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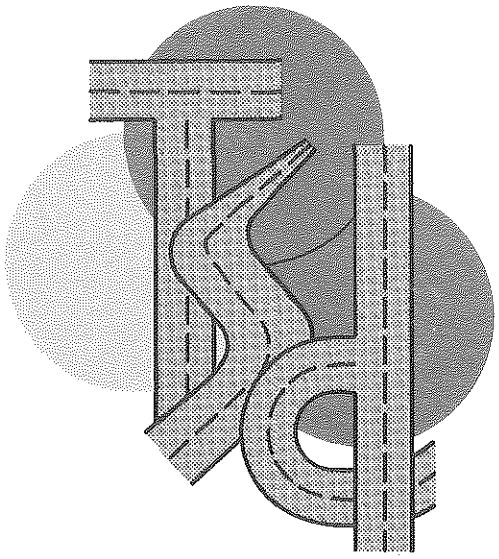
Report TSD-TR-105-69



TRAFFIC and SAFETY DIVISION

DEPARTMENT OF STATE HIGHWAYS
STATE OF MICHIGAN

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MICHIGAN DEPARTMENT OF STATE HIGHWAYS

A REVIEW OF THE MICHIGAN CRITERIA FOR MARKING "NO PASSING ZONES" - 1968

Report TSD-TR-105-69

By

Herbert Schoepke

Conducted by

Traffic Research Section
Traffic & Safety Division

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CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study is to review and evaluate the Michigan criteria for marking no passing zones. From the data obtained, the following recommendations are made:

1. The 85th percentile speed table be adopted on all state trunklines with special provisions for traffic control zones.
2. The target height be lowered to 3.75 feet.
3. A provision for extension of the ending of a zone be provided in the Michigan Manual when a dip or depression occurs within the minimum sight distance.
4. If the above recommendations are adopted, all zones should be re-established using specialized, highly trained and properly equipped personnel.

The recommended changes should provide adequate safety to the motoring public for many years.

PROBLEM

A review of Michigan's criteria for marking the "No Passing Zone" (hereafter referred to as zone) was made by the Traffic and Safety Division's Traffic Research Section with a subsequent report published in May, 1963. The report dealt with two major areas:

1. Driver eye height related to lower total overall height of modern motor vehicles.
2. Passing sight distances related to improved performance of new automobiles.

The report made three basic recommendations:

1. Lower target height criteria from 4 1/2 feet.
2. Sight distances in the Michigan Manual were sufficient and safe.
3. Criteria should be reviewed again in 1967.

In 1963, a Division committee was revising the Michigan Manual of Uniform Traffic Control Devices. Because of the 1963 report, the Manual was revised to require a target height of four feet. Upon lowering the target height, a resurvey was ordered in 1964 for all zones. After the resurvey, concern was expressed by traffic engineers in two subject areas: (1) target height used in setting zone ends, and, (2) accuracy of resurvey methods. The

accuracy was questioned due to some large differences between present and resurveyed zone endings. This review will investigate current criteria and will center mainly on those areas of concern expressed by the traffic engineers.

METHOD OF REVIEW

In May of 1967, District Traffic Engineers and Traffic and Safety Division Section Heads were invited to comment regarding establishment of zones by applying the new standards. It was felt that a simple review of the new criteria could be made if no adverse comments were received, and a check of the accident experience revealed no significant change. The new criteria could then be considered operating in an efficient manner. Answers were received from seven engineers with six commenting on resulting zone ends, and four commenting on minimum sight distance used. From comments received, it appeared each engineer had a different approach toward a remedy. The reaction to zone ends marked in the resurvey was unanimous. That is, an approaching vehicle would disappear from view in a dip or depression located within the 1,000 foot minimum sight distance.

Minimum sight distance remarks involved two subject areas: 1) on some recently improved two-way roadways, the 85th percentile speed exceeded 60 miles per hour, therefore, for traffic safety, a longer minimum sight distance should be

used, and, 2) the minimum sight distance used was often too long. The latter occurred in sections of roadways where roadside features resulted in speed control zones, or poor alignment caused the 85th percentile speed to be lower than 60 miles per hour. In this type of area, many zones were extended, adding large amounts of yellow line, thus, unnecessarily restricting the driver. One particular case is US-41 in Keweenaw County from northeast of Delaware to Copper Harbor. The speed control zone is ten miles in length. The resurvey crew, by using the 1,000 foot sight distance, established ten miles of continuous double lines. A minimum sight distance governed by the speed control zone would have resulted in several passing opportunities.

COMPARISON OF NO-PASSING ZONE CRITERIA

Elements Used In The Establishment Of Zones	Present Michigan Criteria	Former Michigan Criteria	National Manual Criteria
Minimum Sight Distance	On State trunkline highways, zones shall be established at all curves when the sight distance is 1000 ft. or less. On other streets and highways, zones shall be established on the basis of the following table: 85th Percentile Speed / Minimum Sight Distance 65 / 1100 60 / 1000 50 / 800 40 / 600 30 / 500	A no-passing zone is warranted if the sight distance becomes less than indicated in the following table: Average Speed / Minimum Sight Distance 50 MPH / 1000 45 " / 900 40 " / 800 35 " / 700 30 " / 600 25 " / 500 The average speed on all Michigan trunklines shall be assumed to be 50 MPH unless speed control zones are in effect. If, because of alignment the average speed is below 50 MPH, such locations shall be studied and the average speed determined for computing the proper sight distance to be used.	A no-passing zone shall be marked where the sight distance is equal to or less than the following listed 85th percentile speed: 85th Percentile Speed / Minimum Sight Distance 70 / 1200 60 / 1000 50 / 800 40 / 600 30 / 500
Target Height	Beginning of Zone 4' - 4' Ending of Zone 4' - 4'	Beginning of Zone 4½' - 4½' Ending of Zone 4½' - 2½'	Beginning of Zone 4' - 4' Ending of Zone 4' - 4'
Minimum Distance Between Zones	400'	400'	400'
Minimum Sight Restriction	200'	200'	200'
Minimum Length of Established Zone	500' Excess to be applied to the Beginning of Zone	400' Excess to be applied to the Beginning of Zone	500' Excess to be applied to the Beginning of Zone
Provision for Dip or Depression	None	The ending of a zone shall be extended at those locations where a dip or depression in the general grade is in evidence so that the 2½' target is visible at any place in this dip or depression.	None

COMPARISON OF CRITERIA

The present Michigan criteria when compared with the National Manual is the same except in one area. The Michigan Manual provides that all no passing zones shall be set at 1,000 foot minimum sight distances on state trunklines. The National Manual provides for the use of a speed table on all highways. In comparing the present Michigan criteria with the former Michigan criteria, several differences are found: 1) the minimum sight distance table was changed to the 85th percentile speed; 2) the minimum length of a no passing zone established was increased to 500 feet; 3) the target height or line of sight was lowered from 4 1/2 feet to 4 feet, and the 2 1/2 feet back sight was no longer used; 4) the difference, which had the great effect on the resulting zones, is the omission of a paragraph in the present manual providing for consideration of a dip or depression within the minimum sight distance. This type of dip or depression frequently occurs, and is of concern to traffic engineers.

