# Passenger Car Overhang and Underclearance As Related to Driveway Profile Design

## I. Vehicle Data

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● THE CURRENT trend in automobile styling appears to be toward lower vehicles. Greater front and rear overhang and reduced road clearances, which make today's cars seem to hug the road, have caused increased concern among highway designers.

The trend, of course, is not new. When automobiles were powered buggies, the driver sat high. Then the engines moved out from under the seat. Pneumatic tires could absorb bumps that the buggy wheels needed size to climb. Independent suspensions allowed the engine to drop between the wheels. The frames moved to the outside, or disappeared altogether with integral body structures. Now, load sensing and leveling devices narrow the margin necessary for spring deflections. With each change, the driver has dropped down and the vehicle has become lower.

Viewed from the beginning, such a trend is alarming. As Stonex' charts [1] would seem to indicate by extrapolation, in another 60 years the driver's eyes will approach the pavement, presumably with the car underbody still in between; and 120-ft personal cars will be traveling on 7-in. wheels. It is suspected that it was from some such worry as this that the Vehicle Characteristics Committee requested a review of automobile underclearance dimensions and a report on the implications of current trends in these dimensions on driveway design. The results, perhaps, are surprising.

The data used in Table 1 are from measurements taken on vehicles of all major domestic makes and several foreign products which are imported in the largest quantities. No attempt was made to determine percentile distributions, either by vehicle make or by numbers of each make in current use, since it is not known what percent might constitute a significant level. It is assumed, however, that complaints will be generated primarily by those vehicles with the most critical dimensions. Because these vehicles are technically or competitively interesting to the manufacturers, they are perhaps also of concern to highway designers.

Have wheelbases been getting longer? The data (Fig. 1) do not show it. Smaller wheels and lower lines just make them look longer. The abrupt rise in the minimum dimension, and likewise the peaks and valleys on some of the accompanying charts, are not necessarily significant; they may only reflect the presence or absence of a single vehicle in the sample for a particular year.

Have angles of approach been shrinking? Not noticeably in the last 10 years, at least (Fig. 2). Sixty years ago there were cars with 180 deg angles of approach, which would roll nicely on the ceiling. This feature must have been of little value for the past 10 years, at any rate.

The 10-year trend used here caught the tail end of the downward progress in angle of departure. It would appear that the limit here has been reached (Fig. 3), and that rear overhangs will get no longer and impact bars no lower. Higher impact bars are not likely, as they must match existing vehicles; one cannot be selective about who hits him. Bumper extensions and spare wheels mounted on behind seem to be losing favor.

Minimum ground clearance curves (Fig. 4) begin to show a slight downward trend. The lowest minimums have been made possible by load-leveling suspensions and progressive bumpers, which decrease the margin necessary for jounce. The low point on cars now is more often found under the passenger compartment, on the muffler or the frame rails, rather than under the rear axle or the engine oil pan as in the past. This is a direct consequence of the emphasis on lowering the occupants, providing no more ground clearance under the floor pan than is necessary for other parts of the vehicle.

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[1] See elsewhere in this Bulletin.

At last there is a trend. Ramp break-over angles (Fig. 5) have dropped 6 deg in six years. This does not necessarily mean that in another ten years all roads must be optical flats. In fact, it is believed that the limit will be reached at about the present 6 deg to 7 deg minimum. As shown later, this has not been as critical a limit as rear overhang, and the reduction merely represents a better balance of clearances.

These trend curves themselves do not afford much clue as to the implications of the dimensions in driveway profile design; although they do excite suspicion. Therefore, two composite vehicles —a short one and a long one—have been put together, each combining the worst possible dimensions likely to appear on a future car (Figs. 6 and 7). Because it also has been observed that most real cars experience pavement interference usually only under dynamic conditions, the extremes these dimensions have been observed to reach have been charted: during severe brake stops or "dive"; again with the rear suspension compressed, as sometimes occurs under accelerations, or with heavy rear seat or trunk loads; and with both front and rear suspensions collapsed in full jounce.

The full jounce situation is surprisingly easy to reach on sag curves; for example, 15 to 20 mph on an 80-ft radius, as is found on many crowned intersections, will do it.

TABLE 1

DIMENSIONS OF COMPOSITE VEHICLES WITH MINIMUM CLEARANCES[a]

| Dimension | Shortest Vehicle | Longest Vehicle |
|---|---|---|
| Wheelbase | 80 in. | 133 in. |
| Overhang: | | |
| Front | 22 in. | 42 in. |
| Rear | 32 in. | 63 in. |
| Impact bar, lower edge | | |
| Front | 7.5 in. | 11.0 in. |
| Rear | 9.0 in. | 10.6 in. |
| Clearance: | | |
| Under wheelbase centerline | 4.9 in. | 4.0 in. |
| Minimum ground | 3.7 in. | 4.0 in. |
| Angle of approach | 15 deg | 15 deg |
| Angle of departure | 8 deg | 10 deg |
| Ramp break-over angle | 11 deg | 7 deg |
| Front jounce | 2 in. | 3 in. |
| Rear jounce | 2 in. | 3 in. |

[a] Critical dimensions taken from various makes of vehicles of same general configuration.

