

SAFETY IN MODERN HIGHWAY
DESIGN

Thesis for the Degree of B. S.
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W. Ross Thompson
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THESIS

C-1

**SUPPLEMENTARY
MATERIAL**
IN BACK OF BOOK

Safety in Modern Highway Design

A Thesis Submitted to

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of

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by

W. Ross Thompson

Candidate for the Degree of
Bachelor of Science

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THESIS

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Chapter one

Introduction

The rise of traffic-accident rates to pre-war levels has become a matter of vital concern to the engineering profession. For many years, engineers have been working to provide vehicles, roads, and operational control which would enable the private motorist, the commercial operator, the passenger in public vehicles, and pedestrians to reach their destinations conveniently and safely.

The problems of the future, though very much like those of the past, will be complicated by a far greater use of motor transportation than has yet been seen. The problem falls into two general classifications, (1) human behavior, and (2) physical conditions. The second part of the problem is the one the civil engineer is most concerned with, however, through his development of safety features in design, he has an influence on the first, in that his success in design can make human errors and misjudgements less likely to occur.

It has been shown over a period of years, that the driver can contribute practically nothing to the relief of congestion and comparatively little to the removal of accidents. Therefore, the major improvements in the transportation system has come and will come through improving the conditions under which vehicles must be operated.

The objectives of the engineer in attacking the transportation problem can be broken down into two divisions: (1) to provide functional design, and (2) control of traffic.

It is with these two above mentioned objects that this paper is primarily concerned.

Chapter Two

A Brief History of the Problem

Ideally, the most efficient transportation system is one in which there is a sound balance between the driver, the highway, and the vehicle. Throughout the history of the automotive transportation, these three factors have alternated. In the beginning, the roadway was ahead of both the car and the driver. The cars were mechanically imperfect, and the drivers were not too sure of themselves. With research and mass production the situation changed. The car had improved so much that it quickly absorbed all the advantages the highways had to offer at the time. The drivers were clamoring for more and better highways.

This sudden change confronted highway departments with the terrific task of building primary roads and all weather surfaces. The entire engineering profession can well be proud of the fine job they did in solving this problem.

Prior to the event of World War 11, the roadways were still not adequate due to high velocities developed by the cars and the increased volume of cars on the roads. The problem today is being solved by new superhighways and advanced methods of traffic control.

Chapter Three

Present Status of the Problem

Progress in America's Highway Safety Program is measured by the record of deaths and injury. Therefore, let us look at the record compiled by the "President's Highway Safety Conference for 1948". In 1946, accidents on the streets and highways took 33,400 human lives. In 1947, the toll was 32,000. The reduction is very encouraging evidence that highway accidents can be curtailed. Safety is the result of effort. To go on with the record. The downward trend continues, during the first seven months of 1948, the number of fatalities had dropped 5% below the same period in 1947. Moreover, the death toll went down while the amount of travel went up. But, the 32,000 deaths of men, women, and children who died in traffic in 1947 must not be taken lightly just because the toll is less than the previous year. Accidents may occur under any set of conditions, but if vehicles, roads, and control procedures and devices are designed to fit conditions of use, and known patterns of human behavior, physical conditions will be provided under which accident frequency may be greatly reduced.

The driver is entitled to roads safe for reasonable use. He is also entitled to a factor of safety against the hazards over which he has no control. Among these hazards are: physical features of the highway, such as limited visibility; inadequate signing; and uncontrolled or unrelieved congestion.

Chapter Four

Planning for Safety

The presently existing highways of the United States have been built under sustained pressure to provide a large mileage of improvements to meet demands of rapidly expanding motor vehicle use. A large part of this mileage carries a volume of traffic exceeding that which it was designed to serve; and thousands of miles were constructed for the use of vehicles capable of less speed and smaller and lighter than those which now use them.

Reconstruction of parts of our highway mileage, already obsolete, will require time. While rebuilding to modern standards of safety is in progress, the traffic meanwhile continues to increase. Therefore, methods must be found and used to reduce the danger of the obsolete mileage.

A good lesson can be found in former highway development. Roads which are built only for today's traffic needs too often become congested and accident-ridden long before the actual life of the road is ended. Safety must then begin in planning.

Through intensive studies made since 1935 in the nation wide State Highway Planning Survey, it has been found that a very small mileage of roads carries extremely heavy duty traffic densities, with corresponding heavy concentration and accidents. The most serious accident factor on these routes is that of "marginal conflicts", ie intersections, movements to and from the roadside, parking on or too close to the highway, and pedestrain crossings.

The very existence of heavy traffic assures the quick developement of roadside commercial establishments. Therefore, the safety hazards they will eventually cause in going to them and subsequent leaving them must be planned for in advance.

Roadside control measures, then become a major planning factor. Without some definite provision neither traffic capacity nor **safety** can long be assured. Such measures include (1) legal control of access, (2) Marginal land aquistion, (3) land use control, and (4) the aquistion by the highway agency of the right to limit private use of land on the roadside.

Chapter Five

Intersections

In designing a highway with safety in mind, "the marginal conflict", intersections must be given upmost thought and consideration, for intersections not only control the time saving service of a route, but also the accident rate. Both railroad grade crossings and highway intersections have a tendency to reduce traffic capacity. This is due not only to the actual stopping and starting, but also to the general slowing down as a precaution on the driver's part.

The ideal solution to the problem arising from intersections would be to eliminate them by constructing grade separations. However except under very favorable topographic conditions, this would be very expensive. In the case of railroad crossings where two or more main-line tracks are operating, a grade separation is imperative, regardless of traffic volumes. In the case of highway intersections with a traffic density of 4,000 or more daily, every effort should be put forth to provide a separation.

Although, more and more grade crossings are being eliminated by separations, in most instances it is impractical, therefore, other means must be found and used to rid the highways of the hazards they create. One phase of the problem depends wholly on acquiring adequate land adjoining the highways at crossings. In this way the obstructions which limit sight distance, such as steep banks, trees etc., standing crops, buildings, parked cars, and billboards can be done away with.

The grade and alignment of the highway at crossings, in order to eliminate hazards to safety, should be level or nearly so and the highway should be straight for at least a 1000 ft. at railroad crossings, and 300 ft. on through highways. This difference in unobstructed view is due to the fact that at highway intersections, with proper speed reducing signs, the speed of highway traffic would be less than that of the fastest train and vehicles can be stopped quicker than trains can.

There are four methods in general use today to make intersections more adequate. They are as follows:

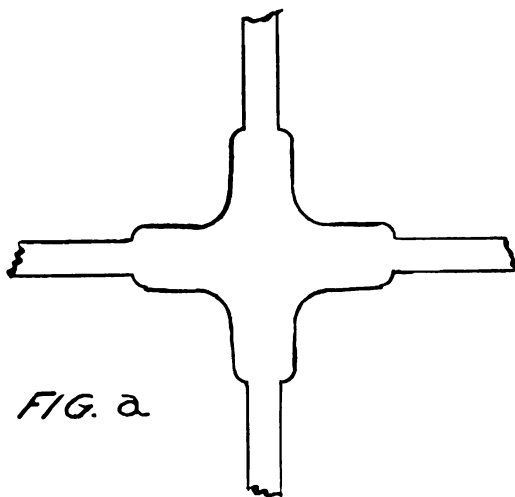


FIG. a

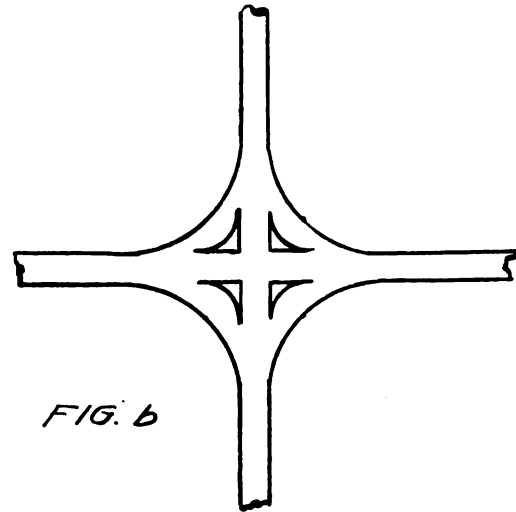


FIG. b

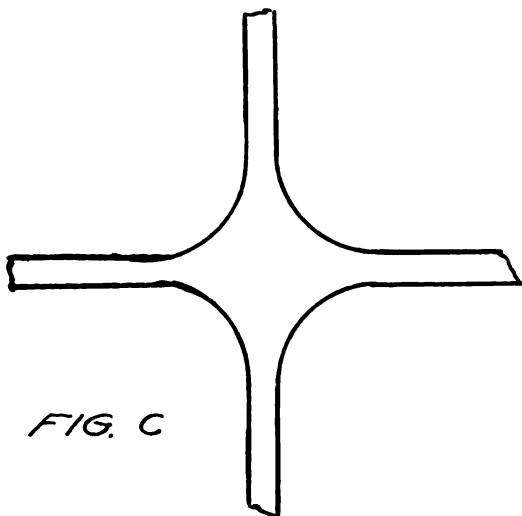


FIG. c

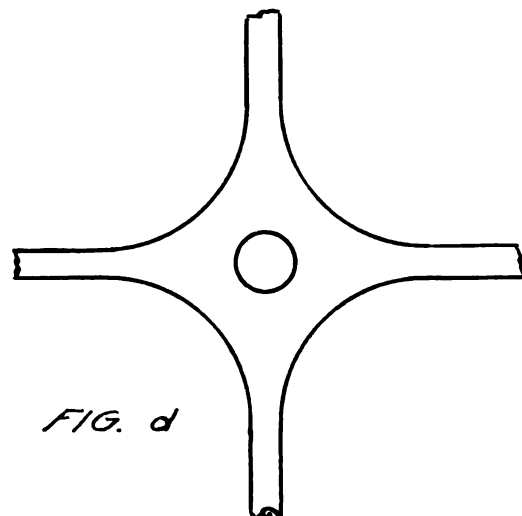


FIG. d

On the preceding page in figures (a) and (b) are shown the most common type of improved intersections. Figure (a) widened pavements, gives two additional lanes for 300 to 500 feet on each side of the intersections. This allows a vehicle which is to make either a right hand or a left hand turn to enter the extra lane leaving the other lane free for traffic going straight through. In figure (b) the intersection has a radii of 300 to 500 feet and requires much more land right-of-way, thus boosting the cost. However, it offers much less chance of collision, and is less expensive to construct than a grade separation. Figures (c) and (d) are modifications of the other two types of intersections and are self-explanatory. From these figures it becomes obvious that when acquiring right-of-way, sufficient land should be obtained to accommodate for additional width at intersections, thus providing not only widened lanes but also uncluttered safe sight distance area.

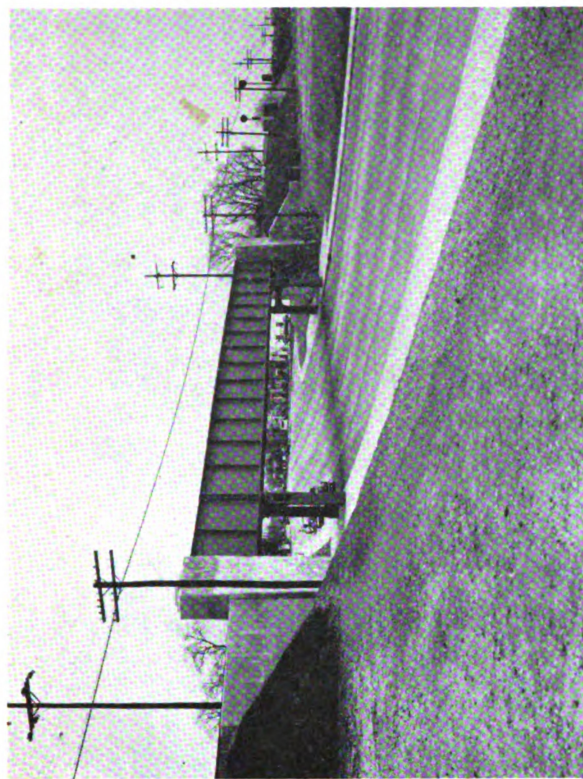
From observation and correspondence, it has been found that the state of New York has a very up to date program on grade separations. In 1947, the highway department of that state had a reserve of completed plans ready for contracts amounting to 300, at a total estimated cost of construction of over 60,000,000. These plans included projects for separating the grades of existing highway-railroad grade crossings, at highway-railroad crossings necessary by the construction of new highways, parkways, and thruways, also by the replacement of unsatisfactory existing highway-railroad grade separations structure. This paper is too limited by time to go

extensively into clover-leaf and similar grade separation construction, however, at the end of this paper will be found a chart showing the safety value of divided highways, and crossings which will serve the purpose of proof of their high safety value.

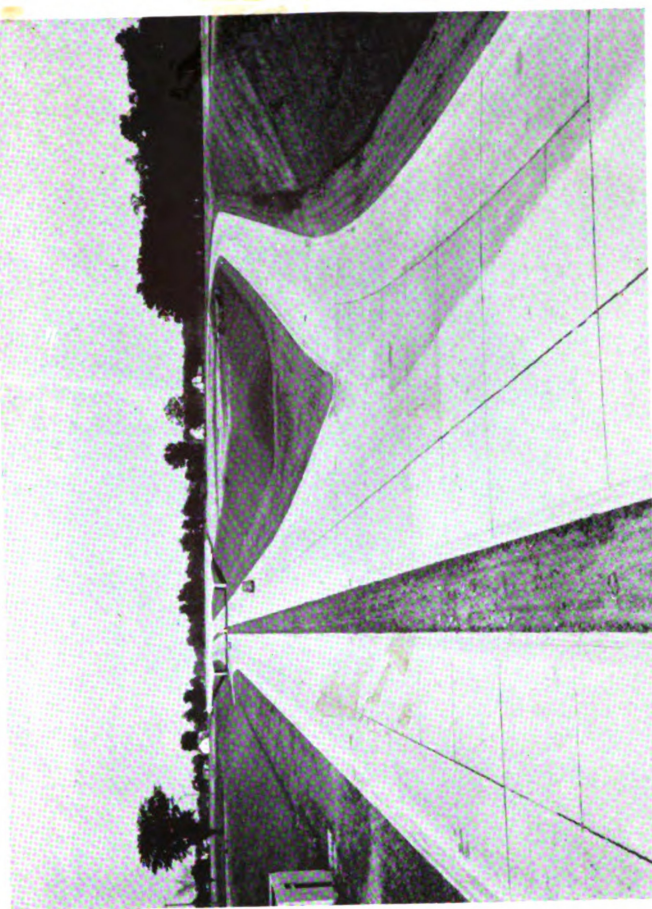


Many huge war plants, among them the Willow Run Bomber Plant, were built on sites without adequate access roads.

- (a) Traffic congestion in Willow Run area—July, 1942.
 (b) The heavy surges of worker traffic which occur when shifts change at the bomber plant find ample room and safe conditions on the new Willow Run Expressways—June, 1944.



Completed grade separation structure carries the Long Island Railroad over Hempstead Turnpike.



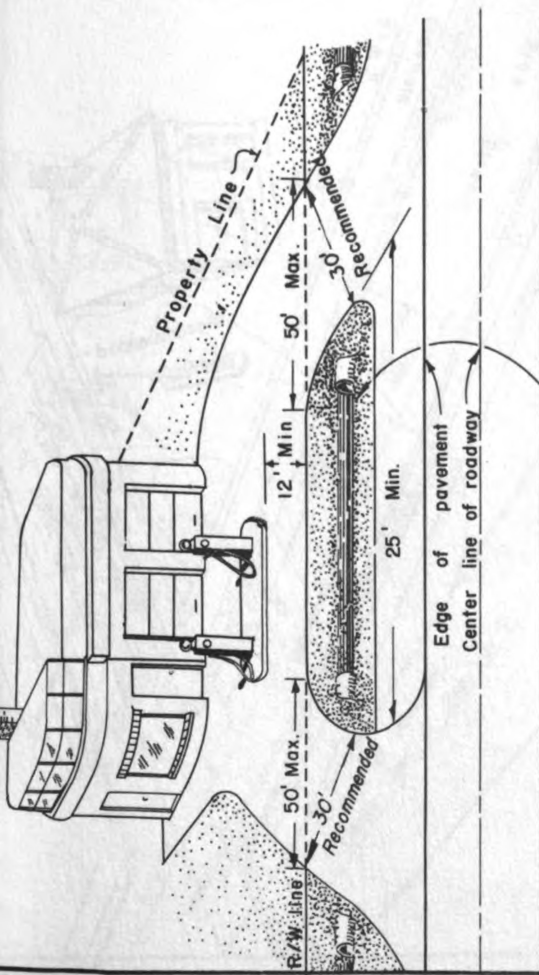
Depressed section of Ecorse Road (M-17) approaching separation with Detroit Industrial Expressway and showing interchange ramps.

Chapter Six

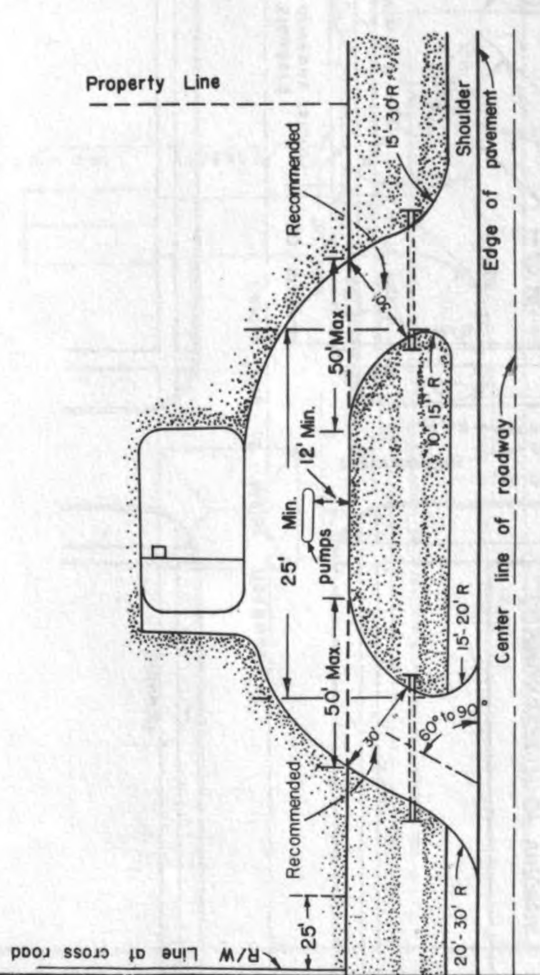
Other Marginal Conflicts

Besides intersections, movements to and from the highway, roadside establishments, roadside parking, and pedestrian crossings comprise hazards to safety that can be eliminated by proper planning and design. As has been stated before, as the highway is developed through a section, commercial establishments begin springing up all along the route. If a great enough amount of right-of-way has not been obtained at the time the highway rights are, these places of business are built so close to the pavement that entering and leaving them is dangerous. Thus it can be seen that safety and traffic serviceability of hundreds of miles of modern costly highways can become severely handicapped by this rapid development of roadside establishments and recreational areas at the roadside. A single business place thus located on a rural road will create new patterns of traffic in its locality. If its traffic connections are not properly integrated with the highway set-up it will create serious hazards. A highway fringed with such places may easily lose a large part of its utility along with having safety hazards caused by these roadside places.