CHECK OF CRITERIA APPLICATION

In September of 1967, a criteria application check was made of three areas in different districts. The areas selected were:

1. M-100 from M-78 to M-43 in Eaton County.
2. M-32 from Gaylord east for 12 miles in Otsego County.
3. M-113 from US-131 west to Kingsley in Grand Traverse County.

The data for the M-113 location was discarded due to malfunction of equipment while making the recheck. The data obtained in the other two areas is presented in the Appendix:

Tables I & IA - M-32 east of Gaylord

Tables II & IIA - M-100 from M-78 to M-43

Tables I and II for each area lists the length of existing paint line for each zone. The data in Tables IA and IIA is referenced to the ends of existing paint lines. If the reference figure is a plus number, the existing line is too short. If the reference figure is a minus number, the existing line is too long. The column headed "T from Survey Crew" represents the position of the beginnings and endings of zones established by the resurvey crew before the present study was conducted. The column headed "4' - 4' " represents the beginnings and endings of zones established by the Michigan criteria as a part of the study. With adjustments at the zone endings for any dip or depression, the column "4' - 4' and 4' - $2\frac{1}{2}$' " represents the beginnings and endings of zones using a criteria with a lower back sight target height and adjustments made for any dip or depression. The column headed "$3\frac{1}{2}$' - $3\frac{1}{2}$' " represents the beginnings and endings of zones established by a criteria using this lower line of sight with adjustments for any dip or depression, In each of the areas, applying the Michigan criteria, a zone is required which is not marked. The length of the zone required is approximately 500 feet.

Some large differences occur between the beginnings and endings established applying Michigan criteria by the resurvey crew and the study crew. The differences occur primarily in the ending of zones such as found in zones 2A, 3A, 4, 6A, 8A and 10A in the area on M-32 east of Gaylord. Some differences exceed 100 feet. Most of the differences experienced involve a dip or depression occurring within the minimum sight distance. Apparently no adjustment was made in these endings for the dip or depression.

ACCURACY OF STUDY DATA

Due to these differences, an investigation was made to find if this could be the normal variance expected, using the present field procedure. Two different crews established zones in the same area as the first study crew. The data showing the relationship between the study crews is presented in the Appendix Table III.

A comparison of zones established by the three crews shows the difference between the extreme values exceed 25 feet, 9 percent of the time. The same difference exceeds 30 feet, 3 percent of the time. Even when a vehicle is traveling at 30 miles per hour or a rate of 44 feet per second, the differences are considered negligible.

A statistical analysis was made of the data to test for crew bias. The results indicate that a multinomial distribution

with parameters 1/3, 1/3, 1/3 for high-low and median for each of three crews would not be unreasonable. Thus, the crews could be considered as giving a common result and no crew bias was present. How close this result would be to the absolute correct value would require an experiment with identical repetion. Even this would be of questionable value as real conditions have too much variance. After testing the results and analysis of the data obtained by the three recheck crews, it is apparent that the method used in this recheck of zones achieved an adequately correct result.

During this recheck, newly designed and more efficient equipment was used to apply the criteria, and a reasonably correct result was obtained with its use.

MINIMUM SIGHT DISTANCE

The present criteria prescribes a 1,000 foot sight distance for all zones on state trunklines. From the previously described results on US-41, an improved two-lane, two-way roadway with a high 85th percentile speed, it is recommended that the 85th percentile speed table be adopted on state trunkline highways. The 85th percentile speed should be assumed to be 60 miles per hour unless a speed control zone is in effect which shall govern the sight distance used. On some improved, two-lane, two-way roadways, with the possibility of a higher 85th percentile speed, the speed should

be determined through speed studies, and the corresponding sight distance used. Normally, this distance will never exceed 1,100 feet.

TARGET HEIGHT

It is recommended that this element of the criteria be lowered to 3.75 feet from the present 4 foot level. Table IV of the Appendix shows 94.47 percent of standard motor vehicles have a minimal loaded eye height of 45 inches or above. Table V of the Appendix shows the measured eye height with one person in the vehicle exceeds 45 inches on all except two of the vehicles measured. Due to the direct relationship between driver eye height and target height used in establishing zones, the lowering of target height is necessary at this time if zones are to be established to take care of the above-mentioned 94.47 percent of standard motor vehicles.

Using the data from Tables I and II in the Appendix, the lowering of target height to $3\frac{1}{2}$ feet results in 6 to 20 percent increase in length of yellow line. It seems reasonable to assume that the lowering of the target height to 3.75 feet would result in a 3 to 10 percent increase in length of yellow line.

MINIMUM SIGHT DISTANCE BETWEEN ZONES

A study was performed by Mr. A. A. Lampela (Appendix Addendum VI) of the Geometrics Section of the Traffic and Safety

Division to determine if a vehicle on a two-lane, two-way roadway can safely complete a passing maneuver within a minimum 400 foot passing distance. This study revealed that a safe passing maneuver can be achieved within the minimum passing zone when the overtaken vehicle is not exceeding 40 miles per hour. Since the purpose of a minimum distance between zones is to allow the overtaking of a slow moving vehicle, the 400 foot minimum passing distance is safe, adequate, and should be maintained.

MINIMUM SIGHT RESTRICTIONS

The sight restriction required before any zone establishment is 200 feet. Assuming this figure was derived from a perception-reaction time, a vehicle would be hidden for approximately three seconds and still be 800 to 1000 feet away. This minimum sight restriction seems very adequate.

