PROGRESS IN STUDY OF MOTOR VEHICLE PASSING PRACTICES

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SYNOPSIS

At the eighteenth annual meeting of the Highway Research Board in 1938, Mr. E. H. Holmes of the U. S. Public Roads Administration presented a paper describing the equipment and procedure employed in passing studies. At that time the equipment had been used on four study sections in Maryland and Virginia. During the past summer, studies have been conducted in cooperation with State officials in Massachusetts, Illinois, Ohio and Texas.

The detailed data for 1,635 passings from the studies in Maryland and Virginia show that 33 per cent of the maneuvers were multiple passings involving a total of 57.3 per cent of the passings that took place with an average hourly volume of 375 vehicles. This fact indicates the importance of studying multiple passing maneuvers as well as maneuvers in which one vehicle passes only one vehicle. Of the multiple passing maneuvers, 63.5 per cent were composed of maneuvers in which one vehicle passed, or was passed, by two vehicles. A very definite relationship was found to exist between the traffic volume and the number of passings per hour, and also between the traffic volume and the percentage of the total maneuvers that were multiple passings.

In nearly 85 per cent of the single passing maneuvers that took place when the traffic volume averaged 375 vehicles per hour, the passing vehicles slowed down to some extent before attempting to pass, and in 53.7 per cent the passing vehicle slowed down to the same speed as the vehicle to be passed.

Although a comprehensive analysis of the passings has just begun, indications are that the data derived from these studies will yield even more information relative to driver psychology and the design of highways for safe and uncongested movement of traffic than had been anticipated.

Knowledge of the manner in which highways are used is a prerequisite to improving their design so that they will more adequately serve highway users. A study of passing practices of motor vehicles is part of a research program recently initiated by the Public Roads Administration to supply information on the normal driving habits of vehicle operators.

During the fall of 1938 studies of the passing practices of motor vehicles were conducted on four sections of highway in Maryland and Virginia with special equipment developed by the Public Roads Administration. A report describing in detail the methods and equipment used, and the purposes of the passing practice studies, has been published.[1]

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

In cooperation with State highway officials, studies were conducted during the summer of 1939 in Massachusetts, Ohio, and Illinois, and studies are now being conducted in Texas. The program also includes studies in California and Oregon next spring. Upon completion of the field work, data will be available for normal passing practices under a wide variety of road conditions, geographically distributed to include any major differences in driving habits.

Several improvements have been made in the equipment to reduce the time required for installation on the study sections and to permit operation at night and on rainy days. The most important improvement has reduced the amount of work required in transcribing the field records to less than two-thirds of its former cost.

The detailed data for 1,635 passing maneuvers recorded during 37½ hours of operation on the four study sections in Maryland and Virginia are now ready to be placed on tabulating machine cards prior to starting the comprehensive analysis.

Although these 1,635 passings are but a small portion of the total number that will be obtained during this study, they illustrate the method of analysis and some of the facts with respect to passing practices and driver behavior that are being obtained.

passing distances and practices a study of multiple passing maneuvers as well as single passing maneuvers.

The most important multiple passing maneuvers are those in which one vehicle either passes or is passed by two vehicles. They compose 63.5 percent of the multiple maneuvers or 46.6 percent of the passings accomplished by multiple maneuvers. Three vehicles passing four other vehicles was the most complicated multiple passing maneuver recorded.

TABLE 1

TYPES OF PASSING MANEUVERS OBSERVED

(Average volume 375 vehicles per hour)

Type of maneuver	Maneuvers made		Passings accomplished	
	Number	*Percent*	*Number*	*Percent*
Single	1,096	67.0	1,096	42.7
Multiple				
1 vehicle passing 2 vehicles	181	11.1	362	14.1
2 vehicles passing 1 vehicle	161	9.8	322	12.6
1 vehicle passing 3 vehicles	63	3.9	189	7.4
2 vehicles passing 2 vehicles	42	2.6	168	6.5
3 vehicles passing 1 vehicle	30	1.8	90	3.5
1 vehicle passing 4 to 6 vehicles	31	1.9	136	5.3
2 vehicles passing 3 to 5 vehicles	13	0.8	102	4.0
All other multiple passings	18	1.1	99	3.9
Total multiple	539	33.0	1,468	57.3
Grand total	1,635	100.0	2,564	100.0

The first classification of the passing maneuvers was made by separating them into the single and multiple passing types. In the single passing maneuvers, one vehicle passed one other vehicle, while in the multiple passing maneuvers, two or more vehicles either passed or were passed by one or more vehicles.

