PASSING PRACTICES ON RURAL HIGHWAYS

By C. W. Prisk
Assistant Highway Engineer, Public Roads Administration

SYNOPSIS

During the past three years the Public Roads Administration has conducted, as part of its traffic research program, field studies of vehicle-passing practice on selected sections of two-lane highways With the cooperation of the highway departments, a complete and detailed record has been made of over 20,000 passings in the States of Maryland, Virginia, Massachusetts, Illinois, Texas, California, and Oregon The information collected on 3,521 passings at eleven sites in four of these States has been analyzed

These 3,521 passings are of the simple type, one vehicle passing one other vehicle. Analysis of data for the multiple-type passings, which involve more than one passed or passing vehicle, is not sufficiently advanced to include in this report.

The simple passings were classified according to the manner in which the passing vehicle was affected by opposing traffic, as follows: (A) delayed start, (B) hurried return, (C) delayed start and hurried return, and (D) free moving passings with no opposing traffic It was found that the average distances used in the left lane by the passing vehicle for these four types were (A), 601 feet, (B), 601 feet; (C), 521 feet, and (D), 703 feet

Most passing vehicles desired to travel about 10 m p h. faster than the vehicles they passed but seldom made a passing before slowing to a speed within 5 m p h of that of the car ahead Passing distance was found to increase not only with the speed of the passed vehicle, but with the speed of the passing vehicle as well

Upon investigation of the spacings between the passed and passing vehicle immediately prior to and following the passing, it was found that the former is consistently lower, averaging 54 ft. as compared with 83 ft after passing. Both the "before" and "after" spacings increased only slightly with higher speed passings and, in all cases, about two-thirds of the spacings were at or below the average values.

Measurements of vehicle acceleration rates during the passing maneuver indicate the rather surprising fact that comparatively few vehicles are accelerated at the maximum rates of which they are presumably capable, even when passing in the face of oncoming traffic During the overtaking stage of a passing, almost all drivers accelerate their vehicles at rates several times higher than they use when returning to the right lane The average rates of 1 4 and 0 4 m p h per second for passings which are delayed at their start and hurried during the return are higher than those in the other three types of passings

The time spent in the left lane is an important factor in any determination of highway capacity. The data from the passing practice studies show that this time value increases with the speed of the passed vehicle and also varies considerably with the several types of passings

Summarization of the work done thus far consists in constructing a series of values of total space required for passing maneuvers at various vehicle speeds. Since the driver does not need to see this entire space along the roadway before starting to pass, these do not necessarily represent passing sight distance requirements. It is emphasized that the passing maneuver is an extremely flexible action and the driver can be expected, within certain limits, to control his passing in accordance with the sight distance restrictions present Further analysis of the simple and multiple types is expected to produce valuable sight distance design information

Hundreds of thousands of miles of two-lane highways have been and will undoubtedly continue carrying the lion's share of this Nation's vehicular travel. It is therefore highly important that the design of this facility be refined to a degree commensurate with its function

To promote the attainment of such a goal, the Public Roads Administration has conducted, as a part of its traffic re-

search program, a series of passing practice studies, believing that in the study of passing many significant facts relative to alinement, sight distance, and highway capacity woud be discovered.

The field work, carried on with the cooperation of a number of the State highway departments, was begun in 1938 and continued through the warm weather months of the following two years. In all, seven States were visited: Maryland, Virginia, Massachusetts, Illinois, Texas, California, and Oregon, and a total of about 21,000 passings was recorded at 32 level tangent locations. The reading of the field charts and summarization of the data have been a rather lengthy task and only recently has it been possible to transfer some of the data to punch cards for mass analysis.

Passings are of two basic types, simple and multiple. The simple passing is one vehicle passing one other vehicle. The multiple passing is a maneuver in which more than one passed or passing vehicle is involved. The discussion presented here deals with 3,521 passings of the simple type which have been analyzed in quite some detail. 2,649 passings of this total were begun and completed within the limits of the test section. For the other 872, more than half the maneuver was made within the section. Eleven of the 32 locations and four of the seven States are represented.

The passing-study equipment records speeds of all vehicles for each 50 ft. of a half-mile section, gives indication of the direction and lane in which the vehicles move, and their spacing at any point. Detailed description of the equipment, field techniques, and a report on progress being made in analyzing the data have been published.[1]

PASSINGS SEGREGATED INTO FOUR GROUPS

Table 1 shows the four main groups into which the passings were divided, A, B, C, and D, and the distance used in the left lane by the passing vehicle under three different conditions of pavement and visibility. The number of passings in each group is also indicated. The criterion for classifying passings into these four groups was the manner in which the passing vehicle was affected by opposing traffic.