To overcome this hazard of movement to and from the roadside, entrance driveways, that are not too wide and not located within a short sight-distance area, should be built. Also, if off the road parking areas are provided much of the danger is avoided. (See illustrations)

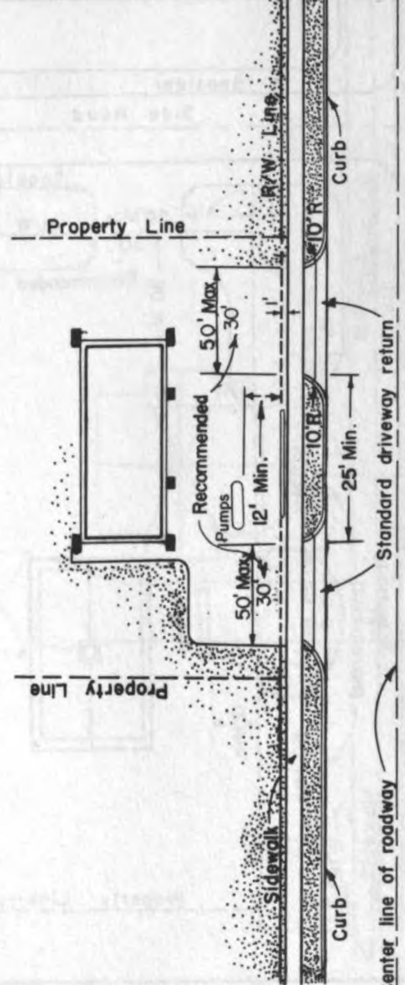
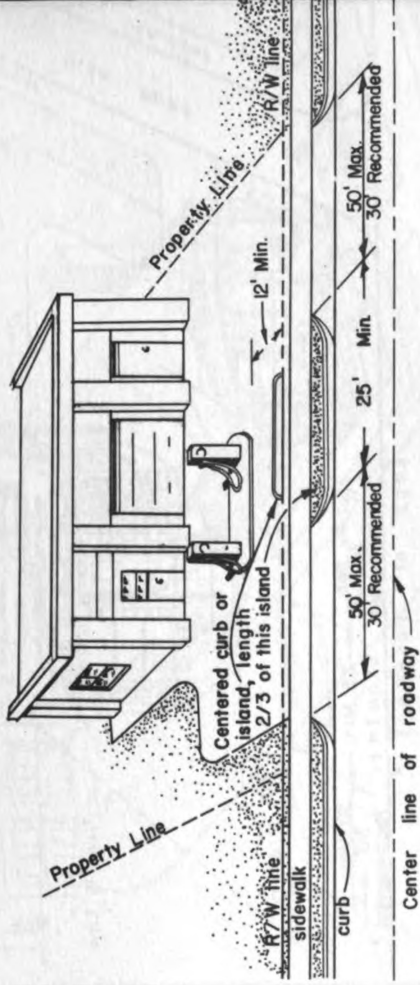


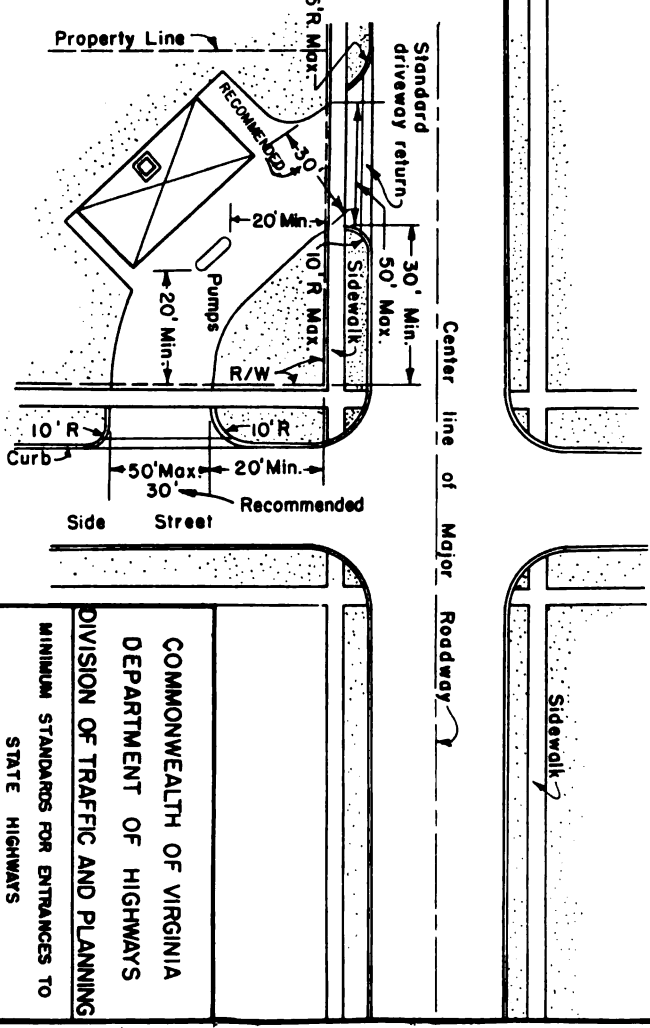
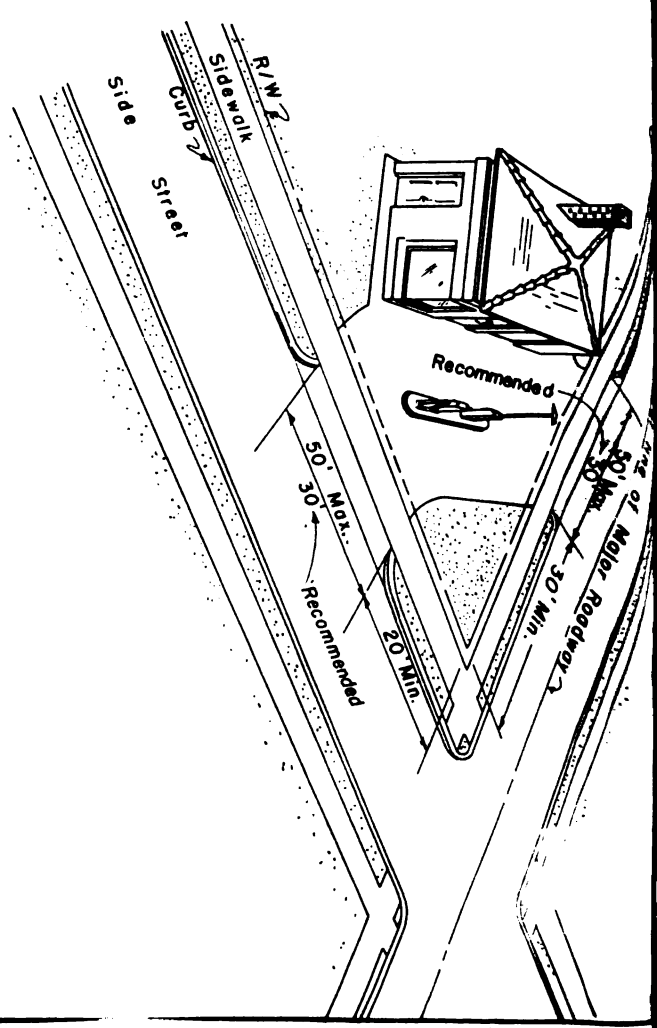
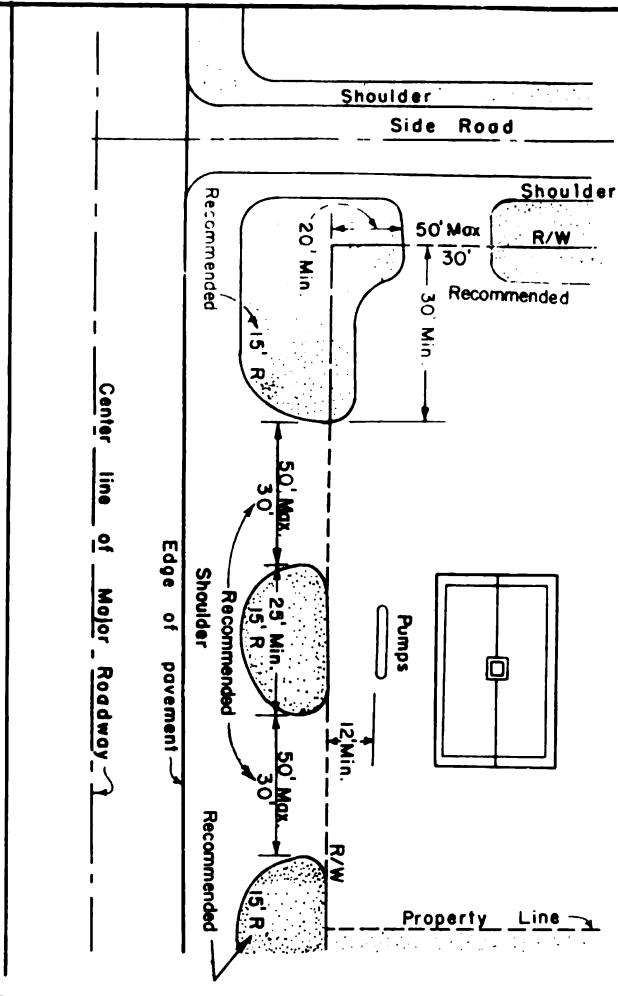
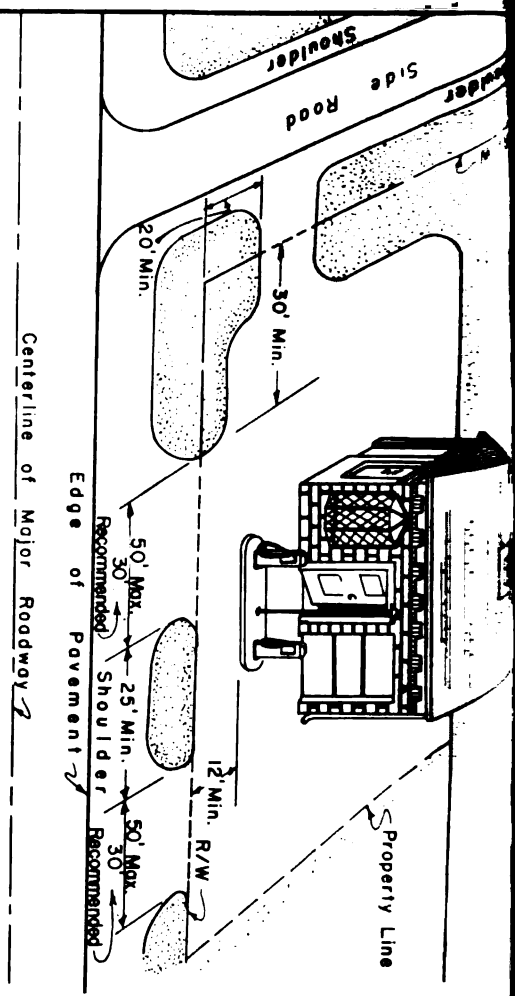
Note: if desired by property owner, drainage structures under separate entrances may be consolidated into one unit with like material, provided a channelizing island prohibiting wheeled traffic is constructed on area between entrances by property owner.