Table 1 shows that 57.3 percent of the passings were accomplished by multiple maneuvers although there were only about half as many multiple maneuvers as there were single maneuvers (one passing two other vehicles accounts for two passings). These figures illustrate the importance of including in a study of

Figure 1 shows, for various hourly volumes, the percentage of the total number of maneuvers and passings ac-

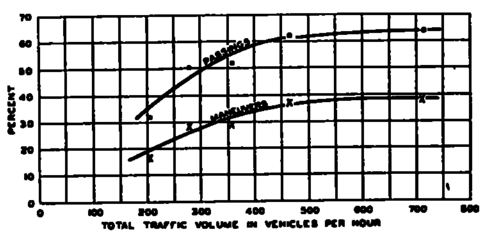

Figure 1. Percentage of Total Passing Maneuvers and Total Number of Passings That Were Accomplished by Multiple Passing Maneuvers at Various Traffic Volumes.

complished by multiple passing maneuvers. At an hourly traffic volume of 200 vehicles, 35 percent of the total passings were accomplished by multiple maneuvers. At traffic volumes above 450 vehicles per hour this figure exceeds 60 percent.

Figure 2 shows the average number of maneuvers and passings observed per hour on the four half-mile study sections during various hourly traffic volumes. As expected, there is a marked increase in the number of passings as the volume increases. These are the number of passings accomplished per hour and not the number of passings that would have been made had all vehicles that desired to pass been able to make passing maneuvers.

One vehicle usually passes another because the driver wants to travel faster than the other vehicle is moving. Within the half-mile study section it was generally possible to determine the speed that the driver of the passing vehicle desired to travel by noting his speed either before slowing down prior to making the passing maneuver or after the maneuver was completed.

TABLE 2

SINGLE PASSINGS CLASSIFIED BY THE SPEED OF THE PASSED VEHICLE AND THE DESIRED SPEED OF THE PASSING VEHICLE

Desired speed of passing vehicle in miles per hour faster than speed of passed vehicle	Speed of passed vehicle in miles per hour					
	20 and under	21-30	31-40	41-50	Over 50	Total
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5 and under	...	1.9	11.2	7.8	0.3	21.2
6-10	...	4.0	18.8	7.1	0.3	30.2
11-15	0.4	6.7	17.6	5.5	0.3	30.5
16-20	0.7	5.0	5.7	0.8	...	12.2
21-30	0.3	2.9	1.6	0.3	0.1	5.2
Over 30	0.3	0.2	0.1	0.1	...	0.7
Total	1.7	20.7	55 0	21.6	1.0	100.0
Average difference is speed between passed and passing vehicle (m.p.h.)						
	20.6	14.2	10.5	8.6	11.1	10.9

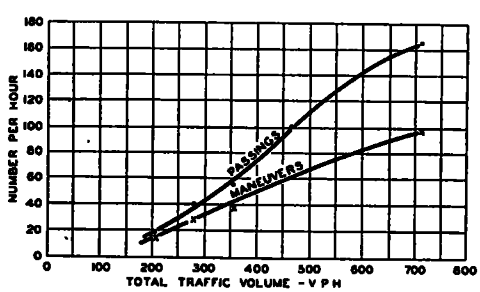

Figure 2. Total Number of Maneuvers and Passings Accomplished per Hour on one-half Mile Study Sections at Various Hourly Traffic Volumes.

Table 2 shows that in 55 percent of the passings the passed vehicle was traveling from 31 to 40 miles per hour. The speeds of the passed vehicles in the remaining passings were almost equally distributed between the 21 through 30 and 41 through 50 mile-per-hour groups.

This table also shows that 51.4 percent of the drivers that passed desired to travel less than 11 miles per hour faster than the passed vehicle and that the desired speed of 21.2 percent was less than 6 miles per hour faster. There is a marked decrease in the average difference between the speed of the passed vehicle and the desired speed of the passing vehicle as the speed of the passed vehicle increases. Besides showing the frequency distribution of the speeds of passed vehicles, these data indicate that drivers desiring to travel at a slightly higher speed than the vehicle ahead would rather pass the preceding vehicle when the opportunity presents itself than reduce their speed slightly and stay behind.

Of all the drivers that were able to accomplish single passing maneuvers on the study sections, Table 3 shows that 84.4 percent had to slow down before they could start to pass; 53.7 percent slowed down to practically the same speed as the vehicle they were going to pass and 16 percent slowed down to within 5 miles per hour of the speed of the vehicle they were going to pass. About one third had to slow down and stay behind the preceding vehicle until they could see that the road was clear for a sufficient distance ahead to permit them to pass, and 50.9 percent had to slow down and wait for an oncoming vehicle to pass before they could start the passing maneuver. The other 15.6 percent were not required to slow down prior to starting the maneuver. They may have had to slow down after completing the maneuver but they started the maneuver at their normal speed.

When the drivers of the passing vehicles had completed the passing maneuvers and returned to the right-hand lane, Table 4 shows that the left lane was clear for a distance of less than 500 ft. in 27 percent of the passings and that there was an oncoming vehicle less than 500 ft. away in 16.8 percent of the passings.