PROVISION FOR DIP OR DEPRESSION

No explicit provision is made in the present criteria for the adjustment of the ending of a zone where a dip or depression occurs within the minimum sight distance. Motion pictures were taken from some of the endings on M-32 east of Gaylord. The pictures taken from some of the zone endings set by the resurvey crew show that an approaching vehicle would disappear from view for one to four seconds within the minimum sight distance. This situation is dangerous and the criteria should be amended to read, "The end of the no-passing

zone shall be extended to a point where the 3.75 foot target is visible any place in a dip or depression occurring within the minimum sight distance".

ESTABLISHMENT OF ZONES

If the criteria changes recommended in this report are adopted, all zones on state trunklines should be re-established by a crew equipped with the latest, most efficient equipment. This crew should be fully trained so that when they finish a section of roadway, no adjustments will be necessary by the District Traffic Engineer unless a problem occurs in sign placement. The roadway would be staked for the movement of signs, and the paint guide T's would be in place with confidence of accuracy. Sign and paint crews could then be sent in to perform the necessary changes from these marks. A complete and detailed instruction manual should be prepared to assist in the training of this crew. The crew will require practice and training until confidence of accuracy is obtained before any actual zone establishment is begun.

APPENDIX

Table I & Table IA	-	Data obtained from zones on M-32, east of Gaylord
Table II & Table IIA	-	Data obtained from zones on M-100 from M-78 north to M-32
Table III	-	Comparison of recheck crews
Table IV	-	Vehicles registered in the U. S. ranked by eye height
Table V	-	Eye height of passenger vehicles fully loaded
Addendum VI	-	"No Passing Zone Analysis" By Allen A. Lampela

TABLE I

M-32 EAST OF GAYLORD

LENGTH OF EXISTING PAINT*

Zones indicated by numbers only are for Eastbound vehicles

Zones indicated by numbers and letters are for Westbound vehicles

Zone	Length	Zone	Length
1	4664'	9	661'
1A	4787'	9A	711'
2	837'	10	640'
2A	850'	10A	607'
3	729'	11	746'
3A	717'	11A	802'
4	3560'	12	1684'
4A	3425'	12A	1460'
5	1249'	13	792'
5A	1190'	13A	824'
6	1226'	14	612'
6A	1249'	14A	614'
7	2295'	15	0
7A	2321'	15A	0
8	1220'		
8A	1259'		

*Beginning with the third zone East of the East City Limits

TABLE IA

M-32 Beginning with the third zone East of Gaylord City Limits

Zone #	Existing Paint	T from Surv. Crew	4' - 4'	4' - 4' 4' - 2½'	3½' - 3½'
1 Beg.	0	+2	+12	+12	+130
1 End.	0	-40	-75	-5	-38
1A Beg.	0	-6	-33	-33	+6
1A End.	0	-5	-55	-27	-41
2 Beg.	0	-4	-15	-15	+4
2 Eng.	0	-70	-69	-51	-50
2A Beg.	0	+47	+13	+13	+32
2A End.	0	-140	-71	-62	-56
3 Beg.	0	-5	-5	-5	+18
3 End.	0	-1	-146	-56	-46
3A Beg.	0	-6	-168	-168	-65
3A End.	0	0	+55	+142	+51
4 Beg.	0	-77	-63	-63	-63
4 End.	0	-74	-119	+7	-60
4A Beg.	0	-60	-96	-96	-43
4A End.	0	+20	+46*	+46*	+46*
5 Beg.	0	+3	-51	-51	-51
5 End.	0	-25	-37	+34	0
5A Beg.	0	-7	-56	-56	-15
5A End.	0	0	-19	-19	-19
6 Beg.	0	+30	+64	+64	+79
6 End.	0	-2	-16	0	+3
6A Beg.	0	-4	-20	-20	-5
6A End.	0	-5	+65	+156	+126
7 Beg.	0	-10	-1	-1	+13
7 End.	0	-15	+7	+31	+25
7A Beg.	0	+18	+20	+20	+27
7A End.	0	0	+22	+45	+24
8 Beg.	0	-6	-6	-6	+26
8 End.	0	-2	+20	+37	+35

*Adjustment for side road

Table IA, continued

Zone #	Existing Paint	T from Surv. Crew	4' - 4'	4' - 4' 4' - 2½'	3½' - 3½'
8A Beg.	0	0	-16	-16	-1
8A End.	0	-132	+10	+53	+20
9 Beg.	0	-3	-8	-8	+4
9 End.	0	-25	-12	-2	+5
9A Beg.	0	0	-25	-25	+6
9A End.	0	-80	-6	+24	+12
10 Beg.	0	-125	-244	-244	-232
10 End.	0	-3	+12	+30	+40
10A Beg.	0	-3	-149	-149	-127
10A End.	0	-100	+38	+84	+77
11 Beg.	0	-5	+1	+1	+26
11 End.	0	0	-14	-2	+1
11A Beg.	0	-7	-28	-28	-5
11A End.	0	-62	-1	+30	+10

Under the 3½'- 3½'method, a new zone is required of approximately 415' in length between existing zones 11 and 12.

12 Beg.	0		-79	-79	-79
12 End.	0		-101	-34	-62
12A Beg.	0		-15	-15	+8
12A End.	0		-5	-58	-58
13 Beg.	0		-27	-27	-12
13 End.	0		-30	-25	-24
13A Beg.	0		-30	-30	-2
13A End.	0		-28	-3	-16
14 Beg.	0		0	0	+21
14 End.	0		+4	+20	+16
14A Beg.	0		+3	+3	+18
14A End.	0		+1	+56	+24

-- No T's found ----------

One zone is required just before the next horizontal curve. It is required by the Michigan method and all others. The Michigan method requires a zone of approximately 535'. At the 3½' - 3½', a zone of about 600' is required.