The "A" passings are those whose start was delayed because of a vehicle in the opposing lane. In the "B" class are passings in which the passing driver was hurried by an oncoming car during his return to the right lane. The "C" group contains passings that have both features, a delayed start and a hurried return. The passings not hindered by opposing traffic are in the "D" section of the table.

Now, what about the passing distance used by drivers in these four groups? The "A" and "B" groups have the same average, 601 ft, and apparently the effect of a delay in starting a passing is the same as a hurried action on the return. The "C" type averages 521 ft. in the left lane, about 80 ft. less than the "A" and "B" groups. The passings which are not hindered in any way by opposing traffic show the longest average passing distance, 703 ft. A relatively small sample is available for passings on wet pavement and under nighttime conditions with dry pavement, but it appears that the latter of these two factors tends, either directly or through its influence on speed, to reduce passing distance considerably.

In order to learn more concerning the environment in which passings occur, a study was made of the speeds of the principal vehicles involved. The bar

[1] E. H. Holmes, "Procedure Employed in Analyzing Passing Practices of Motor Vehicles," *Public Roads*, Vol. 19, No. 11, January 1939. Also abstract in *Proceedings*, Highway Research Board, Vol. 18, p 368.

O. K. Normann, "Progress in Study of Motor Vehicle Passing Practice," *Public Roads*, Vol. 20, No. 12, February 1940 Also *Proceedings*, Highway Research Board, Vol. 19, p. 206.

TABLE 1

FREQUENCY OF VARIOUS TYPES OF SIMPLE PASSINGS AND AVERAGE PASSING DISTANCE FOR EACH

Type of passing	Visibility and pavement condition									All passings[a]		
	Day—dry			Day—wet			Night—dry					
	No of passings	% of total passings	Average passing distance	No of passings	% of total passings	Average passing distance	No of passings	% of total passings	Average passing distance	No of passings	% of total passings	Average passing distance
A (Delayed start)	956	38 4	605	27	35 5	618	33	39 3	472	1,016	38 3	601
B (Hurried return)	328	13 2	607	14	18 4	564	7	8 3	418	349	13 2	601
C (Delayed start and hurried return)	681	27 4	522	16	21 1	550	18	21 4	472	715	27 0	521
D (Free moving)	524	21 0	706	19	25 0	653	26	31 0	669	569	21 5	703
All types	2,489	100 0	604	76	100 0	603	84	100 0	529	2,649	100 0	601

[a]Begun and completed within the test section

graphs presented in Figure 1 show this information for the A, B, C, and D groups. The following facts relative to vehicle speed are significant.

1. The average passing driver wants to travel approximately 10 m p h. faster than the vehicle he passes and about 6 m p.h. faster than the average speed of all traffic.
2. The passing vehicle, on the average, slows down before passing to within 5 m.p.h of the speed of the vehicle to be passed.
3. The normal or desired speeds of the passed and passing vehicles are approximately the same as their average speeds during the passing.
4. There is no appreciable change in the speed of the passed vehicle during the passing
5. The average maximum speed attained by the passing vehicle during the maneuver is 3 to 4 m p h above its normal driving speed and about 10 m p h. higher than the average for all traffic on the highway.

CUMULATIVE DISTRIBUTION OF PASSING DISTANCES

Figure 2 shows passing distance data for approximately 2,500 complete passings recorded during ideal visibility and pavement conditions The average distance required to pass, which means the distance the passing vehicle occupied the left lane, was 604 ft It will be seen that about one-third of the drivers took more than this distance. Interesting too, is the condition at the lower end of the curve where 10 percent of the passing drivers