TABLE 3

PERCENTAGE OF VEHICLES MAKING SINGLE PASSING MANEUVERS THAT WERE DELAYED BEFORE STARTING TO PASS

(Average traffic volume 375 vehicles per hour)

	Delayed by insufficient sight distance	Delayed by oncoming vehicle	Total
	Percent	*Percent*	*Percent*
Slowed down to same speed as vehicle to be passed....	18.0	35.7	53.7
Slowed down to within 5 m.p.h. of the speed of the vehicle to be passed....	6.6	9.4	16 0
Slowed down, but not to within 5 m.p.h. of speed of vehicle to be passed....	8.9	5.8	14.7
Total delayed in starting maneuver....	33.5	50.9	84.4
Total not delayed in starting maneuver....	....	....	15.6
			100.0

TABLE 4

DISTANCE THAT DRIVERS OF PASSING VEHICLES COULD SEE THAT LEFT LANE WAS CLEAR AT THE TIME THE PASSING MANEUVER WAS COMPLETED

Distance that left lane was clear	Sight distance limiting factor	Oncoming car in view	Total
Feet	*Percentage of total maneuvers*		
Less than 500....	10.2	16.8	27.0
500 to 1,000.....	19.0	16.0	35.0
Over 1,000......	30.5	7.5	38.0
Total..........	59.7	40.3	100.0

The data for the passings in which the passing vehicle was not forced back into the right lane may not be very useful in determining minimum passing distances but they will show actual driving practices during unrestricted conditions. Driving practices during unrestricted as well as restricted conditions must be known when designing highways to fit the normal driving habits of vehicle operators.

The data obtained for each passing maneuver are illustrated by Figures 3 to 9 inclusive, each representing one of seven critical positions. All speeds, distances, time intervals and relative positions of each vehicle with respect to the other vehicles as shown in these figures were obtained from the data sheet for one passing maneuver.

Similar data have been compiled for the 1,635 maneuvers recorded on the study sections in Maryland and Virginia and also for 500 of the maneuvers recorded during the Massachusetts studies. It is not intended that this much detail be obtained for all the thousands of passings that will have been recorded when the scheduled field work is completed, but the factors that appear to be the most important as the analysis progresses will be taken from the field records for enough maneuvers to obtain a representative sample of each type of maneuver at a series of speeds for each available road condition.

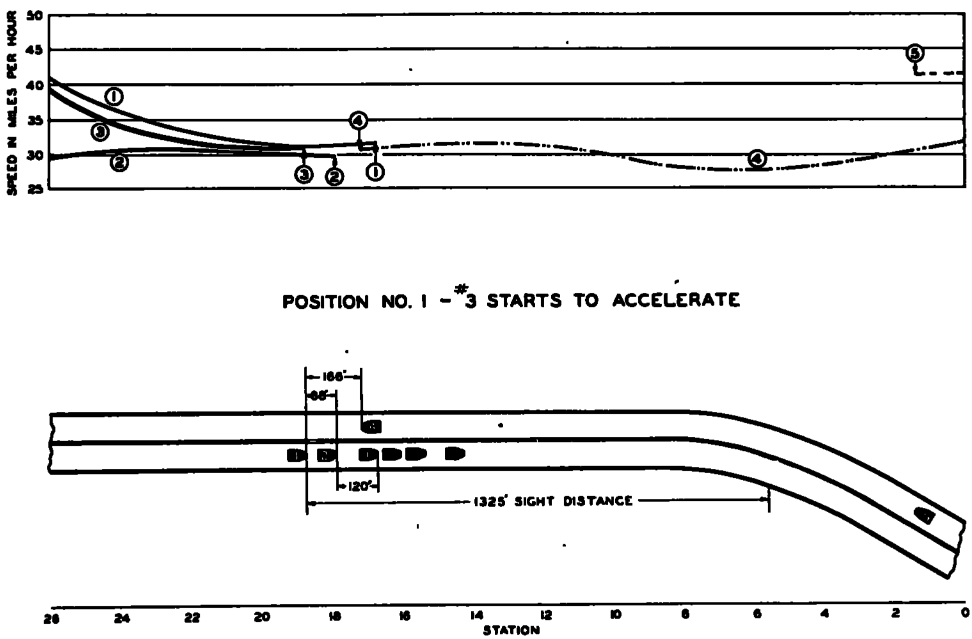

Figure 3

Figure 3 shows the position of each vehicle that is likely to affect the manner in which the passing maneuver is made. At this instant, vehicle No. 3 starts to accelerate in order to pass vehicle No. 2 and possibly the four vehicles ahead of vehicle No. 2, the closest one being vehicle No. 1, a distance of 120 ft. ahead of No. 2. All dimensions between vehicles represent the distances between the fronts of vehicles. Vehicles Nos. 4 and 5 are oncoming vehicles in the opposing lane of traffic, No. 4 being the vehicle met by No. 3 before encroaching on the left lane, and No. 5 being the first oncoming vehicle met by No. 3 after completing the maneuver. The space between No. 4 and No. 5 represents the "hole" available in the opposing lane of traffic.

