Results of Handling, Stability, and Braking Tests of the Minicars RSV

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INTRODUCTION

For her share of the worldwide testing of the Minicars RSV, the Federal Republic of Germany agreed to test its handling and braking characteristics—as was done a year ago with the Calspan RSV. The task issued to the German Government was delegated by the BAST (Federal Highway Research Institute) as coordinator of the automobile manufacturers represented in the VDA (Automobile Industry Association).

Due to the outstanding cooperation of all participants, despite the sometimes poor weather conditions, it was possible to complete the manoeuvres required by the RSV specifications on time, as well as to carry out other additional tests.

TEST CONDITIONS

The test car used was the Minicars RSV M 5–10 (figure 1). General Data for the test car are shown in the table in figure 2.

Test equipment was installed in the car by Daimler-Benz. Manoeuvres requiring larger surface areas were carried out on the VW proving grounds in Ehra-Lessien, as was done with the Calspan RSV, while the other tests were performed at Daimler-Benz in Stuttgart. The test conditions complied with the RSV specifications. The following criteria were tested:

- braking in a straight line
- braking in a turn
- brake pedal force as a function of deceleration
- effectiveness of the parking brake
- steady-state yaw response
- transient yaw response
- steering returnability
- maximum lateral acceleration
- control at breakaway
- crosswind sensitivity
- steering control sensitivity
- pavement irregularity sensitivity
- slalom course
- passing time (acceleration)

In order to make a general assessment of the handling characteristics, the following vehicle parameters were also determined:

- turning circle diameter
- maximum speed
- drag coefficient
- kinematic changes in toe-in and camber
- suspension rate

Figure 3 lists the parameters to be measured and the transducers used.

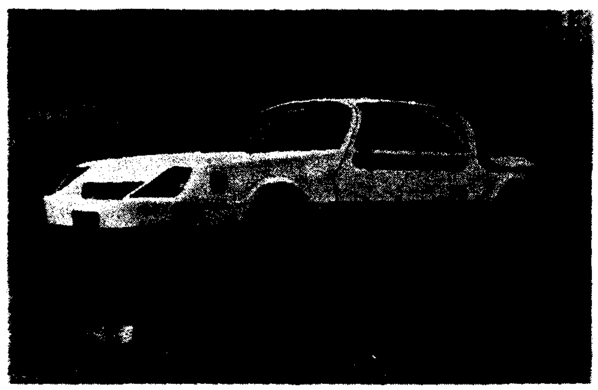


Figure 1. Minicars RSV.

Curb weight	2579 lbs
Weight (loaded to 60% capacity)	2986 lbs
Axle load distribution (vehicle loaded to 60% capacity)	46/54%
Track front	62 in
rear	62 in
Wheelbase	104 in
Tires	200/65 hr 370 Dunlop de Novo 2 run-flat

Figure 2. Minicars RSV general data.

The electronic test equipment arrangement is shown in figure 4. It consists of data acquisition and data processing. The data acquisition equipment was installed in a special test rack in the rear of the passenger compartment (figure 5). This consisted basically of an HP 2100 process computer for digitizing and editing, and a Columbia cassette unit for data storage. The data processing equipment was carried in a separate vehicle acting as a mobile computer centre (figure 6), equipped with a second cassette unit, an HP 9845 B desk computer and an HP 9872 A plotter for the computation and plotting of the diagrams required by the RSV specifications. This enabled rapid evaluation and checking of the recorded data immediately after each test run. It was the first time that data processing with a computer in the vehicle and at the test site had been used for tests of this kind.

TEST RESULTS

Meeting the RSV Specifications

In the manoeuvre braking in a straight line (figure 7), the maximum permissible stopping distances for both load conditions and all three brake system operating conditions were not exceeded. However, the stopping distance for the 100% load condition was only 6.8% below the requirement. The specified lane width (3.7 m) was maintained with only slight steering wheel corrections (< 10°).

Measuring parameters	**Transducer**
Yaw angle	Directional gyro
Yaw velocity	Directional gyro
Lateral acceleration	Stable platform
Forward velocity	Optical sensor
Wheel angle	Induct. displacement transd.
Steering wheel torque	Strain gauge bridge
Steering wheel angle	Potentiometer
Steering wheel velocity	Rate sensor
Stopping distance	Optical sensor
Course deviation	Measuring tape
Brake pedal force	Mech. pneumatic pressure transducer

Figure 3. Measuring parameters and transducers.