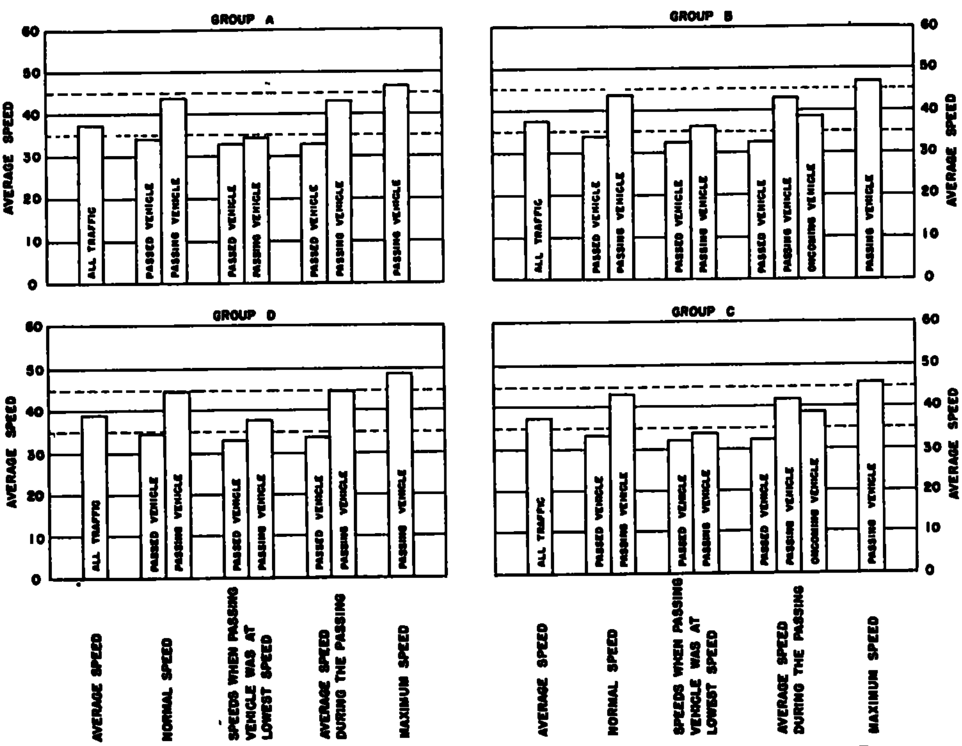

Figure 1. Average Speeds of All Critical Vehicles in the Four Passing Groups

used less than 325 ft. One percent, or very few, stayed in the left lane more than 1,400 ft

These are the simple type passings and were of course recorded under widely varying traffic conditions. It is therefore necessary to consider the effects of these conditions on the passing maneuver.

PASSING TIME INCREASES WITH SPEED OF THE PASSED VEHICLE

The time values shown in Table 2 for the various types of passings are of primary significance in any study of high-

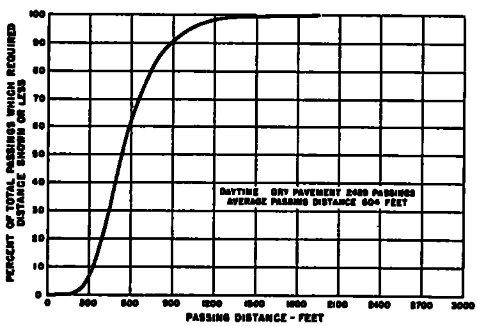

Figure 2. Cumulative Distribution of Distances Passing Vehicle Used in the Left Lane.

way capacities. As might be expected, the "C" passings have the lowest average time value, 8.6 sec., as compared with 9 6 sec. for all types combined. It will also be observed that there are definite increases in time with the higher speeds. The fact that the time used to pass was, in most cases, shorter when the speed of the passing car was 10 m p h. above that of the passed vehicle is also worthy of mention. It should be remembered, of course, that these time values are not equal to the time spacing required between vehicles in the opposing lane for the passing. If an approaching car travels at the same speed as the passing vehicle, a spacing at least twice these values will be required.

PASSING DISTANCES VARY WITH SPEED OF PASSED AND PASSING VEHICLE

Another phase of the analysis consisted in segregating passings by the speed of the passed and the passing vehicles. Figure 3 illustrates how passing distances change with speed. Eighteen different 10-m.p h speed group combinations are shown. The speed of the passed vehicle is shown at the extreme top and the speed of the passing vehicle is on each bar. The height of each bar represents the passing distance The lengthening of passing distances with increases in speed of the passed vehicle is plainly seen. It will also be noted that the passing distance gets longer as the difference in speed between the passed and passing vehicle increases. Seventy-five percent of the passings are included in the groups which have a difference of 10 m.p h. between the passed and passing vehicles. Only 13 percent of the passings have an average speed group difference of 20 miles per hour or more between the passed and passing vehicle

SPACING BETWEEN PASSED AND PASSING VEHICLES

Vehicle spacings between passed and passing vehicles at various stages of the passing maneuver is another part of the analysis which has received consideration. Spacings were measured from front to front of vehicles and all distances mentioned here as spacings should be interpreted in that way.