At the top of Figure 3 is shown the speed of each of the five vehicles over the portion of the study section traversed up to this point. Vehicle No. 3 entered the section traveling about 40 miles per hour at a speed of 31 miles per hour and No. 5 at a speed of 47 miles per hour, but No. 5 cannot be seen by vehicle No. 3. The fact that vehicle No. 3 starts to accelerate at this point indicates that the driver has already decided to attempt to pass even though No. 4 is still 166 feet away.

In the second position, occurring 1.7 sec. later and shown by Figure 4, the fronts of No. 3 and No. 4 are parallel; No. 3 has accelerated to 36 miles per hour and is now 74 ft. behind vehicle No. 2. It is

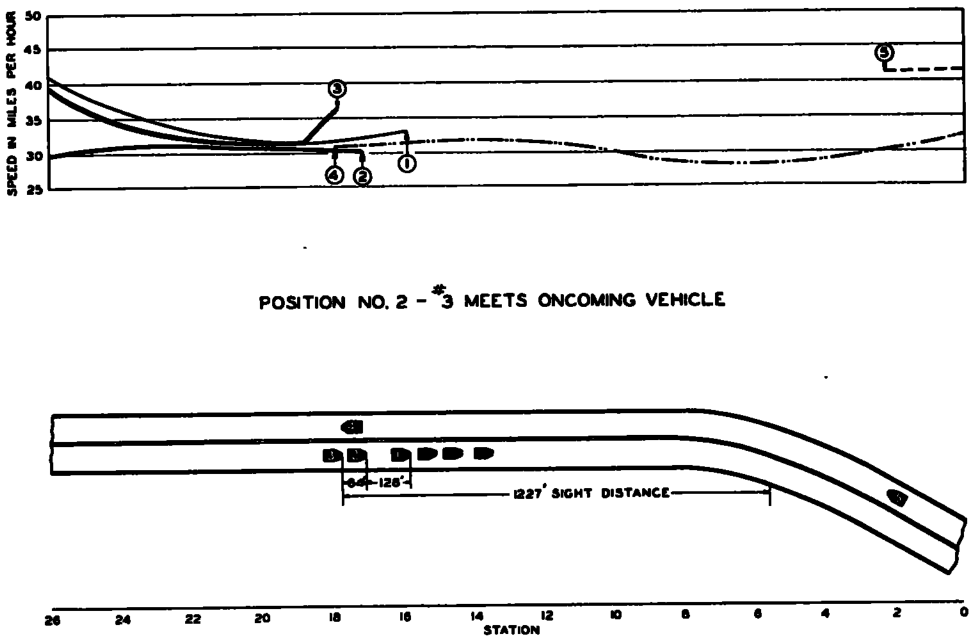

Figure 4

but has been required to slow down to 31 miles per hour, the approximate speed that No. 2 has maintained. (Table 3 indicated that 53.7 percent of the observed passing maneuvers were started after the passing vehicle had slowed down to the same speed as the vehicle to be passed.)

The data sheets for another passing maneuver indicate that vehicle No. 1 has just finished passing No. 2 and has also slowed down to a speed of about 31 miles per hour. Vehicle No. 4 is approaching immediately after this instant that the driver of vehicle No. 3 has his first opportunity to enter the left lane without hindrance from oncoming traffic (vehicle No. 5 still being out of sight).

In the third position, occurring 1.1 sec. later and shown by Figure 5, vehicle No. 3 first encroaches on the left lane while 63 ft. behind vehicle No. 2 and traveling 8 miles per hour faster than the vehicle to be passed.

In the fourth position, taking place 2.7

sec. later (Fig. 6), No. 3 is entirely in the left lane for the first time and is still 37 ft. behind vehicle No. 2. In the meantime vehicle No. 2, which has been traveling at a uniform speed throughout the first 900 ft. of the section, starts to accelerate. The driver evidently doesn't like the idea of being passed or unintentionally steps on the accelerator. He can't accelerate very long without hitting No. 1 but he can reduce the space between his car and vehicle No. 1 so that No. 3 will be required to crowd his way back to the right lane. Neither No. 2 nor No. 3 can as yet see the oncoming car No. 5.

Position No. 5 (Fig. 7) occurs 2.9 sec. after position No. 4, and the passing vehicle is now even with No. 2 and is no longer accelerating. Vehicle No. 2 has decelerated a little and the oncoming vehicle No. 5 is now in view.

From Figure 8, representing the sixth position of the maneuver, it is seen that the driver of the passing vehicle has decided not to try to pass more than one vehicle and is now cutting back into the "hole" between No. 1 and No. 2. This occurs 2.7 sec. after No. 2 and No. 3 were parallel. Vehicle No. 3 is traveling 10 miles per hour faster than vehicle No. 1.

Figure 9, the seventh position, 2.6 sec. later, shows that the passing vehicle completed the maneuver when 107 ft. from the oncoming car. After returning to the right lane, the speed of No. 3 decreased until it was below the speed of vehicle No. 1 and then increased to the same speed. All vehicles slowed down slightly going around the curve.

