therefore concludes the following:

1. The conclusions and recommendations in the original report are reasonable, appropriate and sound.

2. The 1960-1963 Corvair, as well as other contemporary cars, is controllable in the lateral acceleration range from 0 g to .6 g.

3. The 1960-1963 Corvair in the oversteer mode, due to its better control sensitivity has greater maneuverability in the hands of a skilled driver than a contemporary car has.

4. The transition in the 1960-1963 Corvair from understeer at approximately .4 g lateral acceleration with its attendant control reversal may confuse drivers unfamiliar with this characteristic. Because some current vehicles exhibit similar handling characteristics, efforts to quantify stability and control limits for handling must be continued. Only then can precise determinations of safe or unsafe vehicle handling characteristics be made.