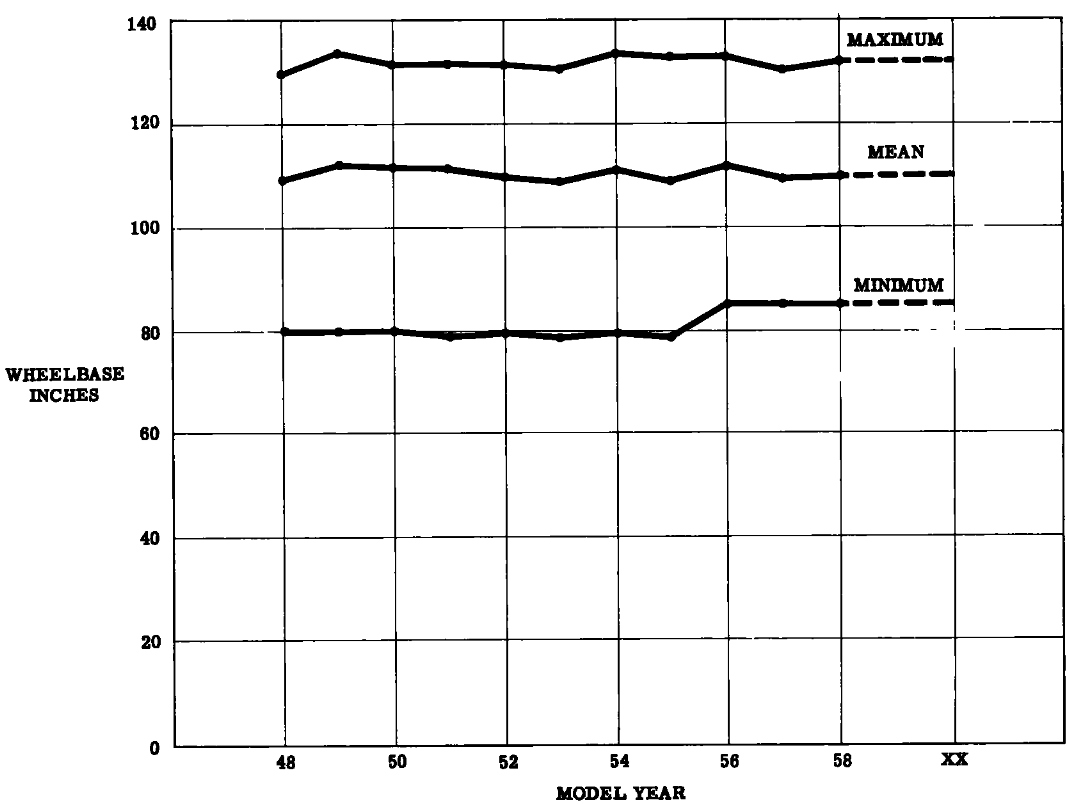



Figure 1. Wheelbase, inches, from 1948 through 1958.

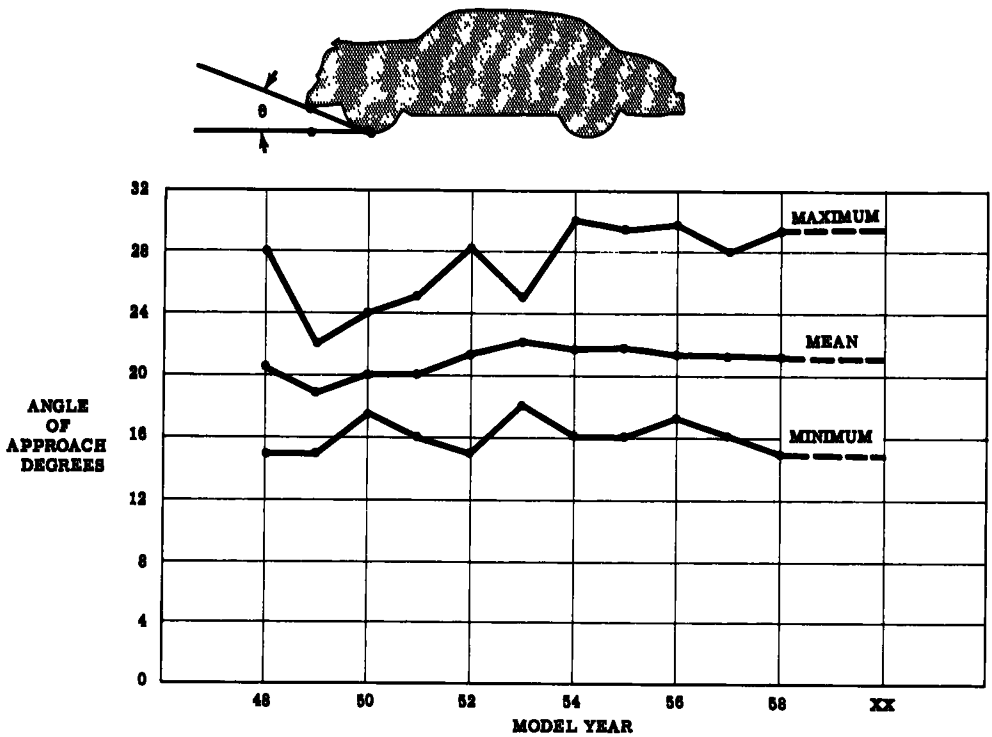



Figure 2. Angle of approach, degrees, from 1948 through 1958.