The acceleration and deceleration curve for the passing vehicle during the maneuver, as shown in Figure 9, indicates a maximum acceleration of 2.3 miles per hour per second. This is considerably lower than any rate that would be assumed in calculating the minimum passing distance under similar conditions.

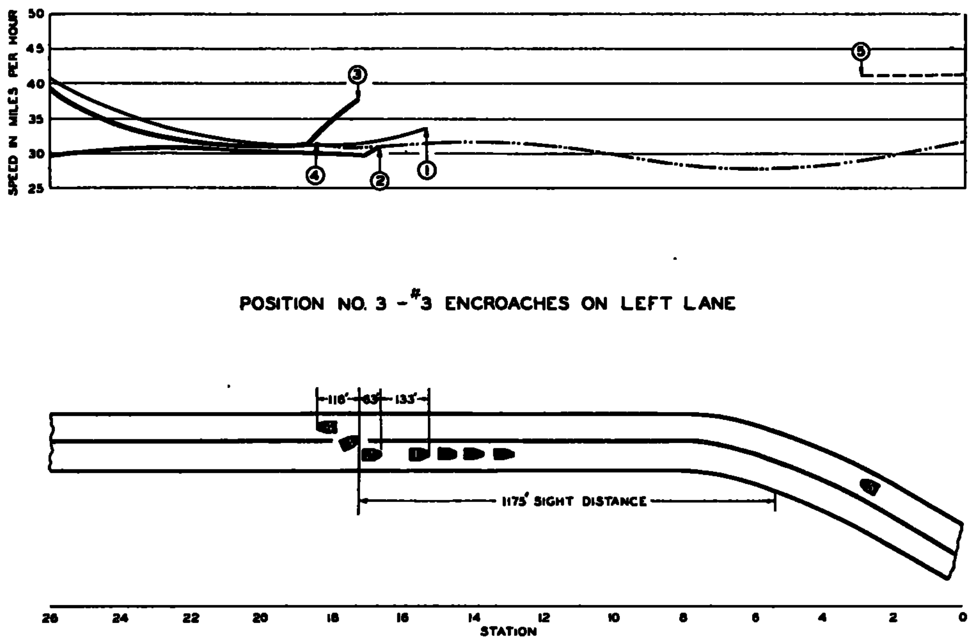

Figure 5

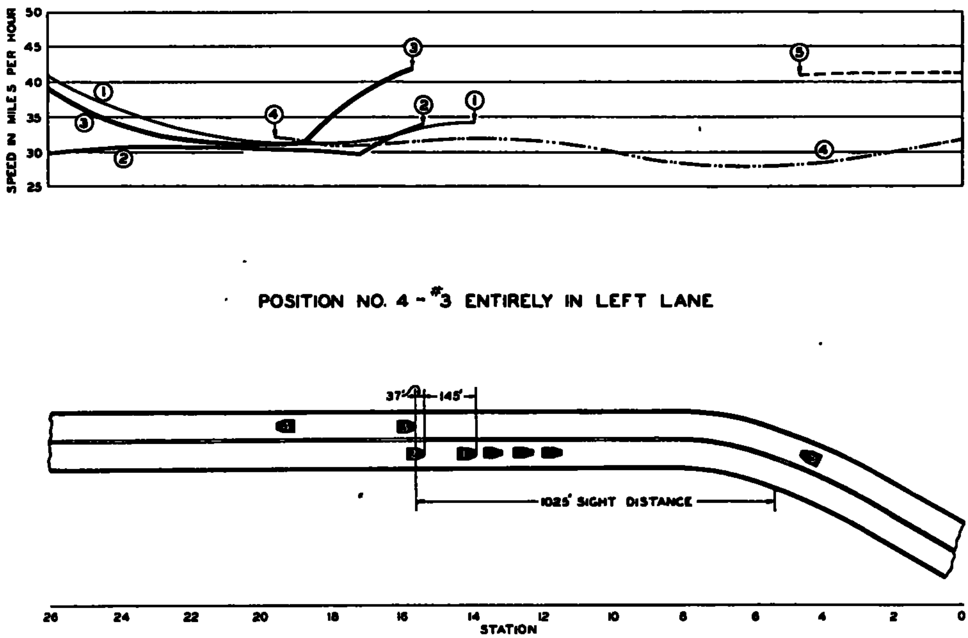

Figure 6

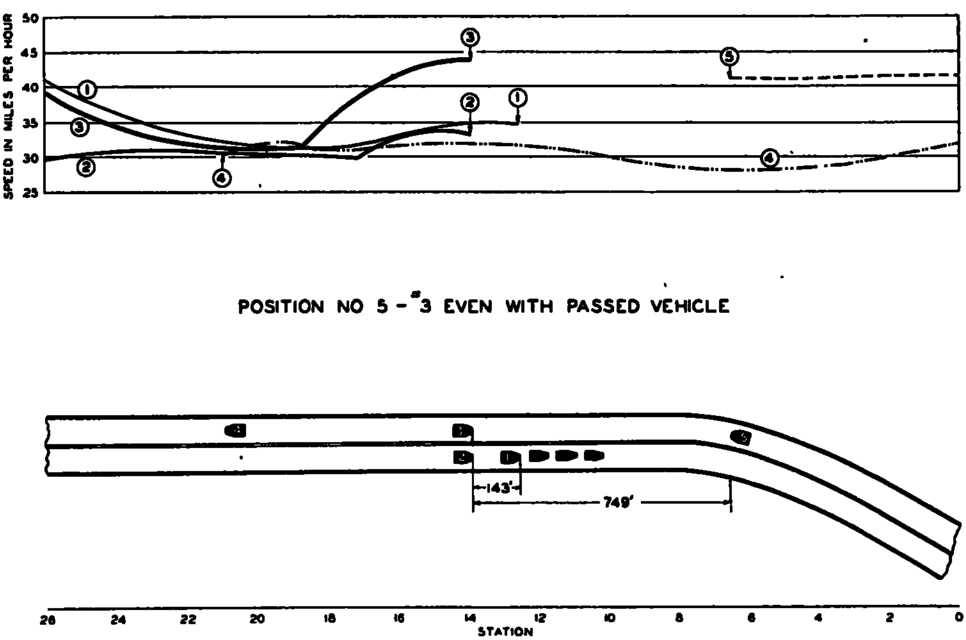

Figure 7

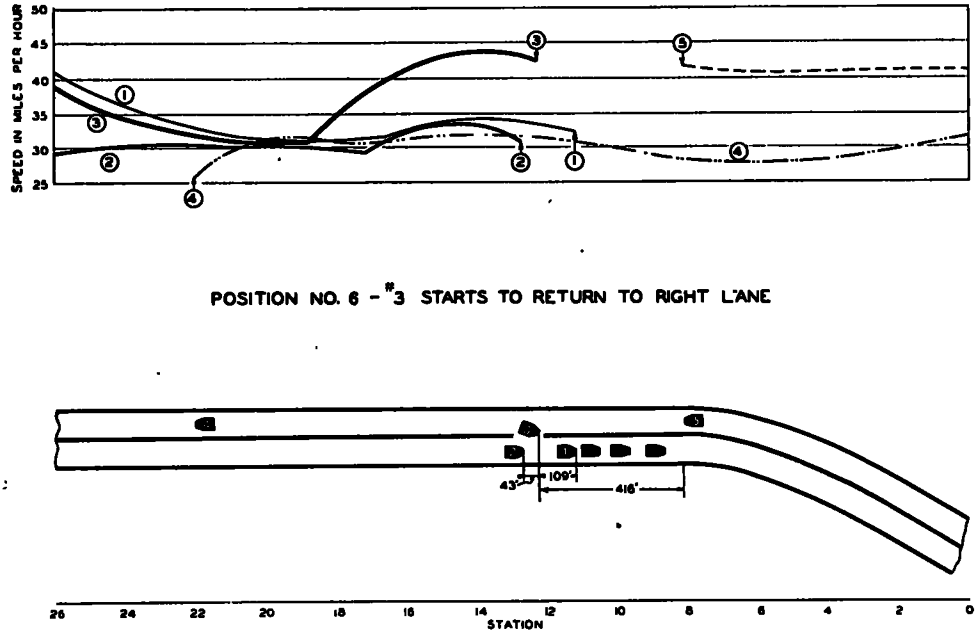

Figure 8

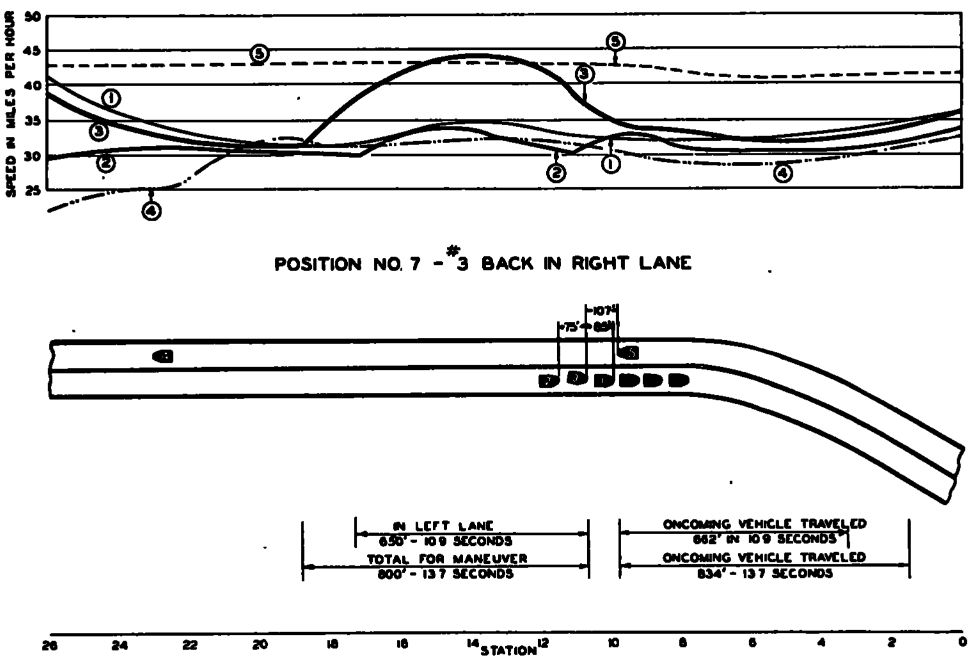

Figure 9

It required 13.7 sec. or 800 ft. to complete the maneuver. The passing vehicle spent 10.9 sec. and traveled 650 ft. in the left lane. The approaching vehicle traveled 834 ft. during the maneuver and 662 ft. while the passing vehicle was in the left lane. The net result of the passing maneuver is that vehicles No. 2 and No. 3 have reversed their respective positions. Providing there are sufficient passing sections and "holes" in oncoming traffic along the remaining portion of this highway, vehicle No. 3 might be able to pass two or three more of the cars of this group before getting to the next town, thereby arriving a little sooner than if no attempt were made to pass. It may be possible for No. 3 to pass all the preceding vehicles in this group at the next section of highway with a long sight distance, providing oncoming traffic does not interfere. Vehicle No. 3 could then continue at the desired speed until catching up with the next group of cars and might reach its destination somewhat sooner than by staying in line. It is evident that this section of highway with a sight distance of 1,900 ft. provided practically no relief from restricted travel conditions for this particular vehicle.

Such a detailed analysis of each passing necessarily takes more time than it would to obtain only such factors as the average vehicle speeds and the total passing distances, but the relative value of the results will more than compensate for the increased work.