TABLE II

M-100 FROM M-78 NORTH TO M-43

LENGTH OF EXISTING PAINT

Zones indicated by numbers only are for Northbound vehicles

Zones indicated by numbers and letters are for Southbound Vehicles

Zone	Length	Zone	Length
1	1175'	8	1972'
1A	1170'	8A	1886'
2	750'	9	800'
2A	740'	9A	809'
3	1029'	10	674'
3A	875'	10A	795'
4	805'	11	500'
4A	813'	11A	497'
5	912'	12	570'
5A	883'	12A	574'
6	767'	13	0
6A	770'	13A	0
7	590'		
7A	604'		

TABLE IIA

M-100 from M-78 North

Zone #	Existing Paint	T from Surv. Crew	4' - 4'	4' - 4' 4' - 2½'	3½' - 3½'
1 Beg.	0	0	-23	-23	+4
1 End.	0	-156	-146	-102	-40
1A Beg.	0	-31	-128	-128	-114
1A End.	0	-45	-36	-20	-5
Under 3½' to 3½' method, a new zone is needed approximately 250' long between existing zones 1 and 2.					
2 Beg.	0	0	-8	-8	+26
2 End.	0	-36	-78	-53	-43
2A Beg.	0	+4	-155	-155	-104
2A End.	0	-50	-60	-48	-29
3 Beg.	0	-160	-201	-201	-172
3 End.	0	-4	-110	-42	-37
3A Beg.	0	0	-99	-99	-40
3A End.	0	-12	-62	-26	-35
4 Beg.	0	+10	-112	-112	-89
4 End.	0	-10	-59	-51	0
4A Beg.	0	+5	-24	-24	-29
4A End.	0	-25	-99	-25	-38
5 Beg.	0	0	-40	-40	-4
5 End.	0	-50	-45	-20	-15
5A Beg.	0	-2	-33	-33	-20
5A End.	0	-10	+8	+38	+13
6 Beg.	0	0	-38	-38	-8
6 End.	0	-22	-43	-13	-16
6A Beg.	0	-2	-33	-33	-6
6A End.	0	-20	-33	0	0
7 Beg.	0	+2	0	0	+22
7 End.	0	0	-22	-5	+31
7A Beg.	0	0	-63	-63	-32
7A End.	0	0	-4	+35	+15
8 Beg.	0	-65	-57	-57	-30
8 End.	0	-107	-127	-93	-122
8A Beg.	0	0	-110	-110	-36
8A End.	0	-72	-102	-40	-22

Table IIA, continued

Zone #	Existing Paint	T from Surv. Crew	4' - 4'	4' - 4' 4' - 2½'	3½' - 3½'
9 Beg.	0	0	-19	-19	+67
9 End.	0	0	-27	+19	-8
9A Beg.	0	0	-97	-97	-19
9A End.	0	0	-8	+53	+39
10 Beg.	0	0	-80	-80	-30
10 End.	0	-4	-53	-30	-36
10A Beg.	0	-3	-97	-97	-35
10A End.	0	-120	-96	-43	-8

Under 3½' to 3½' method, a new zone is needed approximately 250' long between existing zones 10 and 11.

11 Beg.	0	+2	-5	-5	+82
11 End.	0	0	0	+63	+26
11A Beg.	0	-2	-68	-68	+52
11A End.	0	0	-19	+22	+3
12 Beg.	0	0	-31	-31	+45
12 End.	0	0	-48	-8	-20
12A Beg.	0	0	-48	-48	+50
12A End.	0	+2	+24	+47	+26

One zone is required before reaching M-43 by the Michigan method. This zone has no existing markings. Under the Michigan method, this should be approximately 500' long. Under the 3½' - 3½' method, it should be approximately 700' long.

TABLE III

Comparison of Recheck Crews

M-32 East of Gaylord
Michigan

4' - 4'

Zone #	Crew #1	Crew #2	Crew #3	Range	Deviations
1 Beg.	+12	0	+10	12	± 6'
1 End.	-75	-93	-91	18	± 0'
1A Beg.	-33	-40	-54	21	± 10.5'
1A End.	-55	-76	-64	21	± 10.5'
2 Beg.	-15	-17	Crew #3 had an equipment problem on these two zones, data not used.	2	± 1'
2 End.	-69	-75		6	± 3'
2A Beg.	+13	+20		7	± 3.5'
2A End.	-71	-89		18	± 9'
3 Beg.	-5	-7		2	± 1'
3 End.	-146	-129		17	± 8.5'
3A Beg.	-168	-120		48	± 24'
3A End.	+55	+14		41	± 20.5'
4 Beg.	-63	-49	-57	14	± 7'
4 End.	-119	-118	-136	18	± 9'
4A Beg.	-96	-85	-116	31	± 15.5'
4A End.	+46	+43	+45	3	± 1.5'
5 Beg.	-51	-42	-48	9	± 4.5'
5 End.	-37	-30	-29	8	± 4'
5A Beg.	-56	-41	-28	28	± 14'
5A End.	-19	-33	-13	20	± 10'
6 Beg.	+64	+47	+42	22	± 11'
6 End.	-16	-19	-14	5	± 2.5'
6A Beg.	-20	-20	-26	6	± 3'
6A End.	+65	+86	+77	21	± 10.5'
7 Beg.	-1	-3	-4	3	± 1.5'
7 End.	+7	+2	+16	14	± 7'
7A Beg.	+20	+19	+3	17	± 8.5'
7A End.	+22	+7	+9	15	± 7.5'

Table III, continued

Zone #	Crew #1	Crew #2	Crew #3	Range	Deviations
8 Beg.	-6	-8	-10	4	± 2'
8 End.	+20	+12	+15	8	± 4'
8A Beg.	-16	-17	-20	4	± 2'
8A End.	+10	+4	+1	9	± 4.5'
9 Beg.	-8	-12	-15	7	± 3.5'
9 End.	-12	-15	-22	10	± 5'
9A Beg.	-25	-20	-31	11	± 5.5'
9A End.	-6	-20	-30	24	± 12'
10 Beg.	-244	-242	-252	10	± 5'
10 End.	+12	+8	+18	10	± 5'
10A Beg.	-149	-146	-156	10	± 5'
10A End.	+38	+48	+34	14	± 7'
11 Beg.	+1	+10	0	10	± 5'
11 End.	-14	-15	-13	2	± 1'
11A Beg.	-28	-15	-27	13	± 6.5'
11A End.	-1	-10	-1	9	± 4.5'
12 Beg.	-79	-60	-65	19	± 9.5'
12 End.	-101	-105	-109	8	± 4'
12A Beg.	-15	-5	-32	27	± 13.5'
12A End.	-58	-67	-37	30	± 15'
13 Beg.	-27	-25	-22	5	± 5'
13 End.	-30	-40	-48	18	± 9'
13A Beg.	-30	-26	-30	4	± 2'
13A End.	-28	-34	-34	6	± 3'
14 Beg.	0	+4	+20	24	± 12'
14 End.	+4	-5	-12	16	± 8'
14A Beg.	+3	+1	-1	3	± 1.5'
14A End.	+1	-4	-11	12	± 6'