Layout when rigid surface is placed.

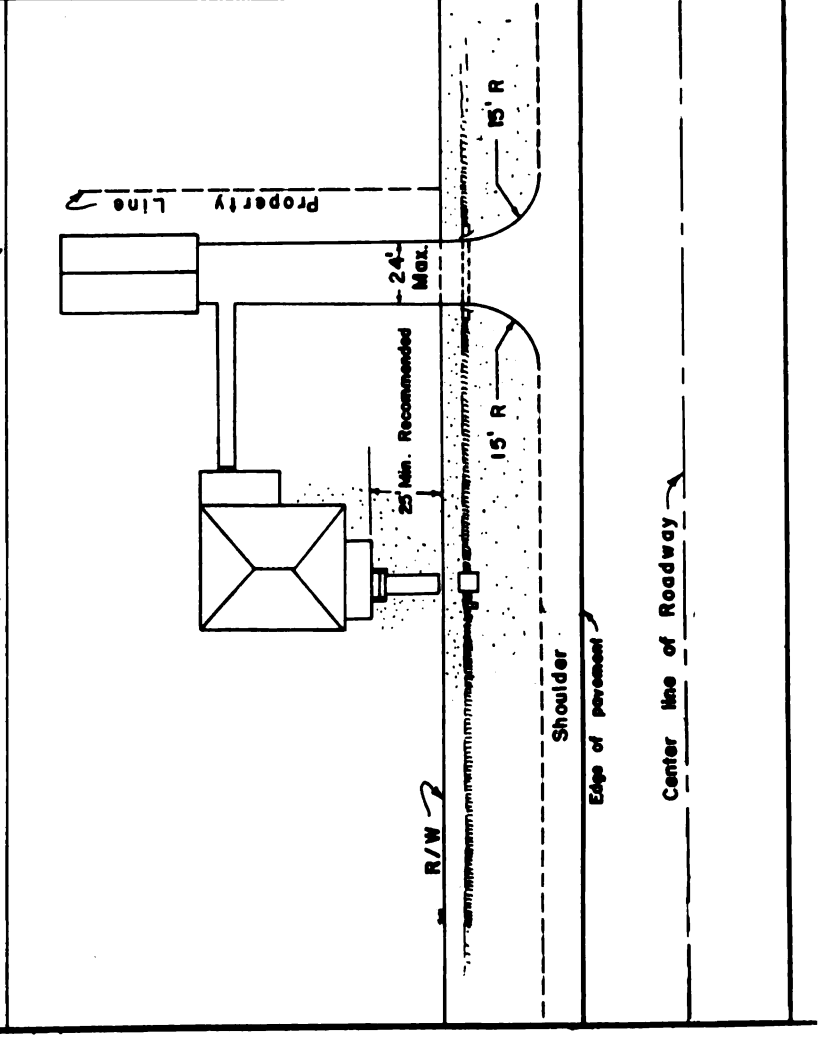
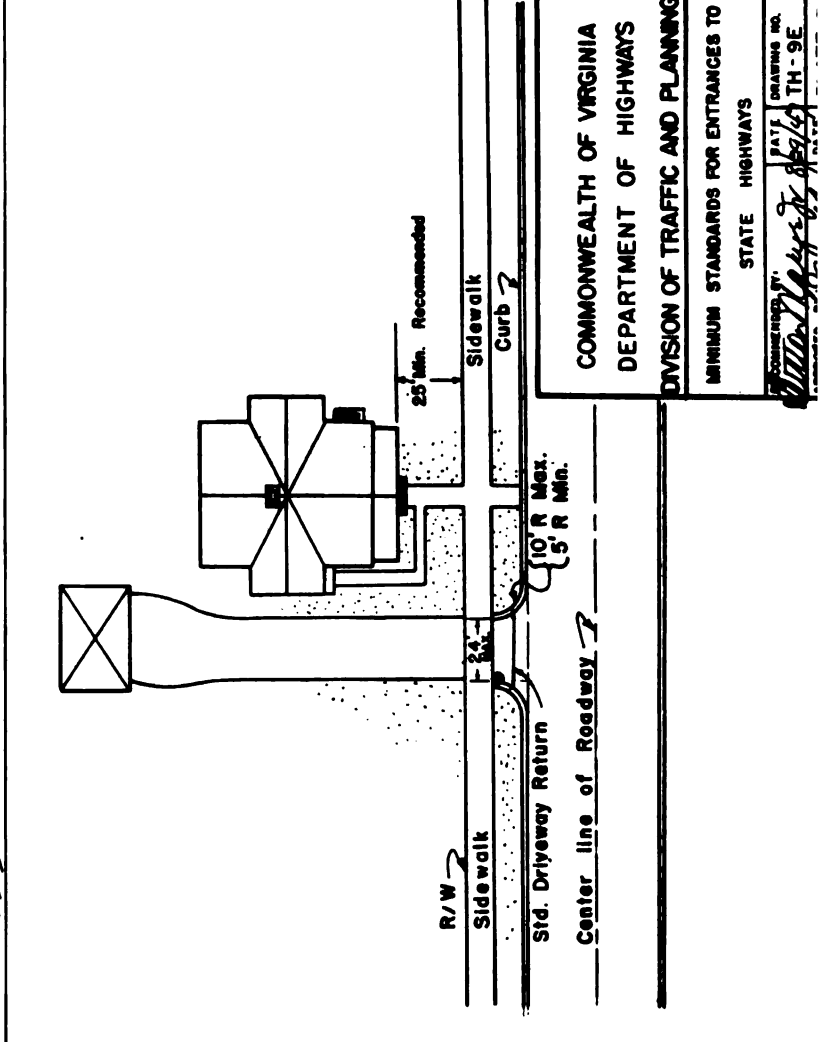
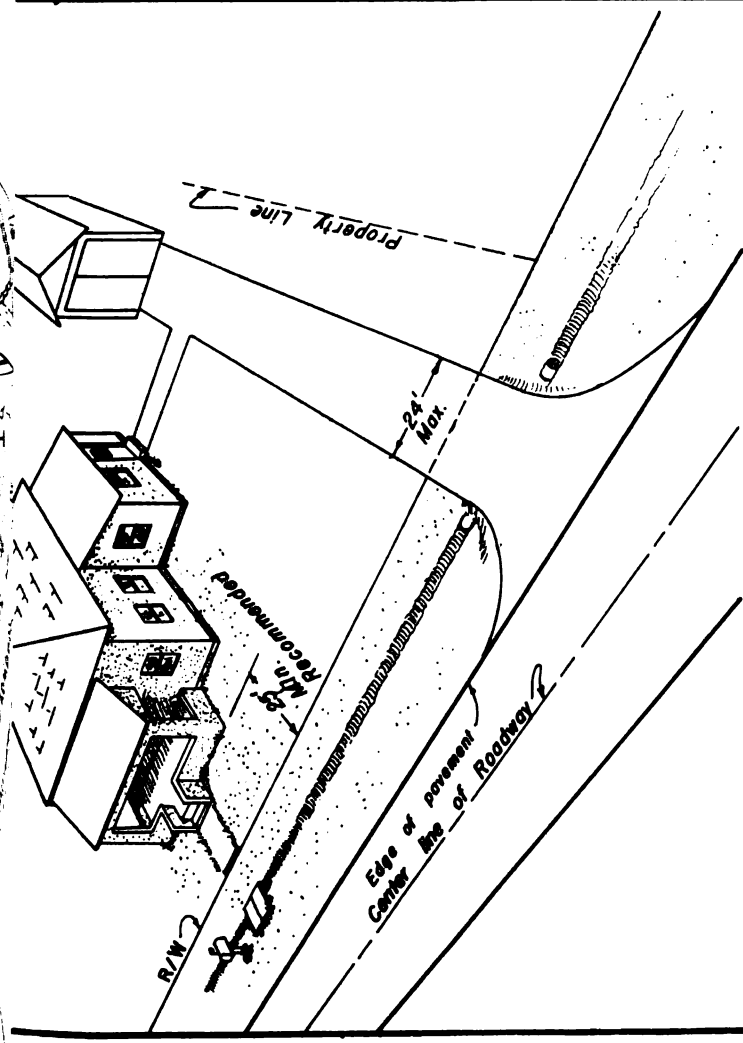
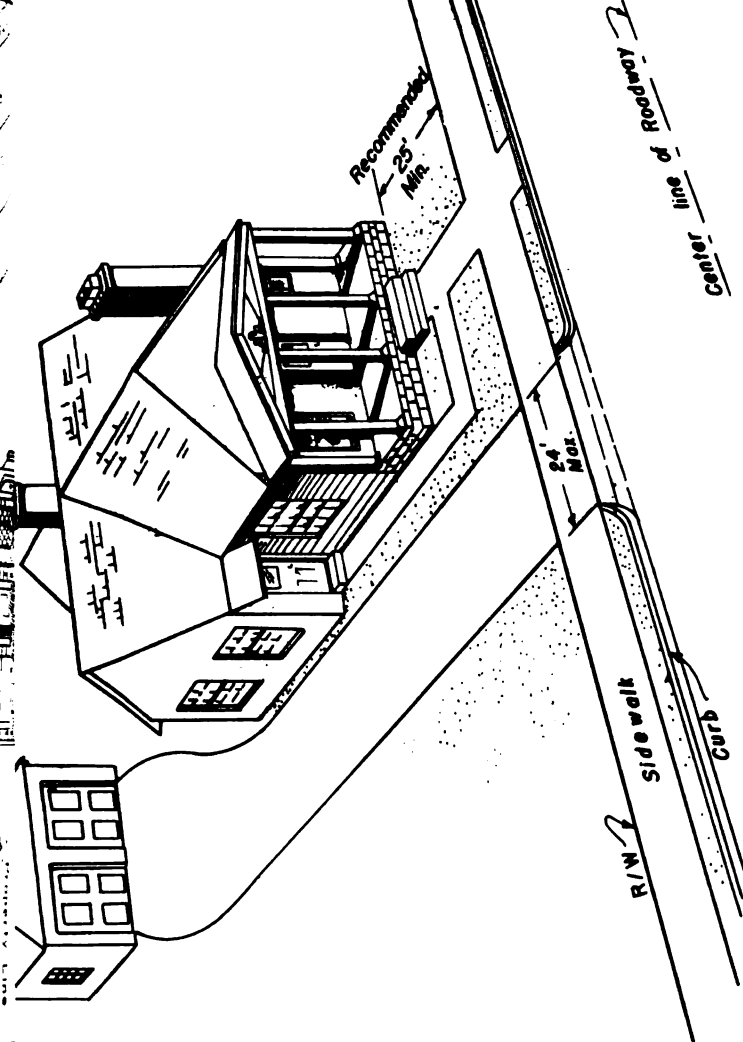
Layout when non-rigid surface is placed.