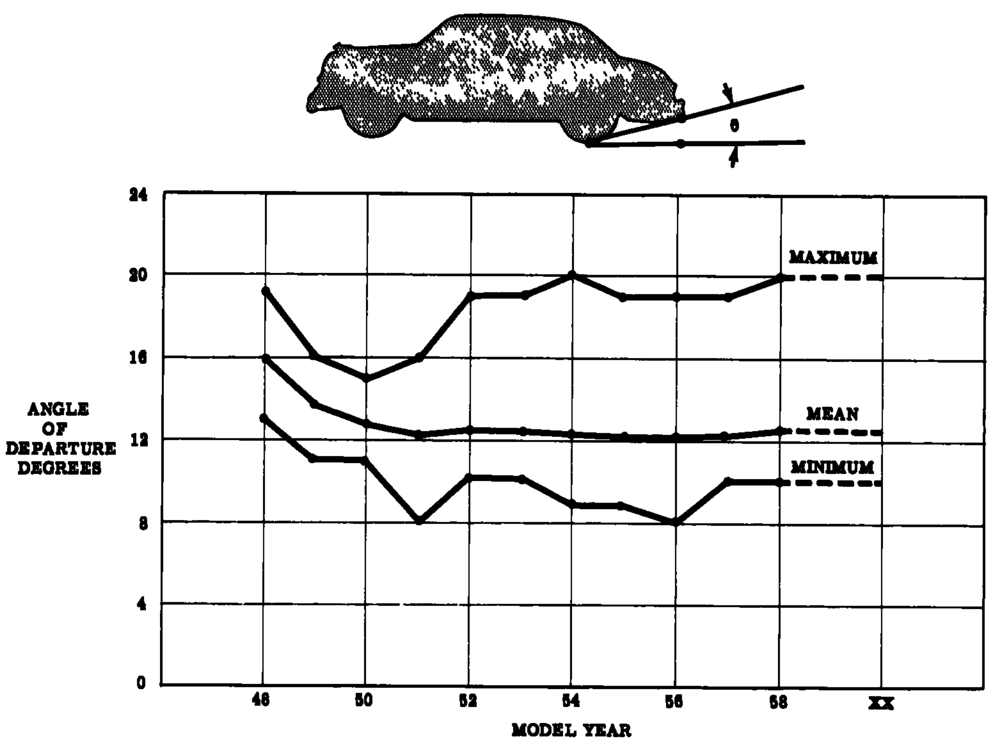



Figure 3. Angle of departure, degrees, from 1948 through 1958.

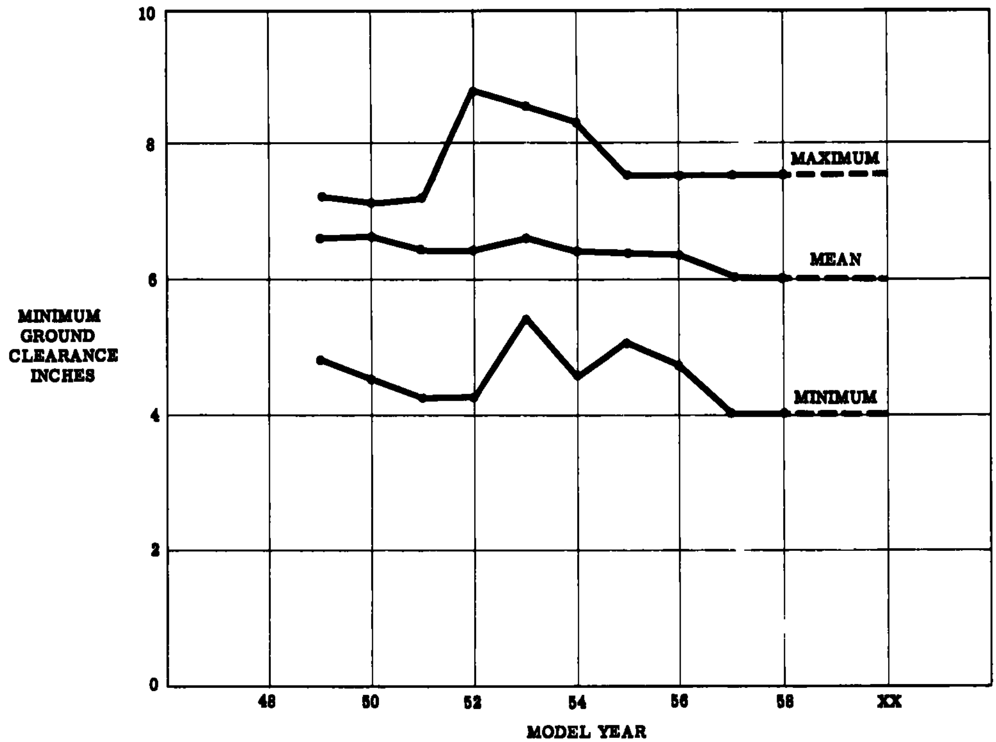



Figure 4. Minimum ground clearance, inches, from 1949 through 1958.