TABLE IV

Vehicles Registered in the U.S.
Ranked by Eye Height

MAKE OF VEHICLE	EYE HEIGHT LOADED STANDARD	COMPACT	% OF TOTAL VEHICLES	ACCUMULATIVE % OF TOTAL VEHICLES
Amphicar	50.8		.000009	.000009
Bentley	50.7			.000009
Rolls Royce	50.7		.004	.004
Volkswagen	49.1		3.12	3.124
Citroen	49.0		.01	3.134
Saab	49.0		.05	3.184
Peugeot	48.1		.05	3.234
Misc. American Assumed	48.0 or higher		5.82	9.054
Volvo	47.7		.18	9.234
Datsun	47.2		.06	9.294
Chrysler	47.0		1.74	11.034
Toyota	46.9		.03	11.064
Imperial	46.8		.17	11.234
Austin	46.5		.03	11.264
Fiat	46.3		.13	11.394
Ford	46.3	43.9	19.93	31.324
Buick	46.2	45.2	5.75	37.074
B M W	46.0		.008	37.072
Chevrolet	46.0	43.5	26.52	63.592
Rover	45.8		.008	63.590
Mercury	45.8	44.1	3.54	67.130
Pontiac	45.7	46.2	6.77	73.900

Table IV, continued

MAKE OF VEHICLE	EYE HEIGHT LOADED STANDARD	COMPACT	% OF TOTAL VEHICLES	ACCUMULATIVE % OF TOTAL VEHICLES
Plymouth	45.6	45.2	6.09	79.990
Lincoln	45.6		.43	80.420
Dodge	45.5	45.0	4.29	84.710
English Ford	45.3		.13	84.840
Rambler	45.0		3.86	88.700
Oldsmobile	45.0	46.7	5.77	94.470
Aston Martin	44.5			94.470
N S U	44.5		.007	94.477
Opel	44.2		.16	94.637
Renault	44.0		.32	94.957
Simca	43.4		.12	95.077
Porsche	43.0		.05	95.127
Alfa Romeo	43.0		.02	95.147
Fanai	43.0			95.147
Morgan	43.0			95.147
Sunbeam	42.5		.13	95.277
Mercedes Benz	42.3		.15	95.427
Austin Healy	41.0		.10	95.527
M G B	40.8		.19	95.717
Jaguar	39.0		.06	95.777
Triumph	38.5		.18	95.957

Note: This is a reproduction of Table VI from the report "Review of Driver Eye Height as Related to Registered Passenger Vehicles" published September, 1967 by the Traffic & Safety Division, Research Section, Michigan Department of State Highways.

TABLE V

Eye Height of Passenger Vehicle
Fully and Partially Loaded

MAKE OF VEHICLE	OVERALL HEIGHT LOADED*	EYE HEIGHT LOADED	MEASURED EYE HEIGHT WITH ONE PERSON IN VEHICLE
Chevrolet Standard	55.4	46.0	47.2
Corvair	51.2	43.5	46.0
Camaro	51.4	43.7	45.6
Ford Standard	55.7	46.3	47.8
Thunderbird	52.8	45.2	
Mustang	51.6	43.9	45.7
Falcon	54.6	45.8	47.9
Lincoln	55.0	45.6	49.1
Mercury Standard	55.2	45.8	49.2
Cougar	51.8	44.1	45.1
Oldsmobile Standard	54.4	45.0	47.9
F 85	55.5	46.7	47.6
Toronado	52.8	45.2	47.4
Pontiac Standard	55.3	45.7	47.8
Tempest	55.0	46.2	46.9
Firebird	51.5	43.8	45.0
Rambler Standard	54.6	45.0	47.4
Cadillac Standard	55.6	46.2	48.4
Dodge Standard	54.9	45.5	48.4
Dart	53.8	45.0	47.6

Table V, continued

MAKE OF VEHICLE	OVERALL HEIGHT LOADED*	EYE HEIGHT LOADED	MEASURED EYE HEIGHT WITH ONE PERSON IN VEHICLE
Buick Standard	55.6	46.2	48.4
Special	54.0	45.2	46.3
Chrysler Standard	56.4	47.0	49.3
Plymouth Standard	55.0	45.6	48.2
Valiant	54.0	45.2	46.6
Imperial	56.2	46.8	48.2
Alfa Romeo	52.0	43.0	
Amphicar	59.8	50.8	
Aston Martin	53.5	44.5	
Austin	55.5	46.5	
Austin Healy	50.0	41.0	
Bentley	59.7	50.7	
B M W	55.0	46.0	
Citroen	58.0	49.0	
Datsun	56.2	47.2	
English Ford	54.3	45.3	
Farrari	52.0	43.0	
Fiat	55.3	46.3	
Jaguar	48.0	39.0	
Mercedes Benz	51.3	42.3	
M G B	49.8	40.8	41.5
Morgan	52.0	43.0	
N S U	53.5	44.5	

Table V, continued

MAKE OF VEHICLE	OVERALL HEIGHT LOADED*	EYE HEIGHT LOADED	MEASURED EYE HEIGHT WITH ONE PERSON IN VEHICLE
Opel	53.2	44.2	46.9
Peugeot	57.1	48.1	
Porshe	52.0	43.0	
Renault	53.0	44.0	48.2
Rolls Royce	59.7	50.7	
Rover	54.8	45.8	
Saab	58.0	49.0	
Simca	52.4	43.4	46.3
Sunbeam	51.5	42.5	45.0
Toyota	55.9	46.9	47.8
Triumph	47.5	38.5	40.9
Volkswagen	58.1	49.1	48.4
Ghia Coupe	52.4	43.4	
Volvo	56.7	47.7	

Note: This is a reproduction of Table III from the report "Driver Eye Height as Related to Registered Passenger Vehicles" published September, 1967 by the Traffic & Safety Division, Research Section, Michigan Department of State Highways.

*Heights taken from AMA Almanac

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NO PASSING ZONE

ANALYSIS

by
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December, 1967

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SYNOPSIS

The purpose of this report is to determine whether a vehicle on a two-lane, two-way roadway can safely complete a passing maneuver within a minimun 400-foot passing zone. The Traffic Division undertook to field-test the adequacy of Michigan's 400-foot passing zone by driving a vehicle at various constant speeds (in 5-mile per hour increments from 10 to 50 miles per hour) while being overtaken by another vehicle in a hurried accelerative manner. These tests revealed that a safe passing maneuver can be achieved within the minimum passing zone when the overtaken vehicle is not exceeding 40 miles per hour.