COMMONWEALTH OF VIRGINIA
 DEPARTMENT OF HIGHWAYS
 DIVISION OF TRAFFIC AND PLANNING
 MINIMUM STANDARDS FOR ENTRANCES TO
 STATE HIGHWAYS

COMPLIANCE: William H. Hays
 DATE: 8/1/74
 APPROVED: [Signature]
 DATE: [Blank]
 PLATE 2



COMMONWEALTH OF VIRGINIA
DEPARTMENT OF HIGHWAYS
DIVISION OF TRAFFIC AND PLANNING
MINIMUM STANDARDS FOR ENTRANCES TO
STATE HIGHWAYS
DRAWING NO. TH-9E
DATE 10/1/77

Roadside parking by the same token is a hazard. Moving vehicles passing a parked car have a tendency to swing wide for clearance, thus using the other lane. The danger of this becomes clear when a situation arises that a vehicle approaching from the opposite direction enters the picture. Also, if the parked car is very close to the pavement, alighting or getting into the car from the roadside makes it necessary for the person to be either on the road itself or very near it. Which brings us to the actual matter of right-of-way. The best width for the right-of-way is largely a matter of judgment and must be determined by the requirements of the particular case. It should be not only large enough for future widening of the road as traffic increases, but wide enough to control the hazards of parking too near the pavement, the roadside establishments, the building of billboards, the planting of trees, shrubs, etc. With this in mind, it is well to note that there is a noticeable trend toward acquirement of 100 to 200 foot strips along the roadside. The state of Missouri has a table based on average daily traffic:

Supplementary
System

Under 100 Vehicles 60 ft ----- 100 to 400 Vehicles 60 Ft

Major system

Under 400 Vehicles 80 ft -----400-1000- 80-100 foot strip

Interstate
System

1000-2000 Vehicles - 120-220 ft.
2000-3000 Vehicles - 120-220 ft.
3000-5000 Vehicles - 120-250 ft.
Over 5000 Vehicles - 150-250 ft.

In the design standards for the national system of Interstate Highways as adopted by the American Association of State Highway Officials, the following are recommended:

Two lane highways --- minimum 120 ft --- Desirable 220 ft.
Divided highways --- minimum 150 ft --- Desirable 250 ft.

Shoulder widths recommended by the A.A.S.H.O. are: " except in mountainous topography, shoulders shall be provided clear of road surfacing or pavement for a minimum width of 10 feet, measured to the intersection of the shoulder and side slope planes. Such shoulders shall provide support for standing or disabled vehicles. In mountainous country an effective shoulder width of at least 4 feet shall be provided.

The side slopes shall not be steeper than 2:1 in cuts except solid rocks or other special soils and on other special material that may justify steeper slopes. On fills of 10 feet or less in height the side slope shall not be steeper than 4:1.

From correspondence with the state of Minnesota, it is interesting to note that enough right-of-way is obtained to provide an area beyond the shoulder for ditches with adequate cross section to provide for snow storage. This would indicate that climate and topography create problems which are special and which must be met in order to have safe highways.

The final marginal conflict to be discussed is pedestrian crossings. Pedestrians are particularly hard to control due to the obvious reason that they are free to move in any direction without notice. The only sure way to control them is by using physical structures which would eliminate any choice by them.

Tunnels, fences, bridges, sidewalks, and separate levels are examples of such structures that should be used if the pedestrians are to be protected as well as the motorist. However, since pedestrians create a far greater urban problem than rural, and since this paper is devoted to the study of safety of highways outside of cities, it is sufficient to say that in rural areas where pedestrians walk in considerable numbers along or across a highway which carries moderate to heavy traffic volumes, sidewalks have a high safety value.

Chapter Seven

Geometry of Safe Highway Design

The geometry of safe highway design includes the principles of alignment, grade, sight-distances, width of pavement and lanes, curves, and various correlatives of these features. They all have a definite effect on safety of highways.

The volume, composition, and speed of traffic are the three basic features that must be accommodated. None can be neglected without producing hazardous operating conditions.

In the past the width of lanes was more or less standardized at 10 feet, but at the present time the trend is toward wider widths- 11, 12, and 13 feet. Wider lanes result in higher safety. The need for using wider lanes came as a direct result of higher velocities and wider vehicles. It has been found that cars traveling at a moderate speed need at least a 2 foot clearance between cars, and as the speed increases the need for a greater clearance becomes a necessity. However, and this is important, there is a limit to the width lanes should be made. By extending the lane-width to more than 12 or 13 feet, the motorist tends to eke out an additional lane, thus creating three narrow hazardous lanes out of the intended two.