Figure 4 shows cumulative distributions of spacings for all types of passings at the encroaching point and at the end of the passing. It will be seen that the spacing between vehicles just as the passing vehicle started into the left lane was much less than the spacing at the end of the maneuver. The average spacing value at the start was only 54 ft as compared with 83 ft. at the end. Twenty percent of the passing drivers allowed a spacing of

TABLE 2

TIME PASSING VEHICLE SPENT IN THE LEFT LANE FOR VARIOUS SPEEDS OF THE PASSED VEHICLE AND VARIOUS TYPES OF SIMPLE PASSINGS (DAYLIGHT — DRY PAVEMENT)

Average speed of passed vehicle	Type A (Delayed start)				Type B (Hurried return)				Type C (Delayed start and hurried return)				Type D (Free moving)				Types A, B, C, and D, combined			
	All passings		Passing veh 10 m p h faster than passed veh		All passings		Passing veh 10 m p h faster than passed veh		All passings		Passing veh 10 m p h faster than passed veh		All passings		Passing veh 10 m p h faster than passed veh		All passings		Passing veh 10 m p h faster than passed veh	
M P H.	No	Av time	No	Av. time	No	Av time	No	Av time	No	Av time	No	Av time	No	Av time	No	Av time	No	Av time	No	Av time
0 – 19	24	8 7	15	9 3	13	8 1	4	6 7	11	7 7	3	7 1	9	10 0	2	7 6	57	8 6	24	8 4
20 – 29	260	8 8	209	8 7	88	8 9	65	8 7	241	8 0	194	8 0	143	9 9	91	10 0	732	8 8	559	8 7
30 – 39	531	9 8	425	9 5	165	9 8	119	9 4	343	8 8	278	8 7	246	11 0	172	11 1	1,285	9 8	994	9 5
40 – 49. .	132	10 9	86	10 4	50	11 8	31	10 8	80	9 4	60	9 2	105	11 8	74	11 4	367	10 9	251	10 4
50 – 59	8	10 5	5	11 0	2	9 3	2	9 3	1	8 4	1	8 4	7	9 6	7	9 6	18	9 9	15	9 9
All speeds combined.	955	9 7	740	9 4	318	9 8	221	9 3	676	8 6	536	8 5	510	10 8	346	10 8	2,459[a]	9 6	1,843	9 4

[a]Does not include 30 passings in the "day-dry" group for which data were not available

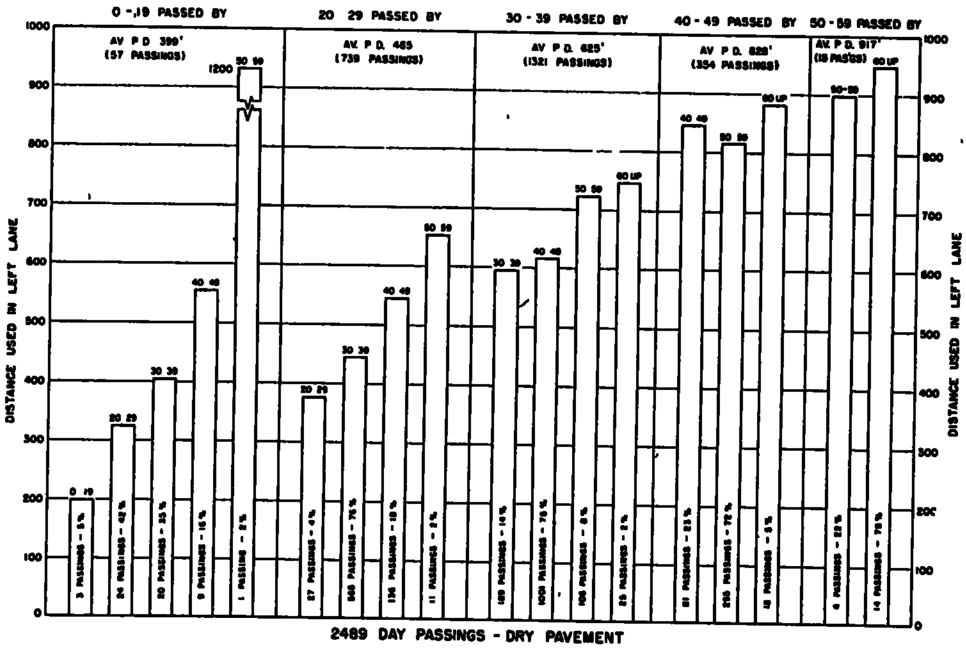

Figure 3. Left Lane Passing Distances for Various Speeds of Passed and Passing Vehicles