There are so many variable factors involved in each passing that it would require almost an unlimited number of passings to obtain a representative sample of each type of passing maneuver possible by different combinations of variables. As the same variable appears in many different types of passing maneuvers, a breakdown of each passing into its component parts will permit a representative sample of each variable to be obtained from a much smaller total number of passings than if the breakdown is not made. The variables may then be recombined to form composite passings covering all types. It is in this respect that the method of analysis, made possible by the complete field records, will differ from other analyses of passing distances and practices that have been made.

The determination of distances involved in a passing maneuver is a relatively simple, though laborious, operation, but the determination of the effect of highway alinement and of driver psychology upon future design requirements is far more difficult. Even though sections of sufficient sight distance to complete individual passing maneuvers in safety are provided, they will not serve their purpose unless the drivers take advantage of their opportunities to pass. Figures 10 and 11 have been constructed from the data for single passings that took place at one particular study location, where vehicles traveling in either direction had maximum and minimum sight distances of 1,900 and 200 ft., respectively. To eliminate a number of variables, only the passings in which the passing vehicle started the maneuver while traveling at the same speed as the vehicle to be passed have been used.

In Figure 10, the passings have been classified by the maximum distance that the driver of the passing vehicle could see that the oncoming traffic lane was clear at the time he encroached on it. Three of the drivers encroached on the left lane when this distance was between 1,800 and 1,900 ft.; 8 encroached when this distance was between 1,700 and 1,800 ft., etc. In 85.5 percent of the passings, the distance was over 1,000 ft. and no maneuvers were started when this distance was less than 500 ft.