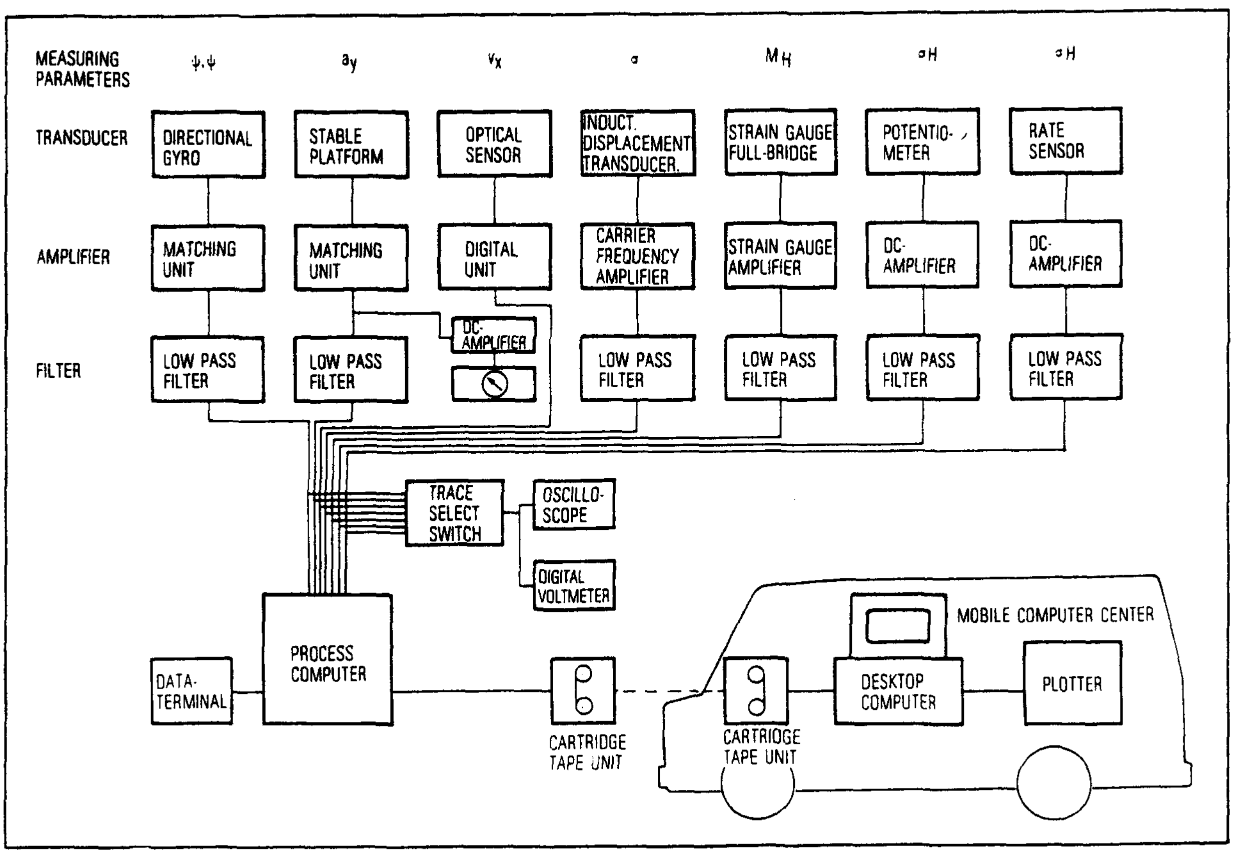


Figure 4. Minicars RSV measuring arrangement.

Figure 5. Test equipment in the test car.

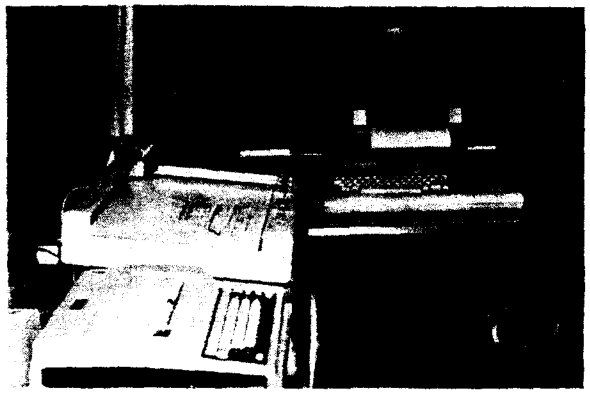


Figure 6. Test equipment in the mobile computer center.

Loading % capacity	Initial speed	Stopping distance	
		Required	Measured
60	60 mph	≤ 190 feet	160.4 feet
100			176.7 feet

Figure 7. Minicars RSV braking in a straight line.

Loading % capacity	Initial conditions	Stopping distance	
		Required	Measured
60	Radius 357 feet	90 feet	83.0 feet
	Speed 40 mph		
100	(Lat. Acc..3G)		87.6 feet

Figure 8. Minicars RSV braking in a turn.

The requirements for braking in a turn (figure 8) in a lane of 3.7 m width were also met, although the measured stopping distances of 83.0 ft and 87.6 ft were only slightly less than the allowed maximum of 90 ft. The main reason for this was the premature locking tendency of the wheels on the inside of the turn, which meant that greater decelerations could not be achieved within the limits specified for lane width and steering wheel correction (< 180°).

The brake pedal force for various, quasi-steady-state decelerations is shown in figure 9. With the brake system in fully operational condition, the pedal forces are to some extent less than the minimum values specified, i.e., up to 0.4 g deceleration for 100% loading and up to 0.6 g for 60% loading. Results under the other conditions (failure of brake booster or of front brake circuit) were within the permissible limits.

The effectiveness of the hand-operated parking brake was not sufficient to hold the vehicle on the 30% grade. With the brakes adjusted as they were, the mechanical stop detent for the hand-brake lever was reached before sufficient braking effect existed.

Figure 10 shows the steady-state yaw response for a lateral acceleration of 0.4 g. Over the entire speed range, the measured values lie within the given limits. Noticeable is the large difference between a left turn (ccw) and a right turn (cw), which made itself evident under steady-state conditions by different steering angles and under

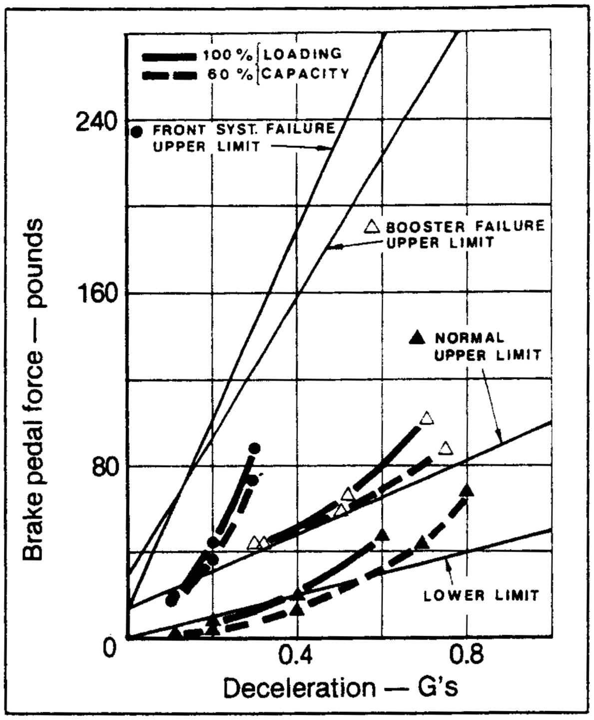


Figure 9. Minicars RSV brake pedal force versus vehicle deceleration.

transient conditions by different steering characteristics.