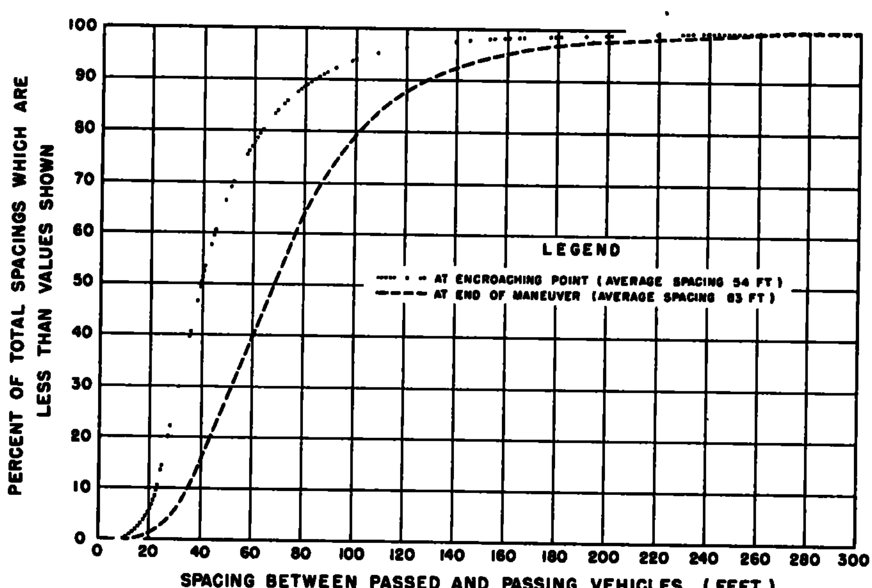

Figure 4. Cumulative Percentage Distribution of Spacings between Passed and Passing Vehicles at Start and Finish of Passing Maneuver (All Speeds—All Types of Passings).

less than 28 ft to the car ahead. The summation of the rear and forward spacings is of course equal to the space interchange, or the distance gained by the passing car relative to the passed car. This was also a minimum in the "C" group where the drivers had an average of 116 ft of space interchange

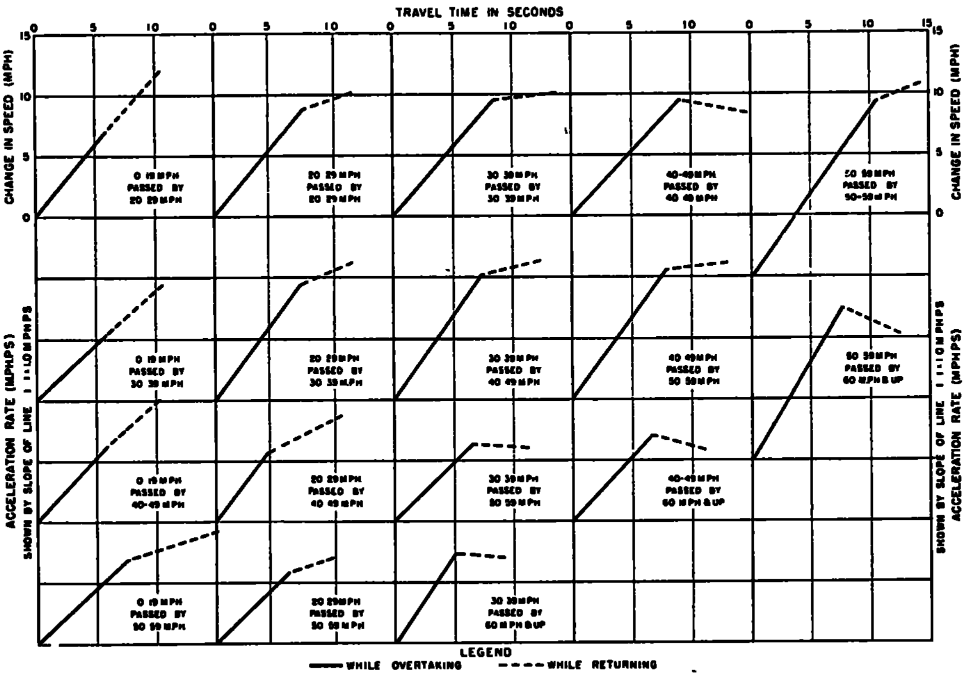

Figure 5. Average Acceleration Rates of Passing Vehicle (All Passings)

ACCELERATION RATES OF PASSING VEHICLES

Another factor of considerable significance in any study of passing practice is the acceleration rate of the passing vehicle Various measurements have been made of acceleration rates, maximum, and so-called "normal," but there has been no great certainty regarding the rates which are used by the average driver on rural highways while making a passing maneuver.