Sixteen vehicles encroached on the left lane before reaching the point of maximum sight distance. Fourteen were within 100 ft. of this point and 2 were between

100 and 200 ft. away. As the measured sight distance decreased to 250 ft. immediately before reaching the point of maximum sight distance, the eyes of the drivers of the 16 vehicles were either more than 4½ ft. above the pavement, or the drivers started the passing maneuvers knowing or hoping that the sight distance would increase while they still had a chance to return to the right lane in case an oncoming vehicle came into view. All 16 vehicles reached the point of maximum sight distance before getting entirely in the left lane.

The passings in each of these distance groups have been divided by a heavy horizontal line into two groups. The sight distance limited the distance that

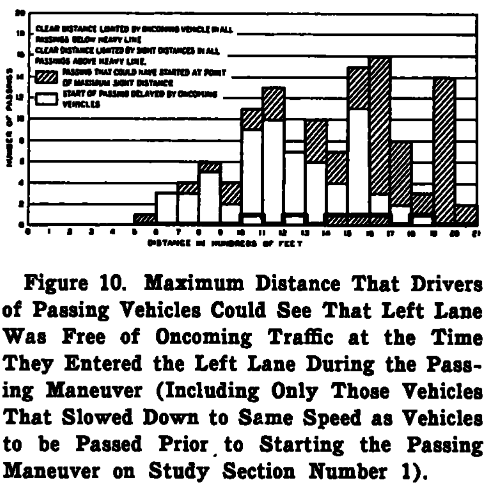

Figure 10. Maximum Distance That Drivers of Passing Vehicles Could See That Left Lane Was Free of Oncoming Traffic at the Time They Entered the Left Lane During the Passing Maneuver (Including Only Those Vehicles That Slowed Down to Same Speed as Vehicles to be Passed Prior to Starting the Passing Maneuver on Study Section Number 1).

the driver could see a clear left lane in all the passings above the heavy horizontal line. There was an oncoming vehicle in sight when the driver encroached on the left lane in all the passings shown below the heavy line. In only six of the passings did the driver encroach on the left lane when there was an oncoming vehicle in view and not a passing was started when the driver could see an oncoming vehicle within 1,000 ft. With no oncoming vehicle in view, passings were started when the sight distance was as low as 500 ft. but relatively few were started below 1,000 ft., there being a marked drop at this point.