INTRODUCTION

Under the Michigan Vehicle Code, the State Highway Commission and county road commission are authorized to establish no-passing zones on two-or-three-lane roadways at vertical and horizontal curves where passing must be prohibited due to dangerously restricted sight distance. These no-passing zones are denoted with both signs and pavement markings (the yellow barrier line). Since snow or dirt and sometimes reflection may hinder driver visibility in distinguishing the yellow line, signs provide added safety to the driver in determining the limits of the yellow line. In Michigan, the yellow line is considered as absolute control, and therefore the passing maneuver legally should be started and completed outside of any area controlled by the yellow no-passing line.

In the determination of no-passing zones on two-lane roadways, there are differences of opinion among engineers in at least three areas:

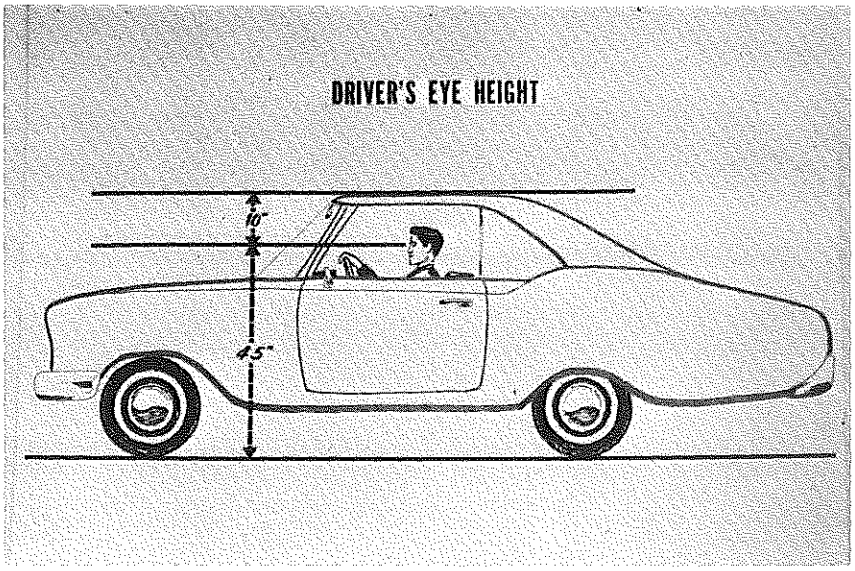
1. The most desirable minimum passing zone length.
2. The criteria used in its determination.
3. The sight distance used in field layout of no-passing zones.

The primary intent of this presentation is to arrive at something more than an opinion in determining the adequacy of Michigan's 400-foot passing zone (the minimum distance from the end of one no-passing zone to the beginning of the next) in providing for a safe passing maneuver.

The Sight Distance Criteria

To provide adequate sight distance in the design of highways, Michigan is using a 3.75 foot high driver eye height (Figure No. 1). The distance from the driver's eye to the top of the vehicle has been accepted as 10 inches, which provides for an overall vehicle height of approximately 4.5 feet. This 4.5 foot represents most cars in current production. Automotive

Figure No. 1



engineers estimate, however, that if the rate of drop characteristic of the past 30 to 35 years continues, by the year 2000 the driver's eye will be near the pavement surface (Figure No. 2).

Figure No. 2

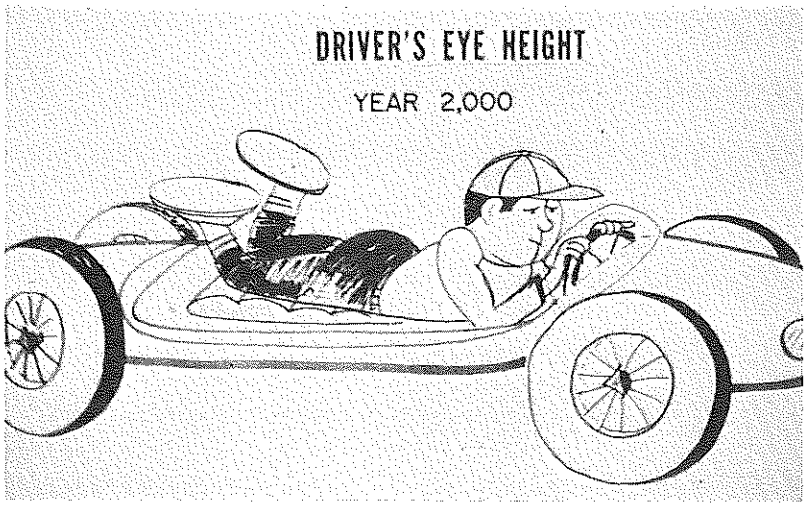
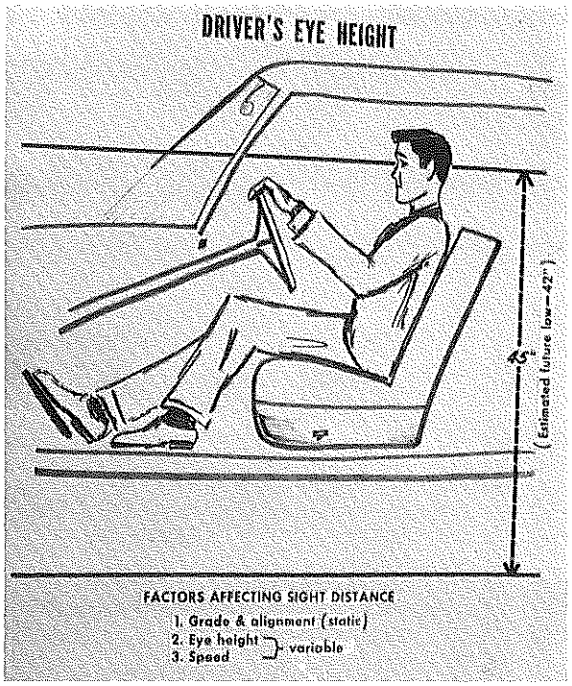