For the greatest safety, rural highways are usually built with an even number of lanes: two, four, six, and eight. The reason for this is obvious. Highways having an odd number of lanes are not as safe as those with an even number of lanes, due to the fact that cars traveling in opposite directions must overtake and pass vehicles in the single central lane,

thus causing a situation that is ripe for the most fatal type of accident - head-on-collision.

Lane efficiency on multiple lane highways can be increased without resorting to the high cost of alteration. This is done by making outside lanes appear and actually be safe. Several methods are being used to accomplish this. Since motorists tend to shy away from outside lanes when there are objects near the pavement edge, if such objects are removed and the shoulders made stable, motorists can be induced to drive along without the feeling of having to give a wide clearance for their safety. Another good method which has been used in the state of Massachusetts with excellent results, is to take advantage of the motorist's preference for smooth, light colored surfaces by constructing the outside lanes of a three or four lane highway of light colored smooth concrete, and constructing the inside lane or lanes of a rough dark Macadam. The Macadam surface will cause the tires of the vehicle to rumble slightly. The difference in smoothness and color of the surfaces will cause the driver to seek the light smooth outside lane, thus leaving the inside lane or lanes free for passing and higher speed vehicles. This type of construction has the added safety value of making it easier for the driver to stay in the lanes, for it is easier to follow a distinctive color than it is to drive between painted line striping.

This brings up the point of pavement marking. Most lane division is made through this device. Basically, for the safest roads, unbroken lines should be used where driving across the line is hazardous and thus prohibited. Broken lines

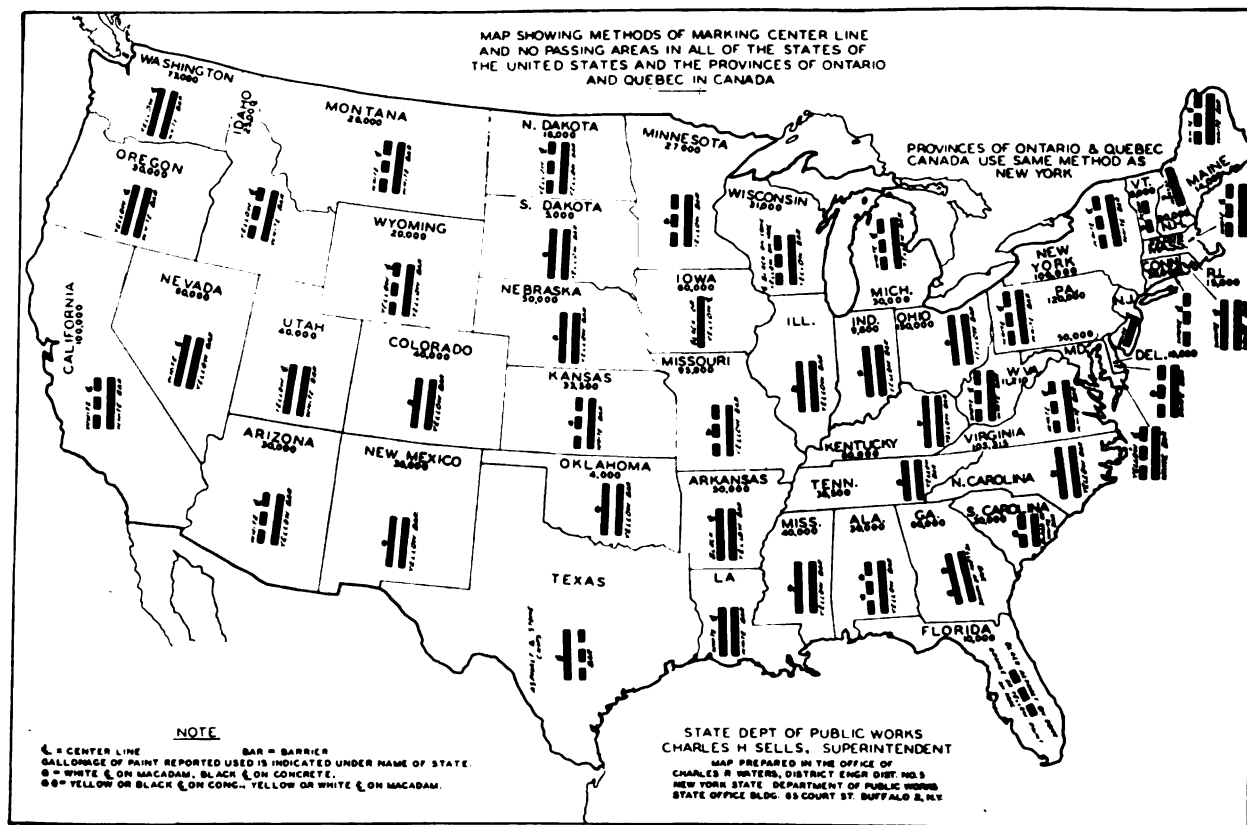
are used where crossing from one lane into another is permitted under favorable conditions. It has been found and is quite universally adopted that white lines from 4" - 8" are the most visible and effective. The American Association of State Highway Officials standards say that the center line should be placed in the following locations: (a) on the approach to the crest of a hill where the clear view ahead is less than 500 feet. (b) on all curves having a radius less than 600 feet or where the clear view ahead is less than 500 feet. (c) and on pavements wider than 40 feet.

Some states use center lines only at points where overtaking and passing is hazardous. In other states, lines are used extensively on straight level stretches as aids for keeping traffic in lanes as well as where it is dangerous to be in the lane where traffic from the opposite direction is. This is by far the better practice, for it takes the human element out of the picture to some degree. The procedure recommended by the A.A.S.H.O. is to have a broken white line 15 feet in length with a 25 foot gap, a shorter line and gap tends to give an annoying flickering sensation which induces fatigue. A yellow solid line has been found to be most effective as a regulatory line used where it is unsafe and therefore illegal to cross. It is recommended because it contrasts with the white line, used where it is not prohibited to cross, and thus gives emphasis to the existing hazard. Also, since yellow has been more or less adopted universally as a symbol for warning signs and signals, it becomes apparent, just seeing the color warns of danger.

The state of New York and others, however, use broken white lines in combination with solid white lines to mark the "no passing" areas. They have a very good reason for not following the standard. Yellow paint can not be distinguished from white at night or during rainstorms. This would indicate that more study should be done on the standard color to be used. The chart of United States that follows shows the 48 states' procedure. It can be noted from this map that the standard is not followed very closely throughout the states.

The center lines themselves can be constructed from the material used to fill the joints if it is of contrasting color, or inserts can be used. The state of Kansas and Texas, also, use this method. It has a very good feature, in that when one passes over these inserts a very slight rumble is noted, thus if the driver unconsciously crossed, it will be brought to his attention.

Letters from several states indicate their center line striping method and in some cases why they use what they do. Quoting from a letter from the state of Wyoming, "In the item of center line marking, we use a solid barrier line with broken center line- 15 foot stripe and 25 foot skip. We use a yellow color for both lines. Yellow traffic paint is a must in Wyoming, as it contrasts with snow and in our state there are sections of roads at different locations that are subject to snow every month of the year. In color we vary from the national standard and feel that our reasons are sound. The design of stripe and skip are standard: we use a 4" line in case of double marking, a 4" spacing between stripes is used."

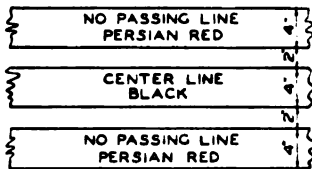
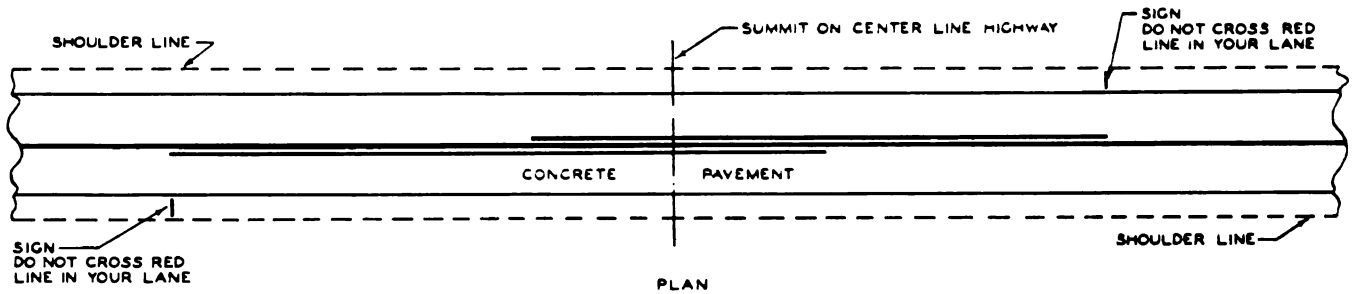


From the New Hampshire Highway department: "Practically all the narrow two lane pavements have a center stripe of yellow paint, six inches in width. On wider pavements, striping is confined more to curves and such portions of the highway as have restricted vision. Some experiments have been carried on with reflectorized paint. To date, however, in climate like ours which over several months of the year requires snow removal, we do not find the same to be durable or worthwhile!"