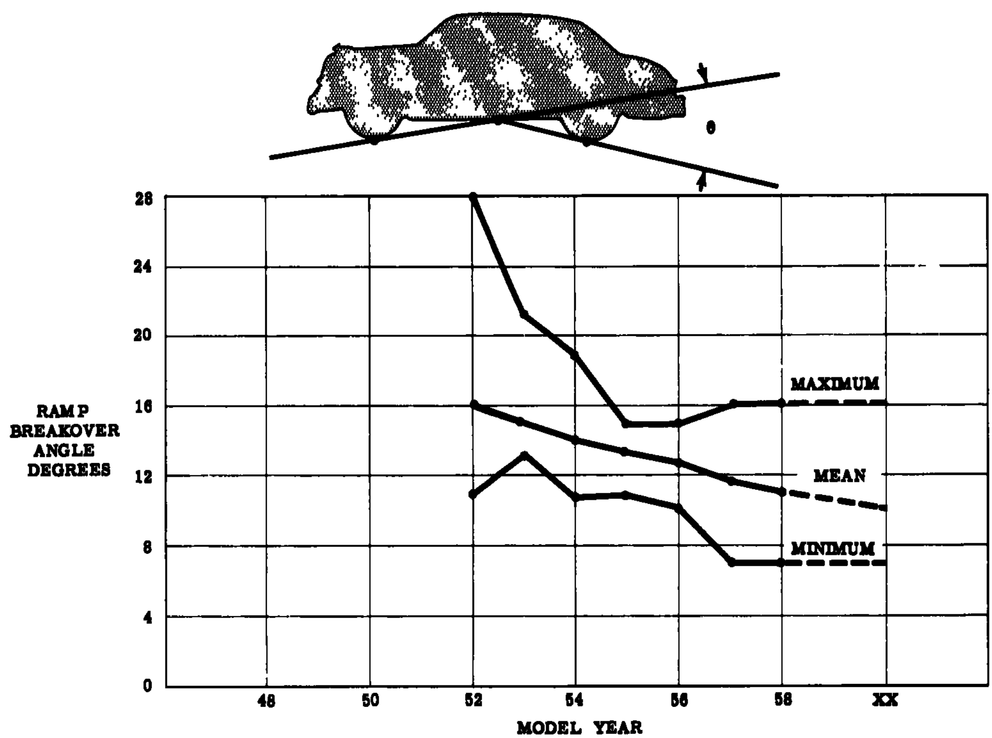



Figure 5. Ramp breakover angle, degrees, from 1952 through 1958.

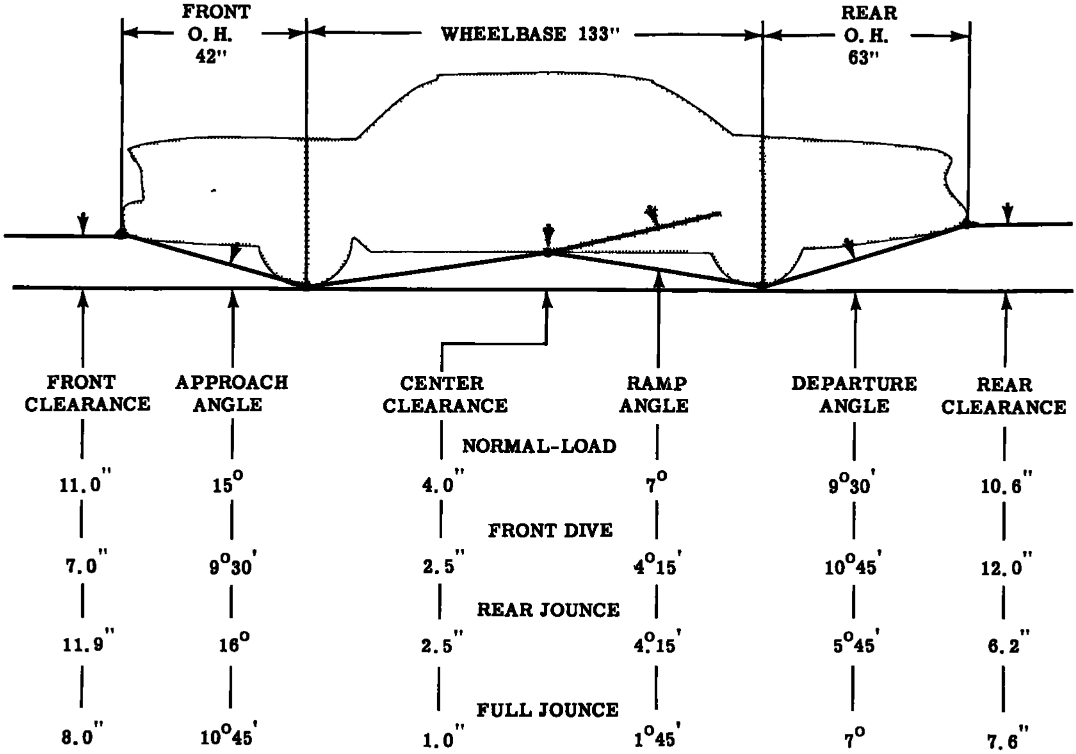



Figure 6. Composite longest vehicle, clearance dimensions under various conditions.