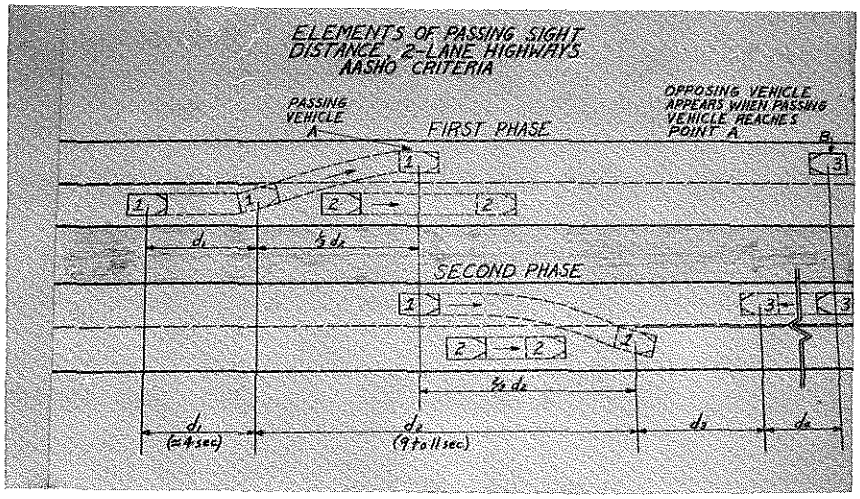
Figure No. 3



More realistically, due to the physiology of man and considering that he is apt to retain the same sitting position, the driver's eye height may obtain a low of about 42 inches (Figure No. 3).

With regard to designing of two-lane, two-way roadways to provide for adequate passing sight distance, the following is a review of AASHO's criteria (Figure No. 4):

Figure No. 4



Initial Maneuver Distance (d_1). The distance includes time for perception-reaction and acceleration (speed increase of 10 miles per hour) to the point where the driver encroaches into the left or passing lane (usually about 4 seconds).

Distance While Passing Vehicle Occupies Left Lane (d_2). The distance when the passing vehicle occupies the left lane. (Usually about 10 seconds).

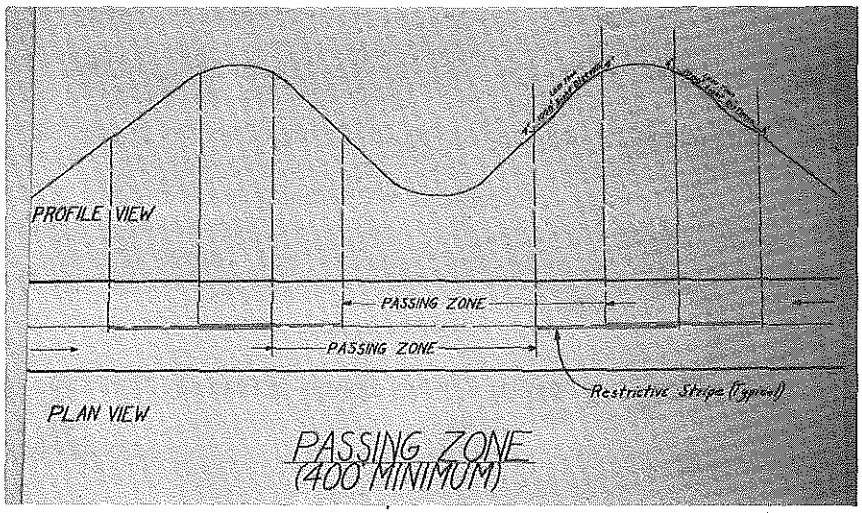
Clearance Length (d_3). The clearance distance between the passing vehicle and the opposing vehicle when the passing vehicle returns to the right-hand lane (100 to 300 feet depending on speed).

Distance Traversed by an Opposing Vehicle (d_4). The distance traveled by the opposing vehicle during the passing maneuver (2/3 of d_2).

The entire passing maneuver includes the combined length of d_1, d_2, d_3, and d_4 which varies from 1,000 to 2,300 feet for various speeds from 30 to 65 miles per hour.

No-Passing Zone Criteria

Since many two-lane, two-way roadways have inadequate passing sight distance, it is necessary to mark no-passing zones. The following fundamental concepts are utilized in this regard (Figure No. 5).



1. A minimum passing sight distance of 1,000 feet on state trunklines.
2. A driver eye height and vehicle height have been chosen as 4 feet.*
3. A minimum passing zone of 400 feet.
4. No-passing zones less than 200 feet are deleted, while those over 200 feet but less than 500 feet are extended to 500 feet.

*The use of the 4-foot high targets was recently adopted and is in accordance with the Bureau of Public Roads' policy.

In the evaluation of the minimum 400-foot passing zone when compared to the AASHO's passing criteria, distance d_1 (the perception - reaction distance) may be disregarded since the driver has predetermined that he is going to pass at any opportune moment. Thus, it is necessary to consider only distance d_2 (when the passing vehicle occupies the passing lane) since distances d_3 and d_4 are in the no-passing zone. It is also theorized that the 1,000 feet of sight distance should provide adequate clearance for a passing vehicle in the left lane to return into the right lane if a vehicle in the opposing lane comes into view. (See point "A" of AASHO's Safe Passing Sight Distance Criteria).

Analytical Analysis of the 400-Foot Passing Zone

In an attempt to mathematically determine the maximum speed of an overtaken vehicle when being passed by a vehicle traveling 55 miles per hour in a 400-foot passing zone, two assumptions were made:

1. 120 feet of overtaking distance and
2. a constant passing speed of 55 miles per hour.

By inspection:

$$D = Vt$$

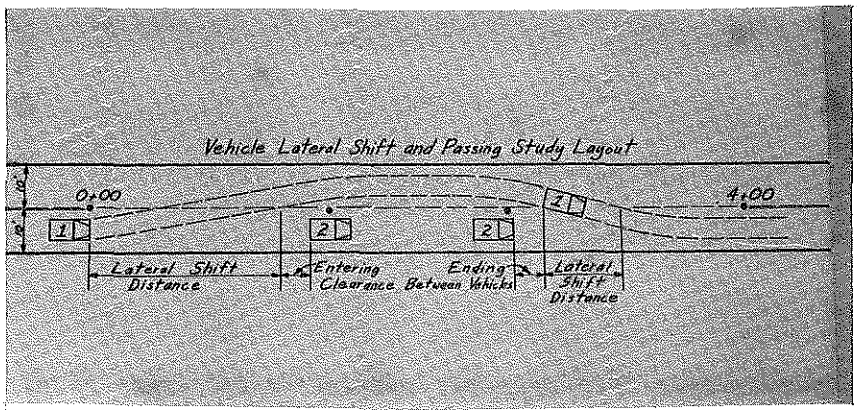
$$t = \frac{400 \text{ ft.}}{55 \text{ MPH}} \cdot \frac{\text{sec.}}{1.47 \text{ ft.}} = 4.9 \text{ seconds}$$

$$\text{Speed of vehicle \#2} = \frac{(400 - 120)\text{ft.}}{4.9 \text{ sec. } (1.47)} = 38 \text{ miles per hour.}$$