The transient yaw response as a result of a step input to the steering wheel (figures 11 and 12) exhibits characteristics typical of oversteer. The specified limits were not exceeded. The difference between right and left turn can be seen especially well at a speed of 70 mph.

Figures 13 to 15 show the returnability of the steering at speeds of 25 to 50 mph when the steering wheel is released in a steady-state turn at 0.4 g. The yaw velocity excursions are greater for left turn than for right turn. This could be caused by a greater aligning torque for left turn and asymmetric steering damping. The characteristic of the course angle (figure 13) shows that there is a slightly increasing tendency at 25 mph for left turn and a slightly decreasing tendency for right turn. Thus in both cases the vehicle turned slightly to the left when the steering wheel was released. The RSV specifications were met in almost all instances; only at 25 mph and for left turn (figure 14) did the remaining yaw ve-

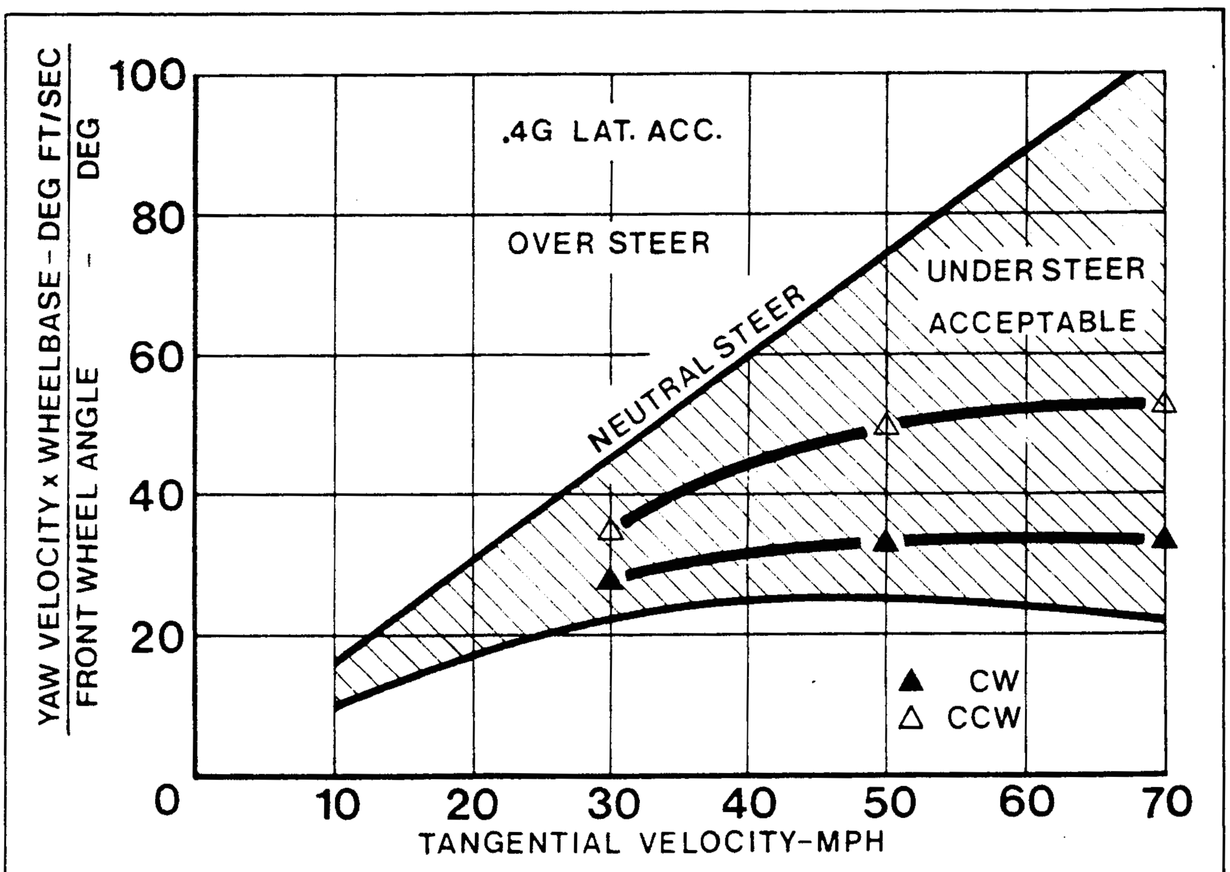


Figure 10. Minicars RSV steady-state yaw response.