Figure 5 shows the average acceleration rates of passing vehicles for passings in the various speed groups. The abscissae represent time in seconds from the start of the passing and the ordinates are average speed change values for the passing vehicle during the overtaking and returning halves of the passing The rates for the overtaking and returning halves of the passings are each indicated by the slope of the lines. A 1:1 slope is equivalent to a rate of one mile per hour per second The solid lines are for the overtaking period and the dotted lines for the returning period.

It will be observed that the rates for vehicles passing the 0-19-m p h. cars are nearly uniform throughout the passing As the speed of the passed vehicle increases, however, there is a definite drop in the returning acceleration as shown by the reduced slope of the dotted lines, and in some cases, the passing vehicle is actually decelerating slightly. The average overtaking acceleration varies very little

with speed, ranging from about 1.0 to 1 6 m.p.h. per sec.

The net acceleration rate for the entire passing falls off slightly as the speeds of the vehicles increase. This is not unexpected but it is rather surprising to find that so few vehicles were accelerated at the high rates of which they are presumably capable. For instance, the average net acceleration rates of all vehicles traveling 30-39, 40-49, and 50-59 m.p h. and passing vehicles going 10 m p.h. slower were only 1.0, 0 8, and 0.9 m.p h. per sec., respectively. Where the passing vehicle was hurried by opposing traffic, these net values were still only 1.2, 1.0, and 1.0 m.p h. per sec

Figure 6 shows cumulative distribution curves for the acceleration rates while overtaking and while returning. It will be seen from this that approximately 40 percent of all passing vehicles studied were actually decelerating during the latter half of the maneuver. Very few vehicles were accelerated at rates exceeding 2.5 m.p.h. per sec.

RELATION OF AVERAGE SPEED OF ALL TRAFFIC TO PASSING DISTANCE

In listing the data for each of the passings, the average speed of all vehicles traveling through the half-mile section for the 10-min. period within which the passing occurred was recorded. This permits examination of the general effect of changes in speeds of all vehicles on the passing maneuver Figure 7 has been drawn to show this relation for each 2-m p h. increase in average speed. Aside from the one exception at the 46.5-m.p.h. point, there is a remarkable degree of uniformity in the increase in passing distance with increases in the general speed of all vehicles. The composite sample of average speeds of all traffic at each location has also been plotted on Figure 7 to show the variation in passing distance due to conditions other than speed peculiar to each location. Location 21 was a high-speed, moderate-volume, level-tangent section with extremely long sight distance, conditions usually associated with long passing distance. Although the volume

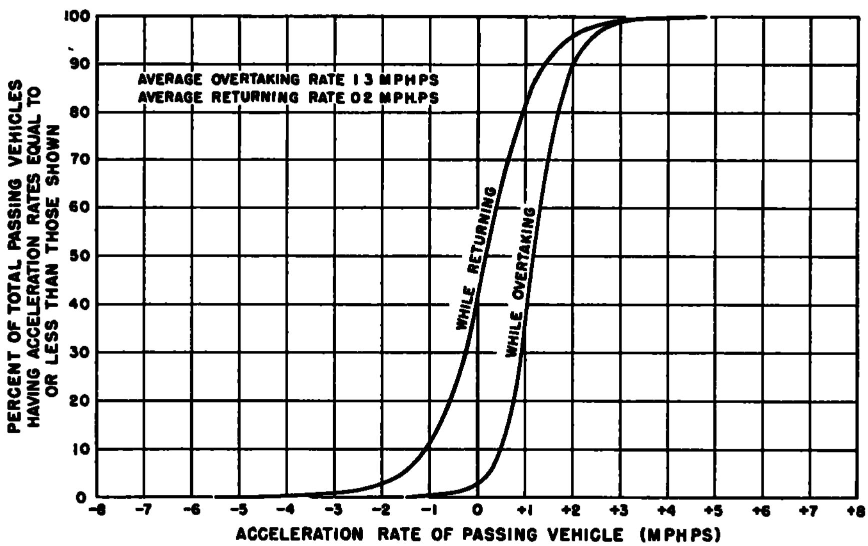

Figure 6. Cumulative Percentage Distribution of Acceleration Rates

was moderate, averaging 500 vehicles per hour, it was relatively light in the direction opposing the passings, 160 vehicles per hour. This undoubtedly accounts for the apparently excessive passing distance value on the 46 5-m.p.h. point. On the average, there appears to be an increase of approximately 19 ft in passing distance with each mile-per-hour increase in the average speed of all traffic.