Field Testing the Adequacy of the 400-Foot Passing Zone

In theory, the 38 miles per hour speed of the passed vehicle appeared reasonable when overtaken in a 400-foot zone, by a vehicle traveling 55 miles per hour. However, there was the skepticism, "will it work in actual practice?" To satisfy the skepticism, field testing was done in the following manner (Figure No. 6): In an effort to simulate a typical two-lane, two-way roadway, a 20-foot wide bituminous surface pavement was chosen and a 400-foot section of the roadway was marked off resembling a minimum passing zone. A traffic cone was

Figure No. 6



placed at the beginning, end and sometimes at intermediate points of the zone. (The use of traffic cones was desirable for at least three reasons:

1. It assisted the observers in determining distance.
2. It gave the passing driver a vivid outline of the passing zone.
3. Any contact by the passing vehicle and the cone was harmless and did not influence the driver to shy away from the cone.)

For safety reasons, 1200 feet of sight distance was provided at the end of the passing zone. The vehicle to be passed was driven at constant speed in 5-mile per hour increments ranging from 10 to 50 miles per hour while the trailing vehicle executed a passing maneuver.

During the study the following was recorded:

1. The entering and final speed of the passing vehicle during each run.
2. The time and distance required for the passing vehicle to make a complete maneuver.
3. The time and distance to execute a lane-change into the left lane.
4. The clearance distance between the vehicles when executing the passing maneuver.

Before beginning the actual study, the drivers were acquainted with the section of road being used for the tests for safety reasons. During the testing, each test-run was begun with the two vehicles starting 1,000 feet to one-half mile in advance of the simulated passing zone. The advance distance permitted the passed vehicle to accelerate to a predetermined constant speed and maintain that speed throughout the passing zone. The passing vehicle upon entering the passing zone immediately began the lateral shift (with full acceleration) into the passing lane and continued to accelerate throughout the passing maneuver. (The speed differential of the vehicles was usually about 5 miles per hour at the beginning of the passing maneuver and about 20 miles per hour at the completion. AASHO's criteria in comparison utilizes a constant speed differential of 10 miles per hour while the passing vehicle occupies the passing lane). Simultaneously, as the passing vehicle entered the passing zone, an observer activated two stop watches; one to measure the time to execute the shift into the left lane and the other to measure the total time required for the passing vehicle to complete the entire passing maneuver. The speed, as determined later by the time and distance to shift into the left lane, indicated too much variance to be significant. The primary reason appeared to be due to the relatively short interval of time associated with human reaction time in actuating the stop watch. The overall time, which was of primary interest, proved to be accurate when related to distance.

In the determination of the overall distance during the passing maneuver, or any portion thereof, the centerline was used as a reference. Also, since the rear wheels closely follow the same track as the front wheels, it was necessary only to observe where either front wheel crossed the pavement centerline. More specifically, in a movement to the left lane, the right front wheel was observed and in the shift to the right lane, the left front

wheel was observed. The time however, was marked only when the passing vehicle had fully cleared the pavement centerline.

The vehicle clearance, which was included for only a portion of the study, was difficult to determine and can be considered only a "rough" estimate. In this case, the observer had to determine the location of both moving vehicles (with respect to a mark on the pavement) when the passing vehicle began the lateral shift to either lane.

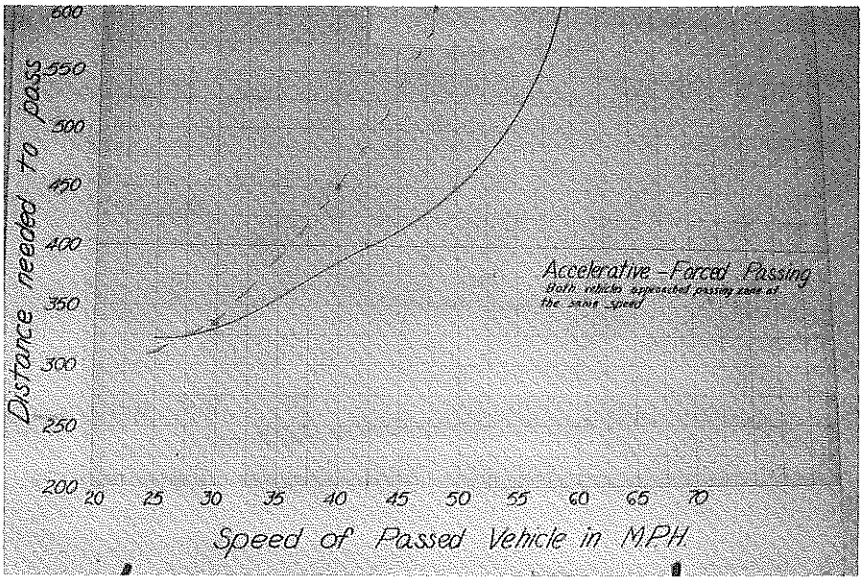
Also, during each run, an observer in the passing vehicle recorded the speedometer reading at the beginning and completion of the passing maneuver while the speed of the passed vehicle was held at a constant predetermined speed. To minimize "driver conditioning" to the passing situation, at least six drivers were intermittently alternated and each 5-mile per hour speed increment driven several times. Although the drivers were all relatively young men (average age in the mid-twenties), age did not appear to be as important as the desire of the driver to pass. Since full acceleration is characteristic of this type of a passing maneuver, passing leisurely or lackadaisically was excluded from the test procedure.

The vehicles used were 1966 standard 6- and 8-cylinder automobiles with 2 or 3 occupants in the passing vehicle during the tests.

In summary, the field testing determined:

1. The distance to execute a lane change, which varied from 70 to 120 feet for speeds of 30 to 55 miles per hour.
2. An average (estimated) clearance distance (with respect to the overtaken vehicle).... 32 feet ahead and 35 feet to the rear.
3. The distance of a passing vehicle to execute a passing maneuver with the passed vehicle moving at a constant speed.

Figure No. 7



In conclusion (Figure No. 7), we feel we have reasonably proved that a vehicle traveling in excess of 40 miles per hour cannot be safely passed in a distance of 400 feet.