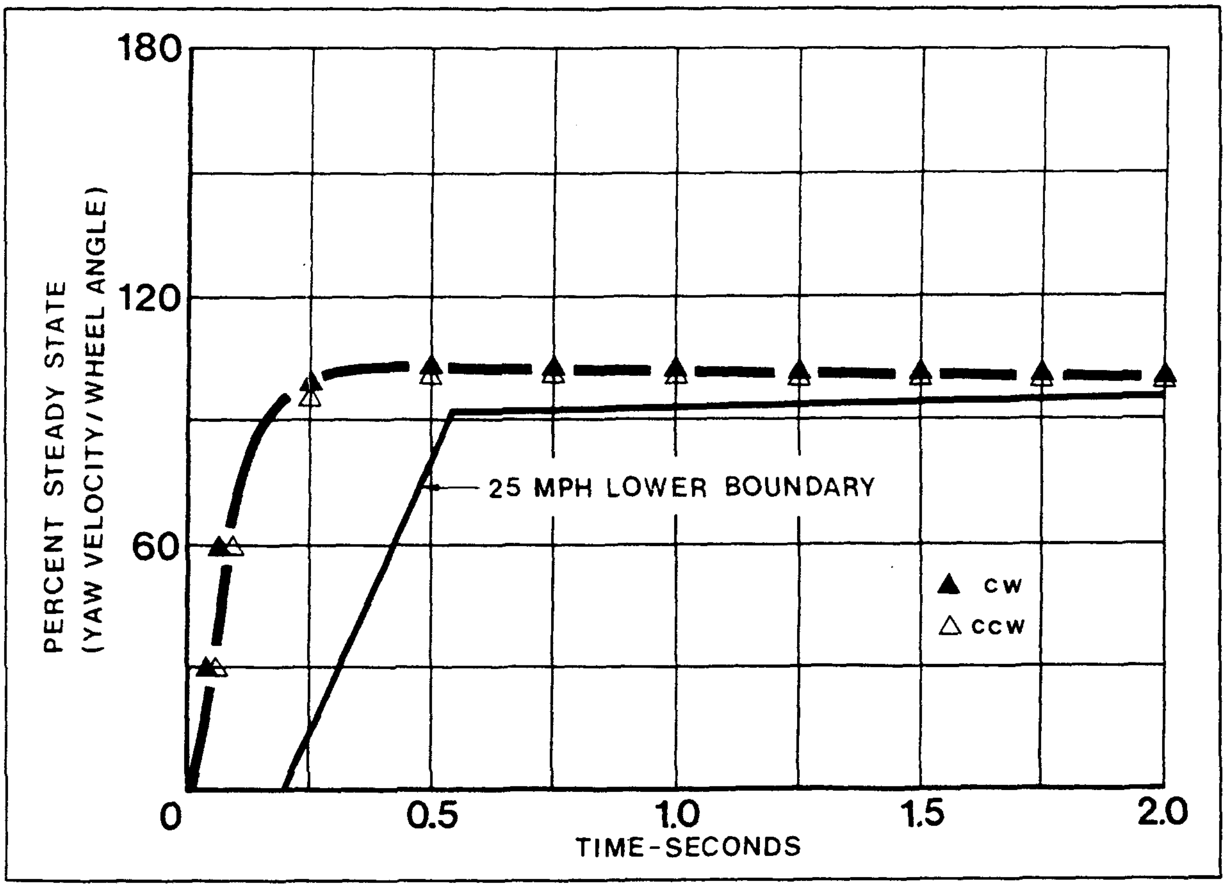


Figure 11. Minicars RSV transient yaw response at 25 mph.

locity lie somewhat above the maximum permissible limit.

Figure 16 shows the maximum lateral acceleration achievable with different tyre pressures. The requirements were fulfilled in all cases. For a short period of time it was possible to achieve about 10% higher values, but handling then was no longer stable.

The test conditions specified for measuring control at breakaway are so difficult to comply with that the test results were hardly reproducible. Consequently a graph of test results cannot be provided here.

However, the test can be described as completed on the basis of the subjective assessments of several skilled drivers and observers.

The crosswind sensitivity of the vehicle is shown in figure 17. The deviation from course is plotted against the distance covered 2 seconds after onset of the crosswind. The test values lie below the maximum permissible limit.

Figure 18 shows the steering control sensitivity at various driving speeds. Although the test values are considerably greater than the required minimum value, the steering was not judged to be heavy.

Testing directional stability after a defined pavement irregularity resulted in the permissible deviation from course after 2 seconds not being exceeded at 30 and 50 mph. At 70 mph, the deviation of 1.65 ft was greater than the permissible value of 1 ft.

The required minimum speed of 50 mph for the slalom course (figure 19) was exceeded, with an attained speed of 51.1 mph.

The acceleration ability of the vehicle was just sufficient to accelerate the vehicle from 30 to 65 mph in a maximum of 24 seconds with gear change as required. The average time was 23.8 seconds. The measured acceleration time from 50–70 mph of 19.2 seconds was well below the permissible value of 22 seconds.

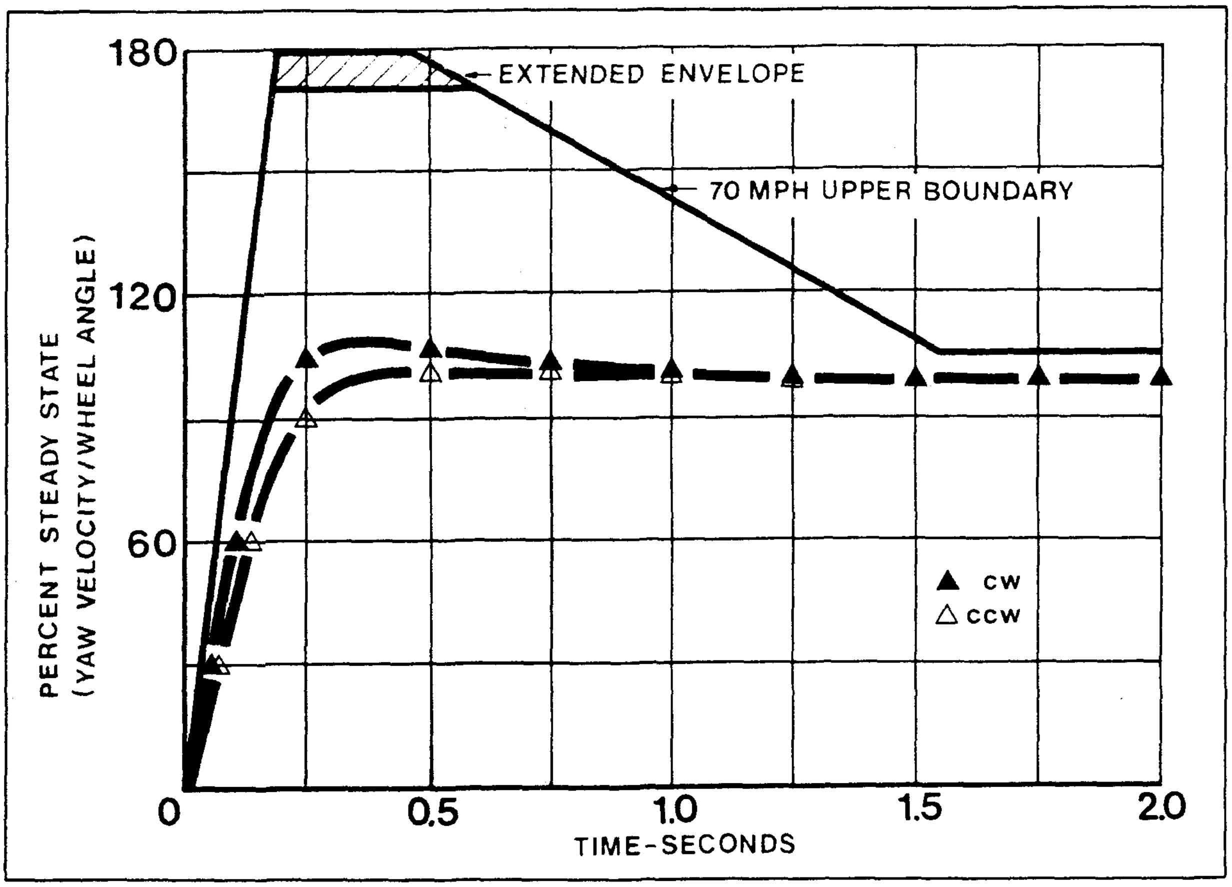


Figure 12. Minicars RSV transient yaw response at 70 mph.