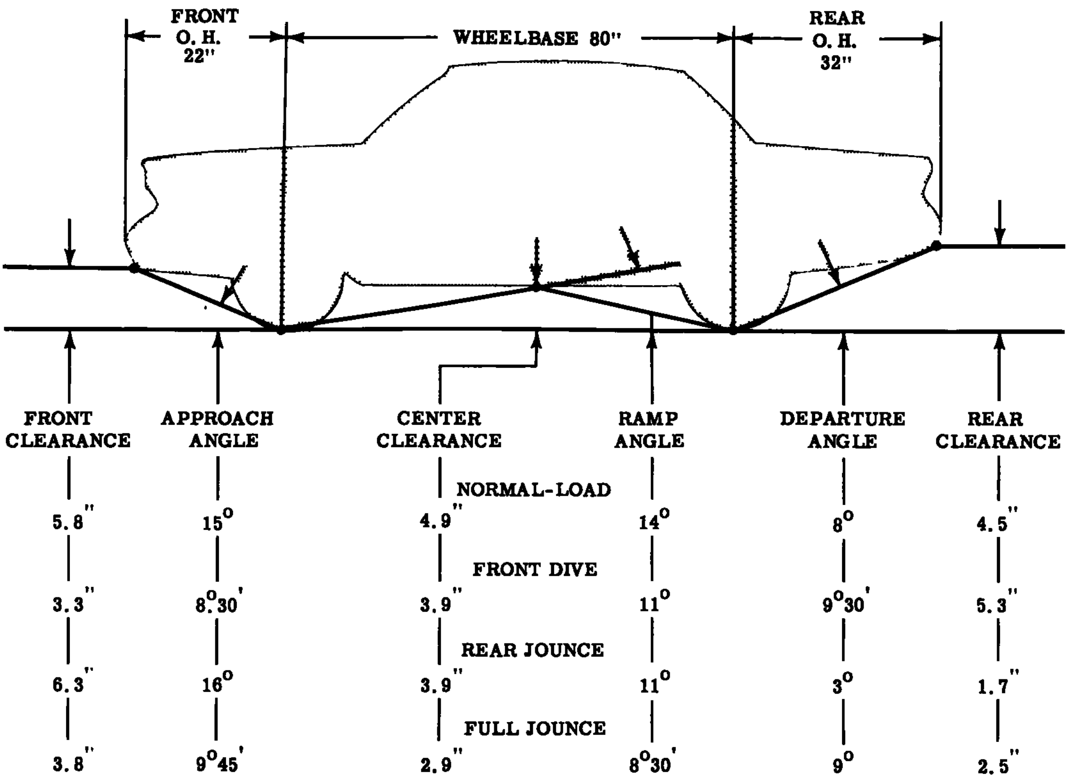
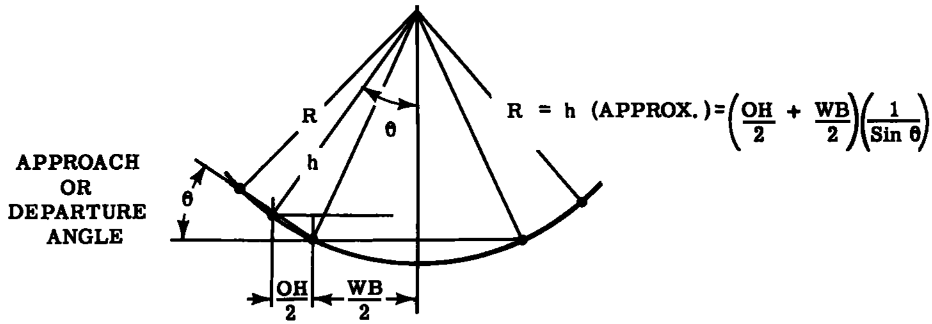
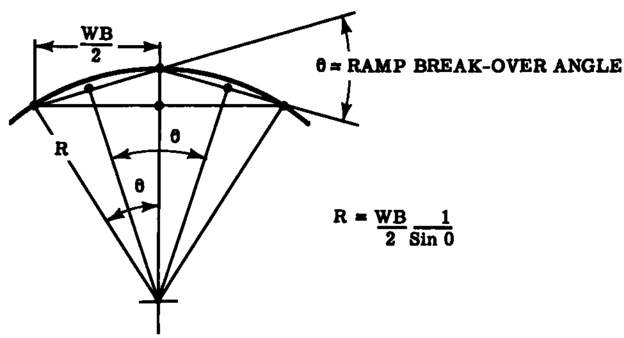



Figure 7. Composite shortest vehicle, clearance dimensions under various conditions.




| SITUATION | θ | (OH/2 + WB/2) | Sin θ | RADIUS |
|---|---|---|---|---|
| **LONG VEHICLE** | | | | |
| NORMAL LOAD - FRONT INTERFERENCE | 15° | 7.3' | .2588 | 28' |
| NORMAL LOAD - REAR INTERFERENCE | 9°30' | 8.16' | .1651 | 50' |
| DIVE - FRONT INTERFERENCE | 9°30' | 7.3' | .1651 | 44' |
| JOUNCE REAR INTERFERENCE | 5°45' | 8.16' | .1002 | 81' |
| **SHORT VEHICLE** | | | | |
| NORMAL LOAD - FRONT INTERFERENCE | 15° | 4.25' | .2588 | 17' |
| NORMAL LOAD - REAR INTERFERENCE | 8° | 4.67' | .1392 | 34' |
| DIVE - FRONT INTERFERENCE | 8°30' | 4.25' | .1478 | 29' |
| JOUNCE - REAR INTERFERENCE | 3° | 4.67' | .05234 | 89' |