The passings are further classified into two groups as determined by whether or not the driver had to wait for an oncoming vehicle before starting the maneuver. All of the passings that are cross-hatched represent maneuvers in which the passing vehicle was immediately behind the vehicle to be passed upon reaching the point of maximum sight distance and could have started the passing maneuver immediately. The areas that are not cross-hatched represent passings that could not have been started at the point of maximum sight distance, because the driver had to wait for oncoming traffic to pass before encroaching on the left lane. Sixty-one (49.2 percent) of the 124 passings that were made, could have been started immediately upon reaching the point of maximum sight distance. In the other 50.8 percent, the passing vehicle waited for an oncoming car after reaching the point of maximum sight distance before starting to encroach.

This one figure in itself contains an enormous quantity of information regarding driver behavior. The number of drivers that did not attempt to pass until after reaching a point where the sight distance was considerably less than it was where they could have started to pass is surprisingly large and offers excellent data for a study of combined perception and judgment time. One driver waited until the clear distance ahead decreased from 1,900 ft. to less than 600 ft. and then started the passing maneuver. He was fortunate, and completed the passing before an oncoming car came into view.

The horizontal scale of Figure 11 shows the clear distance ahead that the driver of each passing vehicle had at the time the maneuver was completed. For all the passings shown below the heavy horizontal line, this distance represents the clearance between the vehicle that had completed the passing and the first approaching vehicle in the opposing lane of traffic. For the passings above the heavy line, no oncoming vehicles were in view, so the horizontal scale represents the sight distances when the maneuvers were completed. In this figure, as in Figure 10, the passings that are cross-hatched represent maneuvers that could have started at the point of maximum sight distance. In those that are not cross-hatched, the driver had to wait for an oncoming vehicle before encroaching on the left lane.

Figure 10 showed that an oncoming vehicle was in view at the start of the

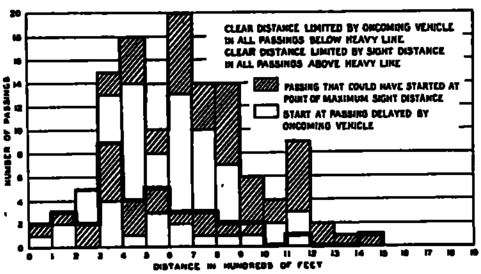

Figure 11. Maximum Distance That Drivers of Passing Vehicle Could See That Left Lane Was Free of Oncoming Traffic at Time Passing Maneuver was Completed. (Including Only Those Vehicles That Slowed Down to Same Speed as Vehicles to be Passed Prior to Starting the Passing Maneuver on Study Section Number 1).

passing in less than 5 percent of the maneuvers. Before the return was made to the right lane, there was an oncoming vehicle in view in about 30 percent of the maneuvers. There is a marked drop in the number of maneuvers that were completed with either a sight distance of less than 300 ft. or a clearance from the oncoming vehicle of less than 300 ft. Two of the five passings that were completed with an oncoming vehicle less than 200 ft. away could have been started when the maximum sight distance was available. The clearances for the vehicles involved in the two maneuvers below 100 ft. were 34 and 49 ft. At the time these vehicles started to return to their right-hand lane, the distances to the oncoming vehicles were 876 and 228 ft. respectively. The first vehicle could have started the maneuver when the sight distance was 1,900 ft. but did not enter the left lane until the sight distance had decreased to 1,675 ft. The second vehicle had to wait for an oncoming vehicle to pass and started the maneuver with a sight distance of 625 ft.

By similar analyses of the passings that occur on different sections, it will be possible to determine the relative effectiveness of different alinements in providing for passing requirements.

Up to the present time, the analyses dealt primarily with the passings that actually occurred on the study sections. Of equal importance are the passings that the drivers wanted to make but did not attempt because they felt that the available sight distances or the "holes" in the opposing traffic were not of sufficient length to complete the passing maneuvers in safety. No attempt has been made to take this particular information from the records, but it is believed that it can be obtained. So far, it has been possible to obtain all the factors that have seemed important in a study of passing distances.

From the rather meager results that have been presented it can be seen that these studies provide, for the first time, accurate information on what actually takes place in a stream of moving traffic. They are certain to provide extremely valuable information regarding the causes of accidents even though none may actually occur during the studies.