Additional Measurements

To get a well-rounded picture of the vehicle, a few other relevant dynamic tests were carried out in addition to the RSV specifications. The results were as follows:

The turning circle diameter of 41.1 ft for right lock and 42.7 ft for left lock is a bit too large for a vehicle of this size. On right lock, the wheel on the inside of the turn rubbed against the body; even adjustment of the steering limit stop gave no improvement.

The maximum speed of 84.5 mph is very low for European conditions, and even in countries which impose speed limits for all types of roads would probably be just acceptable.

The drag coefficient determined for the vehicle's frontal area of 23.6 ft^2 (2.19 m^2) was $c_w = 0.414$. In modern terms this value is relatively high, especially with regard to minimizing fuel consumption. There are some standard production cars which have much better values.

The kinematic change in toe-in of the front axle (10'/10 mm vertical wheel displacement) was very large compared to modern production vehicles. Roll mode particularly results in a severe worsening of the straight-ahead characteristics on an undulating surface.

On the other hand, only minimal changes in toe-in occur on the rear axle. The camber angle changes are normal.

The suspension rates measured for the front and rear axles point to indicate a very stiffly sprung vehicle. As no roll stabilizers are fitted, there is no difference between jounce and rebound mode and roll mode.

SUMMARY

According to the results of the tests carried out as prescribed by the RSV specifications, the Minicars RSV can be said to have met the requirements in general. In three cases some of the limit values were not met, and the vehicle just

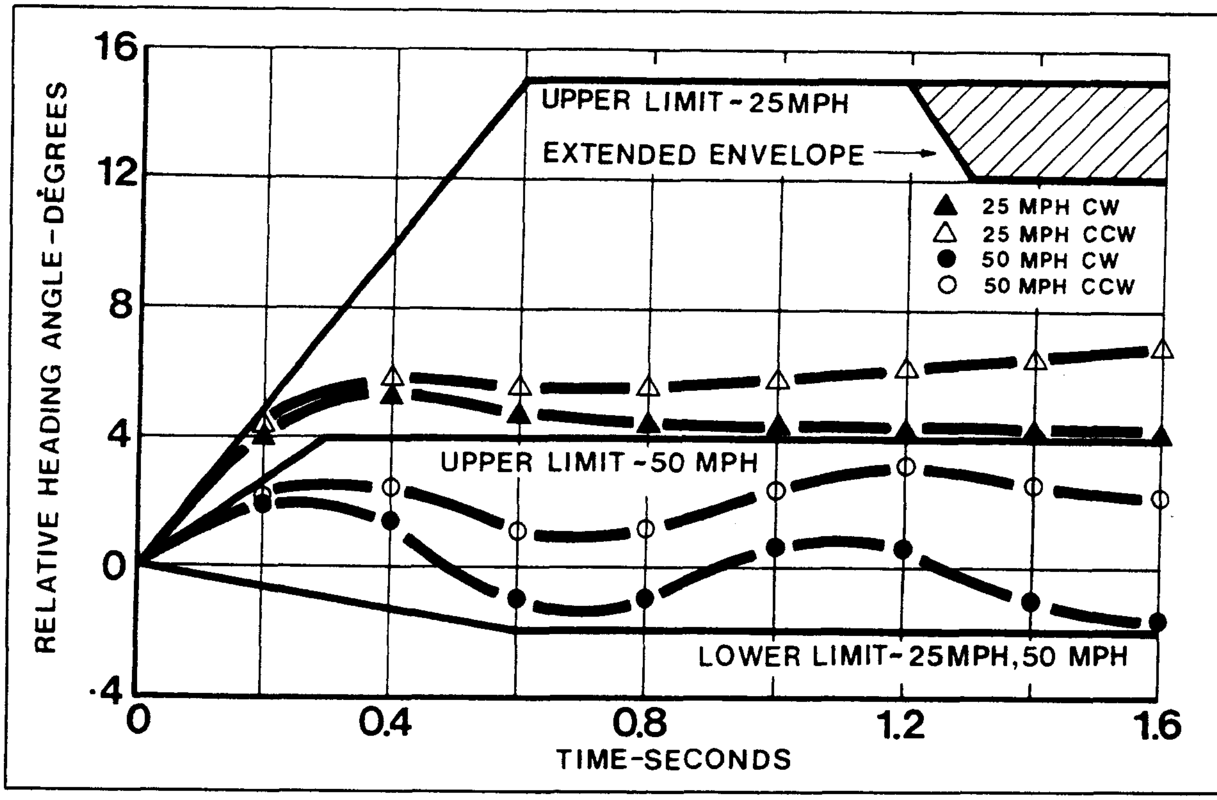


Figure 13. Minicars RSV Steering returnability free control heading.

barely met the required performance in some of the tests.

For example in the braking with quasi-steady-state decelerations test the pedal force is too low in the low and medium deceleration ranges with the brake system in fully operational condition. Only at higher decelerations do the pedal forces lie within the permissible limits.

The effectiveness of the parking brake on the 30% grade was insufficient and thus is a second unfulfilled requirement.

Directional stability with pavement irregularity negotiated at 70 mph was also below the required standard.

The requirements for both braking manoeuvres are only just met. For braking in a straight line as well as for braking in a turn, the stopping distance reserves are minimal. The safety margin for the turn manoeuvre in fully loaded condition is very small, at less than 3%.