Figure 8. Sag vertical curve radii for overhang clearance.




| SITUATION | θ | Sin θ | WB/2 | RADIUS |
|---|---|---|---|---|
| **LONG VEHICLE** | | | | |
| NORMAL-LOADED | 7° | .1219 | 5.55' | 46' |
| DIVE - FRONT | 4°15' | .0741 | | 75' |
| JOUNCE - REAR | 4°15' | .0741 | | 75' |
| FRONT & REAR JOUNCE | 1°45' | .0305 | | 180' * |
| **SHORT VEHICLE** | | | | |
| NORMAL-LOADED | 14° | .2419 | 3.33' | 14' |
| DIVE-FRONT | 11° | .1908 | | 18' |
| JOUNCE - REAR | 11° | .1908 | | 18' |
| FRONT & REAR JOUNCE | 8°30' | .1478 | | 23' |

*NOTE: THIS CONDITION EXPERIENCED ON CREST CURVES ONLY UNDER UNUSUAL CIRCUMSTANCES OF LOADING AND PAVEMENT GEOMETRY.

Figure 9. Crest vertical curve radii for underbody clearance.

Although this will bottom the suspension, center clearance is never a problem on sag curves. The author's organization has been unable to produce center interference requiring a full jounce condition, except on one rather unusual railroad crossing. Front or rear jounce alone, however, is relatively easy to experience, as in jumping curbs or on steep driveways.

On the composite vehicles, as might be expected, center clearance is quite low, and can be troublesome. However, the most critical interference is at the rear, during a rear jounce condition. On driveways and ramps, the rear impact bars will strike, even though the center may clear.

What is perhaps surprising is that the shortest vehicle is even more critical than the long one under dynamic conditions. Rear clearances are especially affected by pitch, and the short wheelbase more than offsets the shorter overhang and smaller deflections.

The relative severity of the possible points of interference can be visualized most easily by determining the radii of sag curves (Fig. 8) and crest curves (Fig. 9) which will produce interference. The most critical condition is the rear overhang on short wheelbase vehicles under conditions of rear jounce. A sag vertical curve radius less than about 90 ft would bother the composite short car. The composite long car would experience the same trouble on a sag radius of 80 ft or less. Crest radii must be below about 75 ft before underbody scraping occurs on the long-low specimen, and then only under unusual conditions.

Because no self-respecting highway engineer would build a turnpike with a vertical curve having a radius as low as 90 ft, it is only on driveways and ramps where interferences might occur. And because it is difficult to measure radii in such places, the following checks are suggested to avoid interferences:

1. There should not be more than a 5 percent change in slope between any two 10-ft chords. Thus, the ramp over a 6-in. curb should be at least 10 ft long.
2. There should be no more than 1½ in. of clearance between the pavement and a 10-ft straightedge.

In conclusion, one significant point should be emphasized in the dimensional data reviewed. Although the names of the manufacturers were deleted from the curves, in very few instances was a critical extreme dimension found on the same make vehicle for more than two years in a row. A customer who finds his vehicle grounded with all four wheels firmly resting on nothing will be just as angry as the owner of a buggy with high clearance with all four wheels fallen off. His wrath will be directed as much at the manufacturer as at the highway commissioner, and no manufacturer with his eye on the road and his hand on his pocketbook wants that to happen.

As was implied earlier, the pavement still dictates the dimensions of the car, and probably will continue to do so as long as cars must travel on existing highways, and until highway designers and construction men can put out a completely new road system every two years, with a major face lift in between.

## *Discussion*

ELMER R. HAILE, JR., Highway Design Engineer, Bureau of Public Roads—McConnell has presented some interesting data on vehicle dimensions based on measurements of vehicles in his test fleet, and has arrived at minimum controls for use in the design of driveway profiles. In this discussion, additional data are presented on vehicle dimensions, and less stringent controls are suggested for driveway profile design.

The author's data indicate that most of the critical passenger car dimensions affecting underclearances have not changed appreciably in the last ten years. This is surprising to many, because popular opinion is that it is becoming increasingly difficult to negotiate private driveways in the newer cars without striking a bumper or a tailpipe.

The Automobile Manufacturers' Association has established standard methods of measuring dimensions. Trade journals publish these dimensions for each model year.

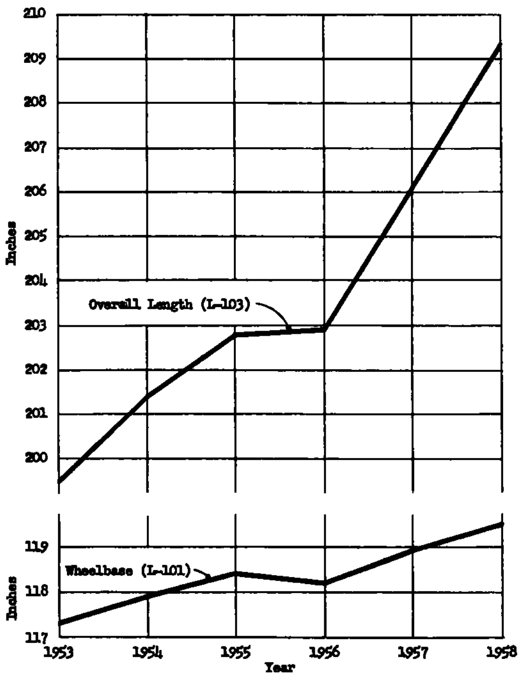



Figure 10. Weighted average wheelbases and over-all lengths of passenger cars.