From the State of Wisconsin: " For a year or two during the war when paint and manpower were scarce, we did not place pavement markings on some of our state trunk highways which had previously had been marked. As a result, we had numerous complaints and we have concluded that pavement markings are an important activity and that its lack is equally noticeable to the traveling public. As a result, we have reestablished the policy of placing center lines on all pavements having a reasonable life. It is probable that we will follow the recommendations as to color, width of line, and type of marking which the A.A.S.H.O. has standardized."

The State of Rhode Island reports: " We use a solid 6" white line on two lane highways regardless of the type of pavement and hope some day to treat the hazardous vertical and horizontal curves where sight distance is limited with a 4" white barrier stripes. On four lane highways we use the double center line which consists of two 4" stripes with a 5" separation with the side lane stripes eliminated on concrete pavements. We like the reflectorized line very much indeed, but on some of our heavily travelled two lane highways, we have

PLAN NO PASSING ZONES

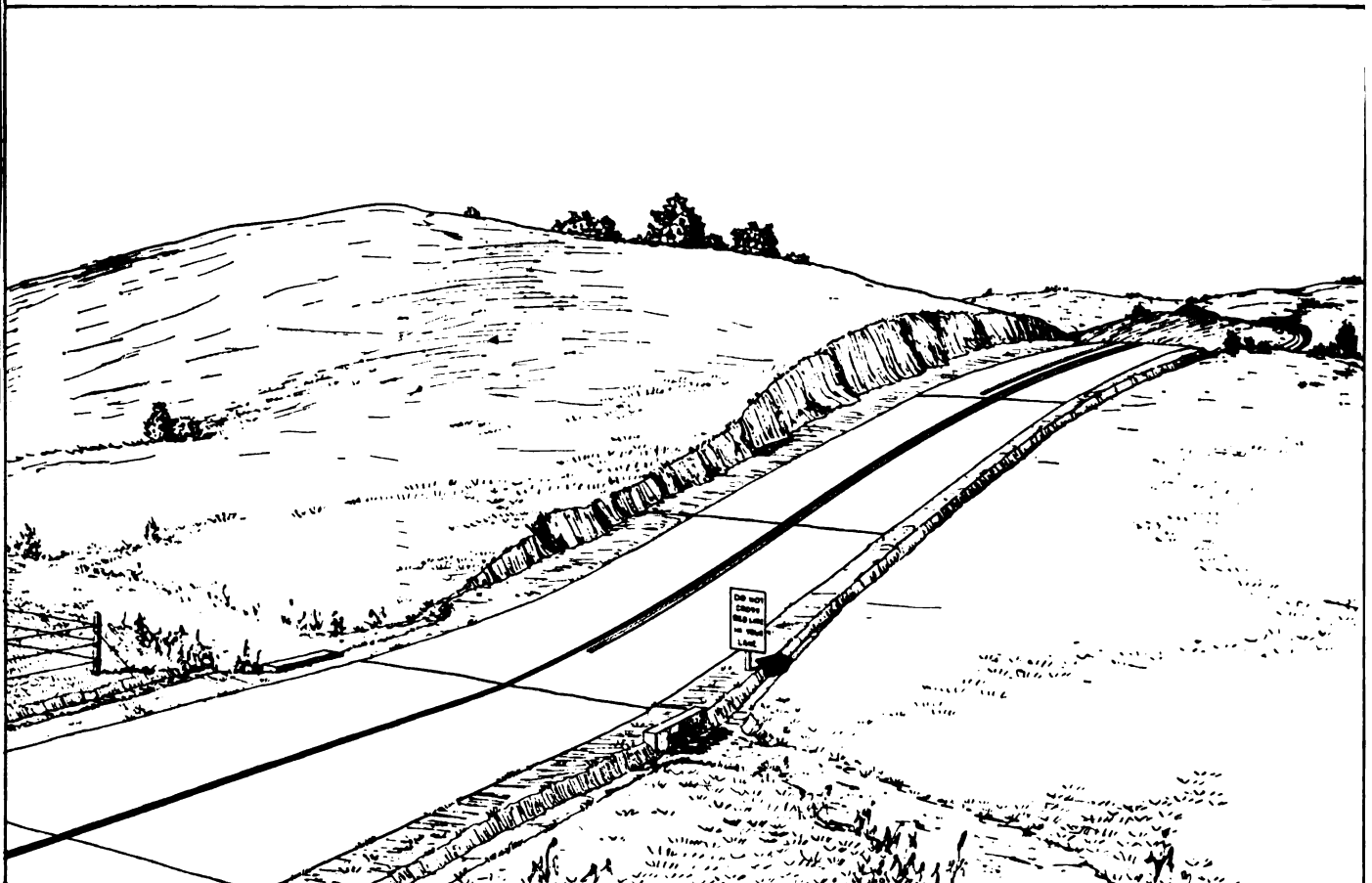
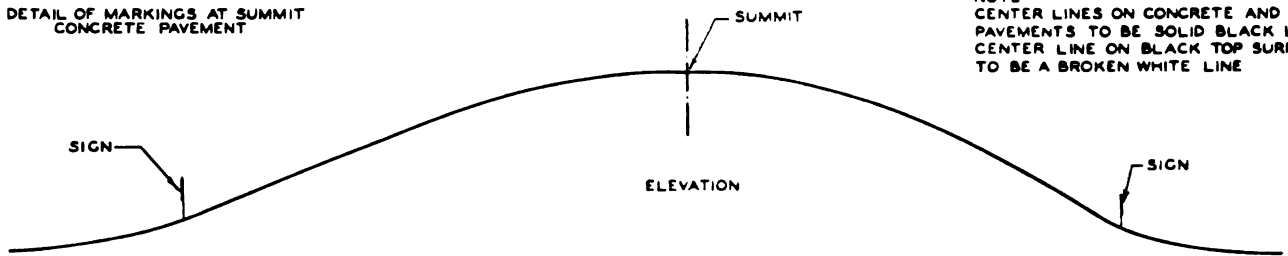


DETAIL OF MARKINGS AT SUMMIT
CONCRETE PAVEMENT

LEGEND

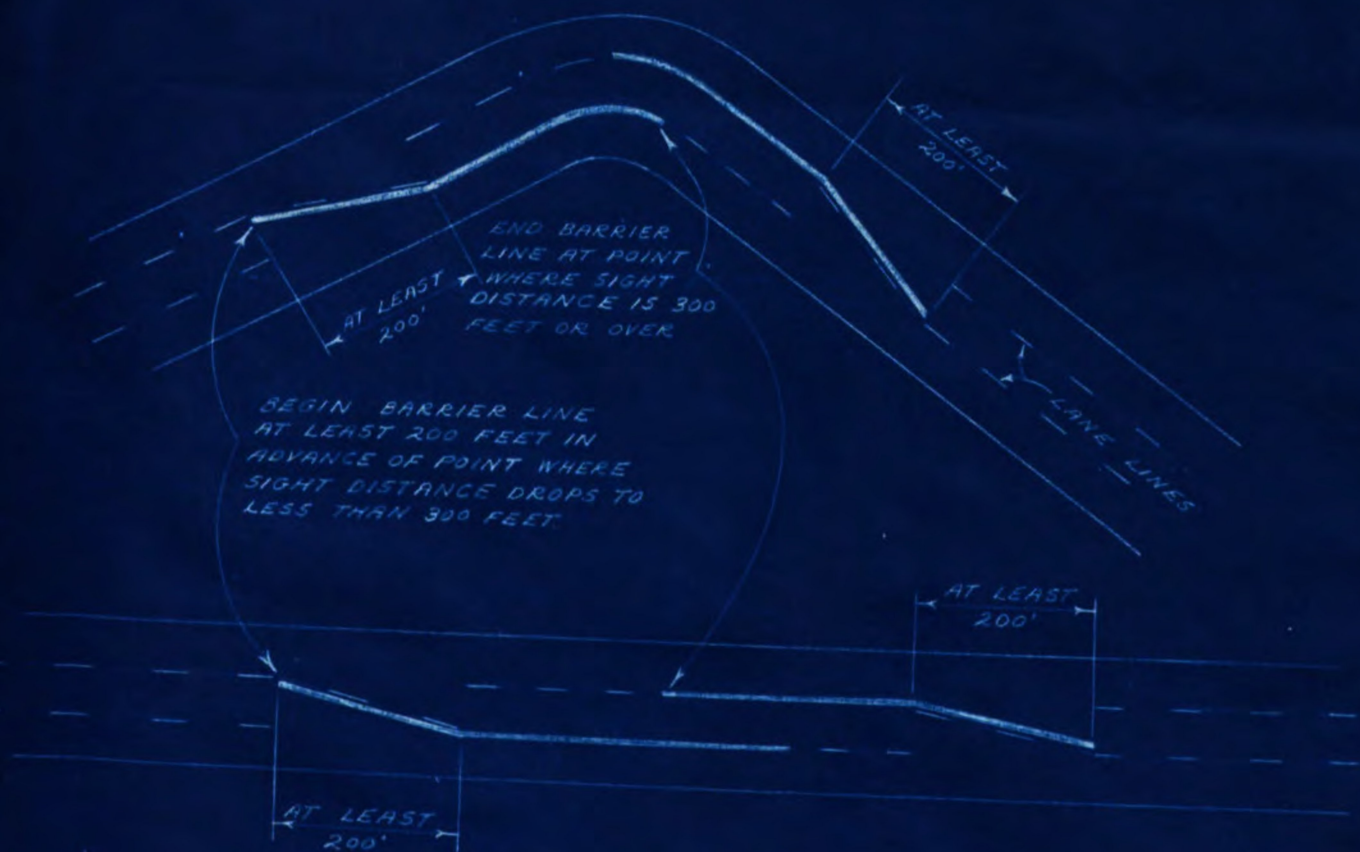
CONCRETE PAVEMENT --	CENTER LINE - BLACK
	NO PASSING LINE - PERSIAN RED
BRICK PAVEMENT ----	CENTER LINE - BLACK
	NO PASSING LINE - WHITE
BLACK TOP SURFACE --	CENTER LINE - WHITE
	NO PASSING LINE - PERSIAN RED