In the steady-state yaw response test, the values achieved are within the stated limits. Noticeable, however, is the great difference between right and left turn.

This varying response is also evident in the steering returnability test. Here the time history of the relative course angle for the left turn is distinctly greater than that for the right turn. The final yaw velocity lies outside of the permitted tolerances.

CONCLUSIONS

Test Criteria

During the tests it became clear that some of the manoeuvres required by the RSV specifications are barely reproducible and therefore difficult to evaluate. It is recommended that such criteria should be altered or omitted from future tests.

For example, the tolerance range for the steering returnability test at 25 mph (figure 14) is smaller than the scatter of the test values and thus is not well chosen.

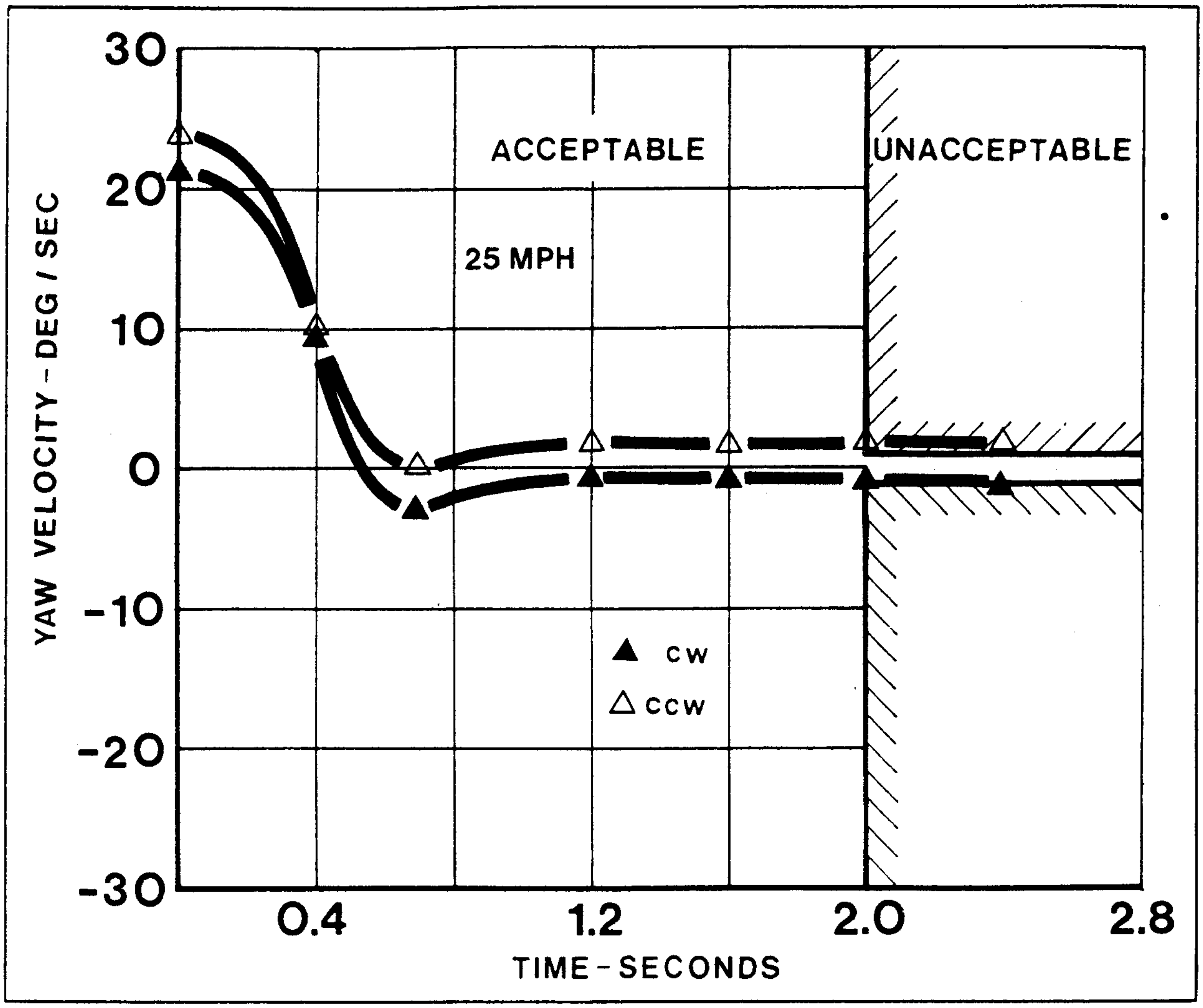


Figure 14. Minicars RSV returnability performance yaw rates at 25 mph.

The required lateral acceleration values for the steady-state circular turn are biased in favour of understeering vehicles. Demands made for non-specification tyre pressures should not be greater than those made for design values.

The test conditions for the control at breakaway test are so difficult to comply with that the test results are hardly reproducible. The specification should be modified.

For the test pavement irregularity sensitivity the permitted deviation from the course after 2 seconds at various speeds is a maximum of 1 ft. Course angle errors of just a few minutes when starting off, or road and wind influences create test value scatter which is greater than the required maximum deviation. The test is therefore not practical and should be changed.

The drastic steer and brake manoeuvre for testing overturning immunity is not reproducible and has no bearing on reality. For this reason this criteria was not tested, and it is recommended that it be omitted from the specifications.