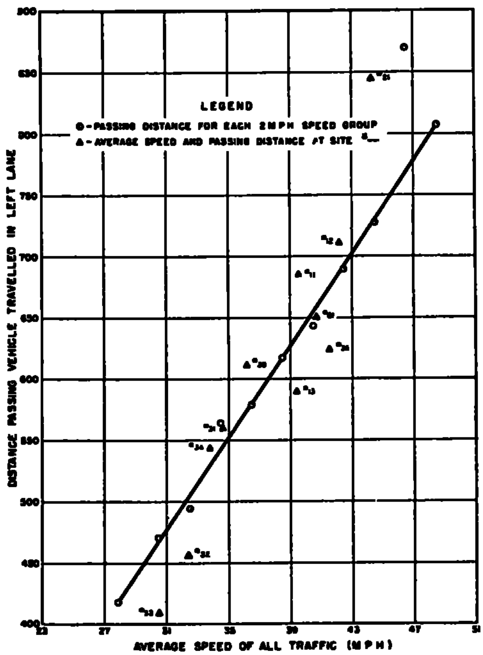

Figure 7. Relation of Average Speed of All Traffic to Passing Distance (2417 Passings—All Types).

THE ELEMENTS OF THE PASSING MANEUVER

The typical passing maneuver has been thought of in this analysis as being a composite of three separate elements, each of which represents a certain amount of road space. These elements have been called preliminary delay, occupation of the left lane, and interval for oncoming vehicle.

Based on characteristic operating data obtained from the passing-practice studies, Table 3 shows these elements for three popular speed group combinations in the "C" classification. A brief explanation of the elements will assist in better understanding this table.

Preliminary delay may consist of two factors. One is the driver's natural ability to perceive and react to his passing opportunities. The other concerns the driver's attitude and the attention he devotes to his driving. This second factor is merely recognized here but does not appear in the calculation for preliminary delay shown in the table. An average of 3½ to 4½ sec. is used by most drivers to get their vehicles from a low initial speed to the point of encroaching on the left lane These preliminary delay values shown as 3.7 to 4 3 sec., together with the observed acceleration rates of 1.41 to 1.47 m p.h. per sec, give distances of 150, 205, and 305 ft., respectively, for the three groups shown.

The distances shown for left-lane occupation are the least distances that would include 80 percent of the "C" group drivers. These values are 477, 670, and 789 ft., respectively, for the three speed groups. The values of space interchange included in these figures are 119, 139, and 147 ft., respectively. From 35 to 40 percent of this interchange is at the start of the passing and the remainder is the spacing at the end of the passing.

The last element, the interval for the oncoming vehicle, is the distance traveled by an opposing car while the passing vehicle is in the left lane, plus an allowance for clearance at the end of the passing. This clearance is from data that show that 90 percent of the drivers allow at least 110, 160, and 300 ft., respectively

The totals in round numbers, 1,200, 1,600, and 2,000 ft., represent the typical amount of space used for accomplishment of passing maneuvers at these speeds. These space values are not necessarily the minimum sight distance requirements. The passing driver does not need to be

TABLE 3

COMBINATION OF ELEMENTS OF THE PASSING MANEUVER

Speed of passing vehicle	30–39 miles per hour	40–49 miles per hour	50–59 miles per hour
Speed of passed vehicle	20–29 miles per hour	30–39 miles per hour	40–49 miles per hour
1. Preliminary delay	$\frac{(3.7 \times 1.41 + 25)}{2} \times 3.7 \times 1.47 = 150$ ft.	$\frac{(3.7 \times 1.43 + 35)}{2} \times 3.7 \times 1.47 + 205$ ft.	$\frac{(4.3 \times 1.47 + 45)}{2} \times 4.3 \times 1.47 = 305$ ft.
2. Occupation of left lane	$9.3 \times 34.9 \times 1.47 = 477$ ft.	$10.4 \times 43.8 \times 1.47 = 670$ ft.	$10.2 \times 52.6 \times 1.47 = 789$ ft.
3. Interval for oncoming vehicle	$(9.3 \times 36 \times 1.47) + 110 = 602$ ft.	$(10.4 \times 39 \times 1.47) + 160 = 756$ ft.	$(10.2 \times 40 \times 1.47) + 300 = 900$ ft.
Total distance for passing maneuver	1229 ft.	1631 ft.	1994 ft.
Rounded value	1200 ft.	1600 ft.	2000 ft.

able to see the entire stretch of roadway that will be used in his passing before he starts any more than he needs to see the entire length of a horizontal curve before driving beyond the point of curvature. What *is* absolutely essential is that he always have sufficient clear distance to maneuver his vehicle to the right lane when a restriction does appear in the opposing lane.