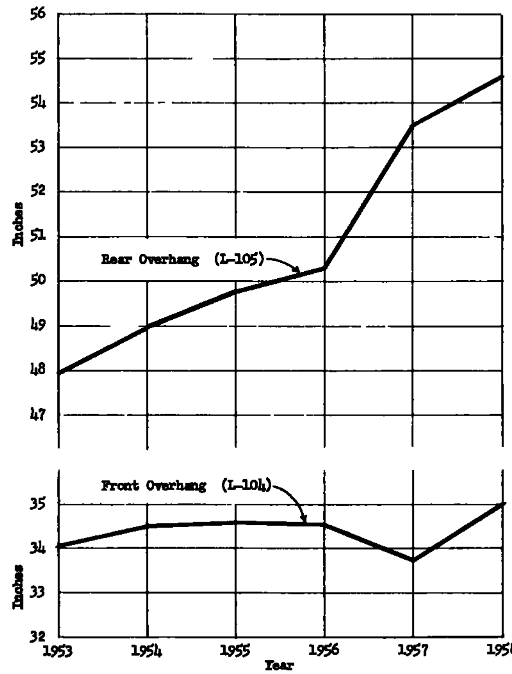



Figure 11. Weighted average overhang of passenger cars.

They also publish registration records of each make of car for each year. The average dimensions shown in the attached graphs (Figs. 10-12) were determined by weighting the dimension for each make according to the number of units registered during the year. This method gives an approximation of the average dimensions of vehicles placed on the road each year. It should be noted that the A. M. A. dimensions apply basically to the 4-door sedan or equivalent. Other body styles have dimensions that may differ from the 4-door sedan, but for the purpose of establishing a trend for successive years, it is believed that 4-door sedan dimensions serve the purpose. Seven-passenger limousines and imported cars are excluded from the averages because published data on such vehicles are incomplete.

The weighted average wheelbase of passenger cars is about 119 in., or about 9 in. longer than the average wheelbase of the cars in the test fleet described by McConnell. The value of 119 in. appears to be representative of the cars marketed in 1957, because the wheelbases of the 11 best-selling makes were in the range of

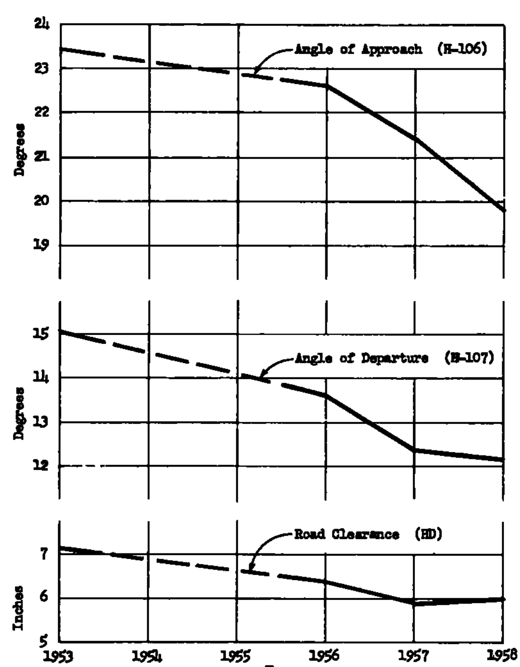



Figure 12. Weighted average road clearance and angles of approach and departure. (Values not computed for 1954 and 1955.)

115 to 133 in. These 11 makes (Ford, Chevrolet, Plymouth, Buick, Oldsmobile, Pontiac, Mercury, Dodge, Cadillac, Chrysler, and DeSoto) accounted for 92 percent of all 1957 cars registered (domestic and imported).

Figure 10 reveals a trend to longer wheelbases in the last 5 years; the aggregate increase is about 2¼ in. The average wheelbase for 1958 is tentative, because it is based on 1958 dimensions and 1957 registrations. The weighted average for 1958 will go down if short cars, such as the Rambler, appropriate a larger share of the market in 1958. Conversely, the average may go up if the Cadillac, for example, takes a larger portion of the market. Also included in Figure 10 is a graph of over-all lengths, which have increased about 10 in. in 5 years.

Figure 11 shows changes in overhang; front overhang has increased only 1 in. in the last 5 years, but rear overhang has increased nearly 7 in., or 14 percent, in the same period.

Figure 12 shows road clearances and angles of approach and departure. Road clearances have decreased 16 percent in 5 years. Angles of approach have fallen off 3.6 deg, a reduction of 15 percent. Angles of departure have decreased 2.8 deg, a reduction of 19 percent.