Test Vehicle

Although research safety vehicle should represent the latest advances in active and passive safety, both of the vehicles tested so far from Calspan and Minicars have exhibited serious defects in basic design which would not allow safe operation in traffic. Accordingly, it seems as if these vehicles were designed primarily to meet certain specifications, which they do to a very great extent. This again is proof of the fact that

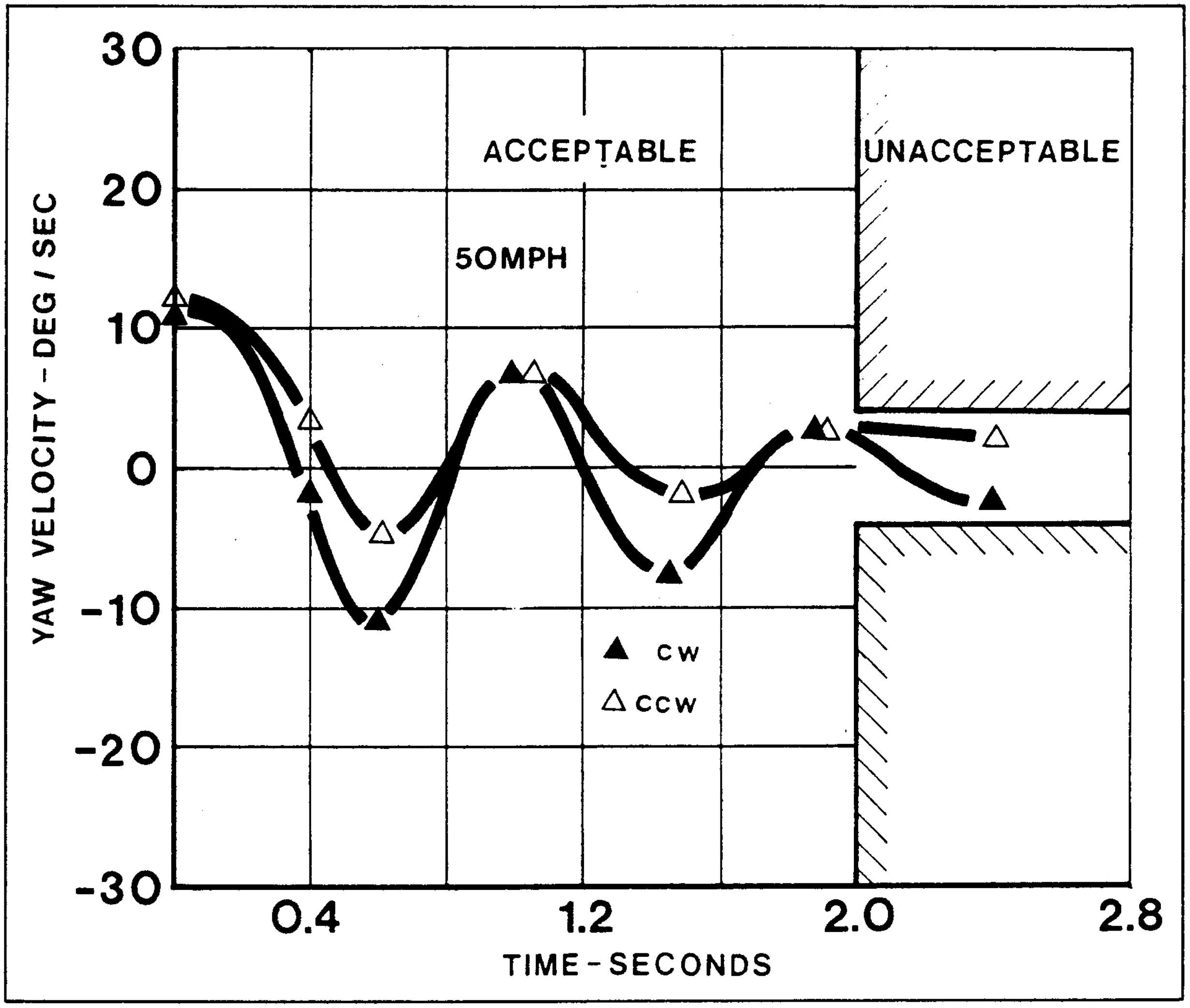


Figure 15. Minicars RSV returnability performance yaw rates at 50 mph.

SURFACE	TIRE PRESSURE	LATERAL ACCELERATIONS (G) FIXED CONTROL	
		REQUIRED	MEASURED
DRY CONCRETE OR ASPHALT	DESIGN VALUE	0.60	0.69
	120%	0.60	0.72
	80%	0.55	0.67
	120% FRONT 80% REAR	0.63	0.66
	80% FRONT 120% REAR	0.59	0.67
WET CONCRETE OR ASPHALT	DESIGN	$a_y(\text{WET}) = \left(\frac{\text{SKID NUMBER(WET)}}{\text{SKID NUMBER(DRY)}}\right) a_y(\text{DRY})$	–

Figure 16. Minicars RSV lateral accelerations.