PASSING MANEUVER IS A FLEXIBLE ACTION

A study of the relation between left-lane passing distance and the sight distance available to the passing driver as he encroaches shows that the passing maneuver

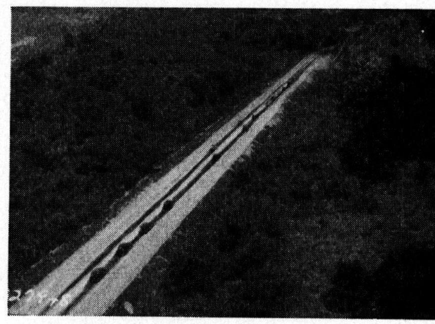

Figure 8. Long Sight Distance Section in California. Possible Passings Are Prevented by the Two Opposing Vehicles.

is really a highly flexible movement. For example, in the 30-39-m.p.h. group passed by the 40-49-m.p.h. group, it was found that drivers who had 750 ft. of sight distance at the encroaching point passed in 400 ft., those with 1,750 feet of sight distance in 650 ft.

Figure 8 is a view of a long sight distance section at one of the California locations. It will be observed that the two cars in the opposing lane are effectively preventing any one or more of the dozen drivers proceeding in the other direction from passing. It seems quite likely that the efficiency of such isolated long sight distance sections is somewhat overrated when they are compared with more fre-

quently occurring moderate length sight distance sections.

It is fairly obvious that the multiple-type passing, where more than one vehicle passes or is passed, requires more distance on the road for its execution. Just how much more distance is needed will become known when the analysis on the multiple type is completed. However, it is true—and this again demonstrates the extreme flexibility of the passing maneuver—that many a possible or intended multiple passing may, in the face of restricted sight distance due to oncoming traffic, quite readily develop into a simple passing.

Figure 9. Closeup View of Multiple-Passing Maneuver in Oregon

Figure 9 shows a closeup of a multiple maneuver with one car passing two others. Little imagination is necessary to visualize the relative ease with which the passing driver could, if necessary, drop back in line between the two cars he is passing and make this a simple passing.

SUMMARY

Thus far in the analysis, it has not been possible to explore all the relationships that exist between vehicle and highway factors at the time passings take place. However, it is considered that, aside from the study of multiple-type passings and an extension of the data presented herein to include more of the higher speed passings recorded in the far western States, a sufficient amount of major information has been summarized to establish certain significant facts regarding passing practice. These may be stated briefly as follows:

1. The distance required in the left lane by a passing vehicle depends to a large extent upon the degree of interference to which he is subjected by opposing traffic. Interference at the start or at the finish of the passing appears to have the same effect.
2. An overwhelming majority of passing drivers want to travel an average of 10 m.p.h. faster than the vehicle they pass. After slowing to within 4 or 5 m.p.h. of the speed of the passed car, they pass with an average speed of 10 m.p.h. greater, thus making their normal speed and their average passing speed substantially the same. The passed vehicle maintains an even speed during the passing.
3. The passing vehicle driver takes more time as well as distance to pass when his own speed increases and also when the speed of the passed vehicle increases.
4. The spacing between passed and passing vehicles immediately before passing is considerably less than between the same vehicles at the end of the passing even where no other traffic is involved. Both spacings increase only slightly with higher speeds and are reduced by the presence of traffic in the opposing lane.
5. Most vehicle drivers do not accelerate their vehicles at the maximum rates of which they are capable. Acceleration during the returning half of the passing is practically always less than during the overtaking half, and on the average is about one-fifth of the overtaking rate. The average

over-all acceleration rate for all passings observed was 0.85 m.p.h. per sec.

6. The passing maneuver is an extremely flexible action and drivers can be expected, within certain limits, to control the performance of their vehicles in accordance with the demands made upon them. The studies show that between 1,200 and 2,000 ft. of road space is used for certain typical passings. It is emphasized that these are not to be interpreted as necessary sight distances because the driver does not unqualifiedly commit himself to completing a passing the moment he begins to accelerate and turn toward the left lane. Many successful passings were observed where sight distance was much less. When it has been determined, through a more exhaustive quantitative analysis what sight distance values can be approached before the driver's ability to pass is seriously restricted, a source of valuable design data will be available. For the present, it seems reasonable to expect that sight distances of moderate length, frequently or perhaps continuously provided, may be found more effective than long sight distance sections that are irregular and isolated in their occurrence.