These graphs confirm what was already suspected, that dimensions affecting underclearances have been getting worse in recent years. This trend is unlikely to continue much longer. Sales volumes of imported cars and the small cars of American Motors are reportedly on the increase. Some of the major manufacturers may react to this report by making a few experimental reductions in length, wheelbase, or overhang. If this takes place, the critical dimensions may begin to show improvement, and the trend of the last few years will be ended.

Accordingly, it is believed that the dimensions on the composite car described by McConnell can be eased off a little. The composite car has an over-all length of 238 in. The longest 1957 car was the 224.6-in. Lincoln, and the longest 1958 car is the 229-in. Lincoln. The former can drive a sag vertical curve of 63-ft radius; the latter can take a sag vertical of 57-ft radius. The longest wheelbase, in both 1957 and 1958, is the Cadillac 60, which can negotiate a 52-ft radius vertical curve.

The critical dimension appears to be the angle of departure. The Dodge had the smallest angle in 1957, requiring a 73-ft radius sag vertical curve. Chrysler has the smallest angle in 1958, requiring a 74-ft radius. Therefore, it is suggested that a 75-ft minimum radius for sag vertical curves be used for design of driveways. In other words, there should be not more than 2 in. of clearance between the pavement and a 10-ft straightedge, or not more than a 6.7 percent change in slope between two successive 5-ft chords.

In a companion paper, Bauer (see succeeding paper) shows a minimum design of a driveway with ascending grade to lot (walk adjacent to curb). The 75-ft radius sag vertical curve suggested herein will be found to conform closely to the profile given in Bauer's Figure 9 except at the hump 3 ft right of the gutter.

As for crest vertical curves, it is suggested that a minimum road clearance of 5 in. be used for design, as most 1958 models have an underclearance of 5.3 in. or more. The composite car with a 5-in. road clearance can travel on a crest vertical curve with 45-ft radius.

It will be noted that a 45-ft radius curve conforms closely with Bauer's profile of a driveway descending to a lot.

In conclusion, it is suggested that the following minimum standards be used in the design of driveway profiles:

Sag vertical curves—75-ft minimum radius.
Crest vertical curves—45-ft minimum radius.

W.A. McCONNELL, Closure—In reviewing passenger car dimensions related to highway design, the author chose to present maximum, minimum, and average dimensions of the various makes of vehicles offered to the public, without regard to their market penetration, because these data reflect trends in automotive design philosophy. It is noted that the critical maxima and minima have remained virtually unchanged in recent years.

Weighted averages used by Haile, adjusted for the number of units of a particular make registered, reveal trends in public buying preference. Similarly, the trends for the three most popular makes plotted by Nagler (see p. ) show that the public has displayed a clear desire for the longer, lower, wider offerings. The popular makes have approached the extremes in dimension in order to remain popular, even, in several cases, to the extent of employing the identical body shell as their more expensive luxury line relations. People who own only one automobile must select a unit to accommodate their occasional maximum needs, rather than their average requirements.

The author is aware that the checks proposed for driveway profiles are stringent. They are intended to be suitable not only for the most popular vehicles of the present, but also for the more extreme vehicles of the present and future, under critical operating conditions. In designing automobiles, provision must be made for satisfactory performance under occasional extreme conditions as well as under average operation, just as highway designers build their bridges to support the heaviest anticipated load. No less stringent guide should be acceptable in highway geometrics.

It is not believed that public interest is served by setting minimum standards for new construction to meet only current average requirements. In the absence of better objectives, minimum standards tend to become standards. To protect the investment in facilities intended to be useful 20 to 50 years hence, it is unwise to adopt criteria which will not be suitable for the most extreme conditions which can now be foreseen.

# II. Street and Highway Design

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● FOR THE past several years, the automobile industry has been changing their design of cars, by making them lower and longer. On most makes and models of cars the underclearance has been reduced and both the wheelbase and over-all lengths have been increased to such an extent, that sufficient underclearance is not being provided for a safe and satisfactory entrance into many of the driveways throughout the country. This is especially true in the City of Cincinnati and like communities where topography is rugged and many steep driveway entrances, either ascending or descending from the main roadway must be used to gain access to the abutting property.

This discussion will deal with experiences in the City of Cincinnati, which experiences, it is presumed, are prevalent in many other areas and communities similarly situated.

The problem of insufficient underclearance of cars entering or leaving driveway entrances exists primarily in the suburban or residential districts, principally on streets which were improved many years ago before the automobile age or, at least, prior to the advent of present day styled cars. Many of these streets have high-crowned macadam roadways, rather deep gutters and often walks are constructed at a considerable height above the curbs.

Figure 1 shows the dimensions of underclearances, wheelbase, overhangs and over-all length of the model car which will be used in the illustrations which follow. As can be noted, this is one of the largest of the cars made.

Figure 2 shows a typical driveway profile where a high-crowned roadway and deep gutters exist. As a car enters the driveway (position 1), the front bumper will often strike the driveway ramp between the walk and gutter. When the car reaches position 2, with back wheels in the gutter, the rear bumper usually strikes the street paving because of the high crown, and the center of the car will drag or scrape over the walk. Often further trouble is encountered wherever the driveway ascends or descends on a steep grade after crossing the sidewalk. This situation occurs quite frequently in suburban areas and is a source of many complaints from users of the driveways involved. Obviously the trouble can be corrected only through extensive walk and driveway re-