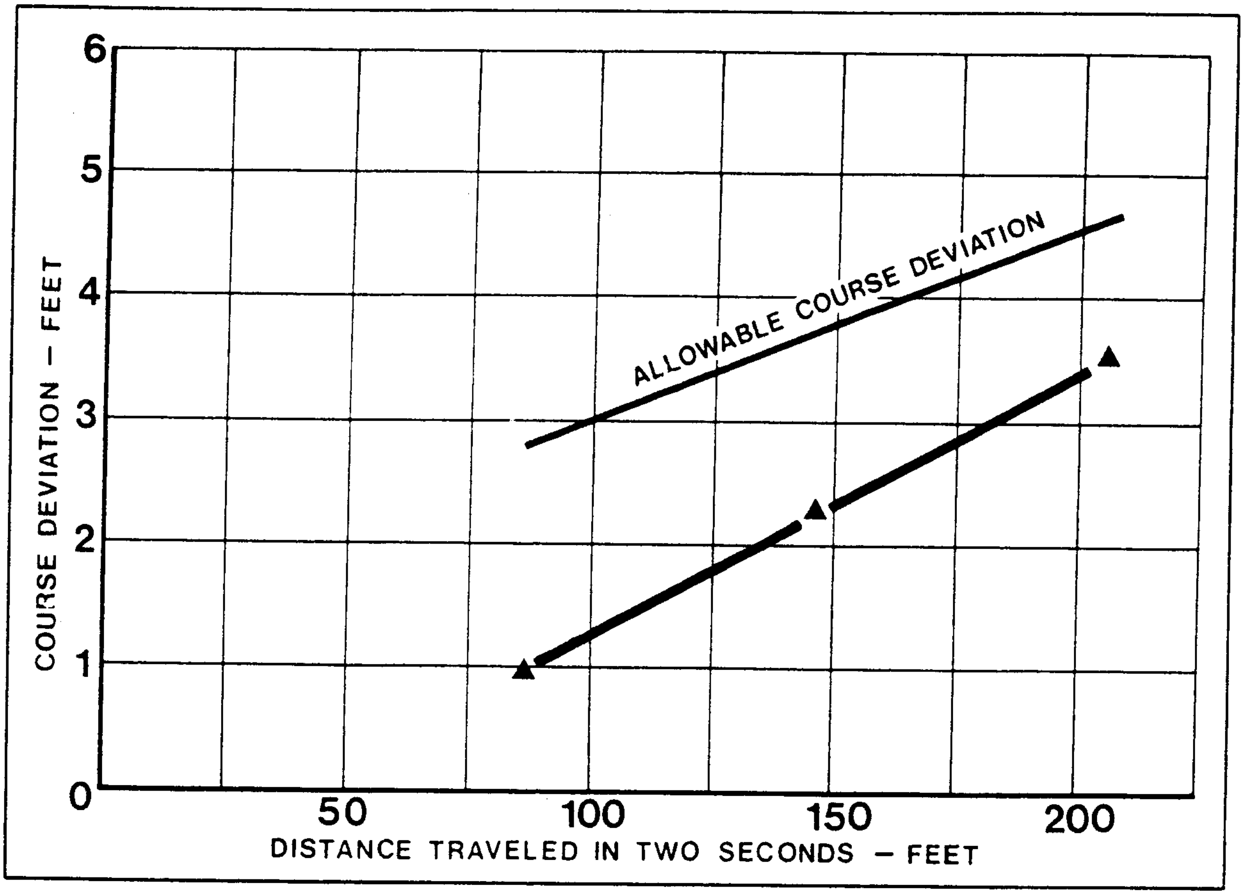
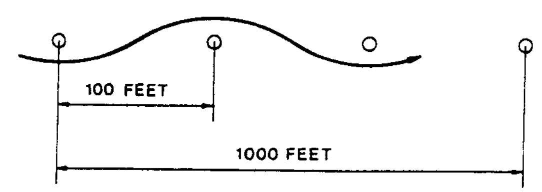


Figure 17. Minicars RSV crosswind sensitivity allowable course deviation by crosswind.

SPEED MPH	STEERING WHEEL TORQUE	
	REQUIRED	MEASURED
30	≥ 5 IN. POUND	16.1
50		20.4
70		25.0

Figure 18. Minicars RSV steering control sensitivity.



MINIMUM AVERAGE VELOCITY	
REQUIRED	MEASURED
50 MPH	51.1 MPH

Figure 19. Minicars RSV overturning immunity—slalom course.

compliance with the specified test criteria is by no means a guarantee, that the vehicle will be adaptable to the demands of real traffic situations.

The Minicars RSV tested, although complying with the specifications, showed such weaknesses in its handling characteristics that operation of the vehicle was considered unsafe.

Despite frequent adjustments, there was extensive play in the very angular steering column train. This had a strong adverse effect on steering precision and straight-ahead stability. When driving in a straight line with the steering wheel held firmly, even slight irregularities in the road surface caused noticeable steering of the front wheels which resulted in corresponding changes in direction.

The handling characteristics on a test track with alternating left and right undulating surfaces is unacceptable. Even at moderate speeds, the steering corrections necessary are so great that the average driver is overtaxed, and even skilled drivers have difficulty in keeping the vehicle on the track. The kinematic oversteering effect causes a strong and difficult-to-control pushing effect when turning into a bend, and the steering lock applied has to be reduced in order to stabilize the vehicle. In the boundary speed range during a steady-state circular turn, there is asymmetry between left and right.

The insufficient pedal force makes steady braking difficult. In emergency stops the pedal was pushed to the floor, although no fading occurred. Readjustment of the linkage eliminated this fault but at the same time resulted in an ergonomically poor pedal position.

For reasons of installation space alone, the overall conception does not allow these details, which are important for active safety, to be harmonized satisfactorily.

Both vehicles built by Calspan and Minicars show clearly that a useful compromise between active and passive safety, as well as between usability and cost, could not be successfully found.

Report on Minicars RSV Tests

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ABSTRACT

Japan Automobile Research Institute, Inc. (JARI) carried out three types of tests on the Minicars RSV's (hereafter referred to as M-RSV's) from April 1980 to July 1980, according to the "Memorandum of Agreements Concerning Test Program for Research Safety Vehicles" that had been concluded between the Department of Transportation (DOT) of the US government and the Ministry of International Trade and Industry (MITI) of the Japanese government.

- *Collision Tests*—The tests included a frontal collision test of a M-RSV against a fixed flat barrier, three side collision tests between each M-RSV and J-Car while both vehicles were running and a baseline side collision test between Japanese passenger cars while both vehicles were running.
- *Handling, Stability and Braking Performance Tests*—Tests were carried out on nine items for the handling and stability, and on three items for the braking performance of the M-RSV's.
- *Visibility Tests*—The field of direct view tests, the field of view tests and lighting equipment tests were carried out for the M-RSV's.

The foregoing three types of tests will be discussed in this report.

COLLISION TESTS

1. Outline of Collision Tests

Collision tests were carried out aimed at the collection of various data for the evaluations of occupant protection performance, compatibility and aggressivity of the M-RSV's.

Collision Modes

Collision modes and impact velocities of the five tests were as follows (refer to Figure 1.1).

Test No. 1—M-RSV (M5–9) frontal impact into fixed flat barrier at 79.6 km/h (49.5 mph).

Test No. 2—Side collision of M-RSV (M5–8) front into J-Car driver's side of 90°, both at 56 km/h (35 mph).

Test No. 4—Side collision of J-Car front into M-RSV (M5–8) driver's side of 90°; both at 56 km/h (35 mph).

Test No. 5—Side collision of C-Car front into J-Car driver's side of 90°; both at 56 km/h (35 mph).

Test No. 6—Side collision of J-Car front into M-RSV (M5–8) passenger's side of 90°; both at 64 km/h (40 mph).

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