NOTE -
CENTER LINES ON CONCRETE AND BRICK
PAVEMENTS TO BE SOLID BLACK LINES
CENTER LINE ON BLACK TOP SURFACE
TO BE A BROKEN WHITE LINE



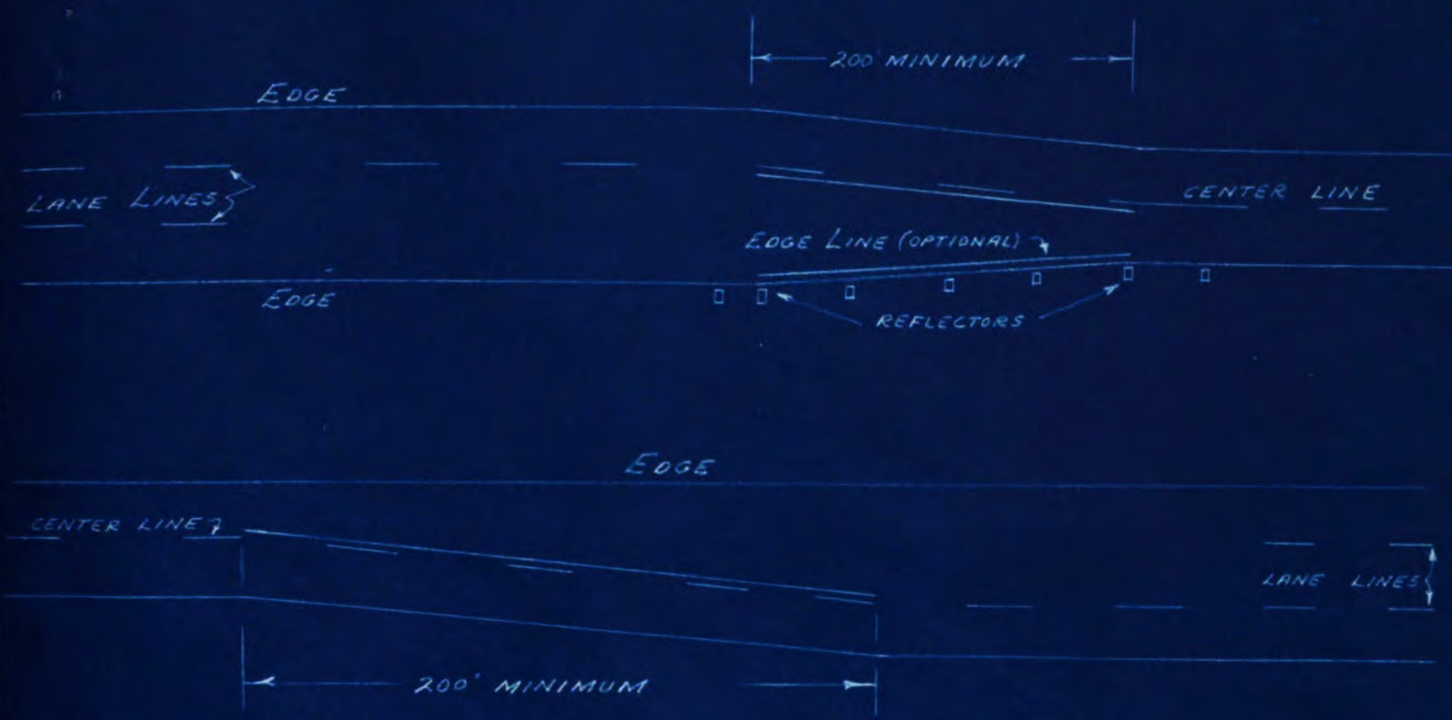
NO PASSING ZONE MARKINGS

FIG. "2"

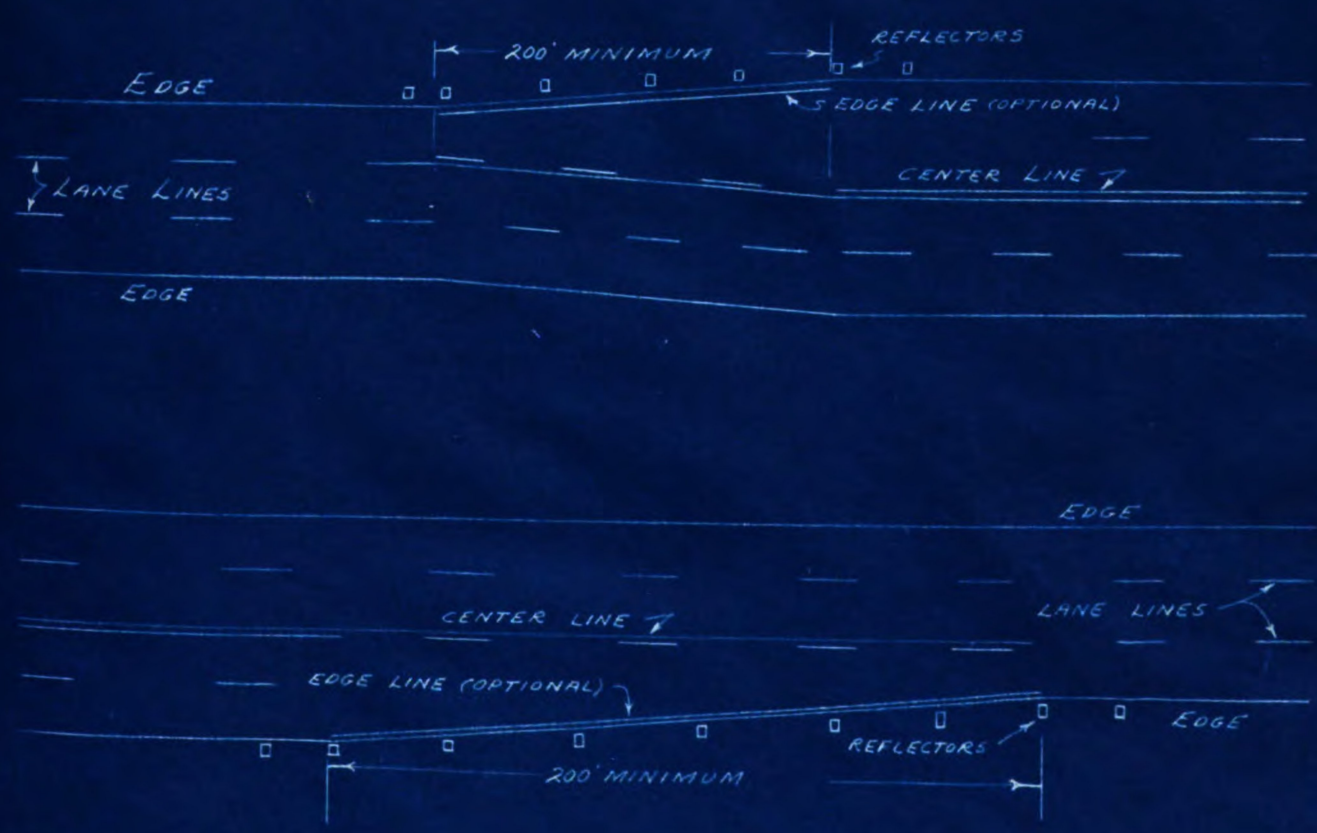
THREE LANE ROADWAY
HORIZONTAL CURVE

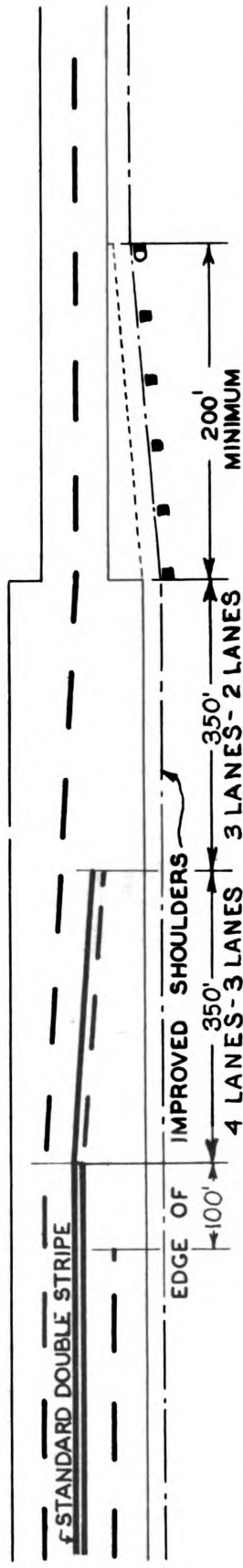
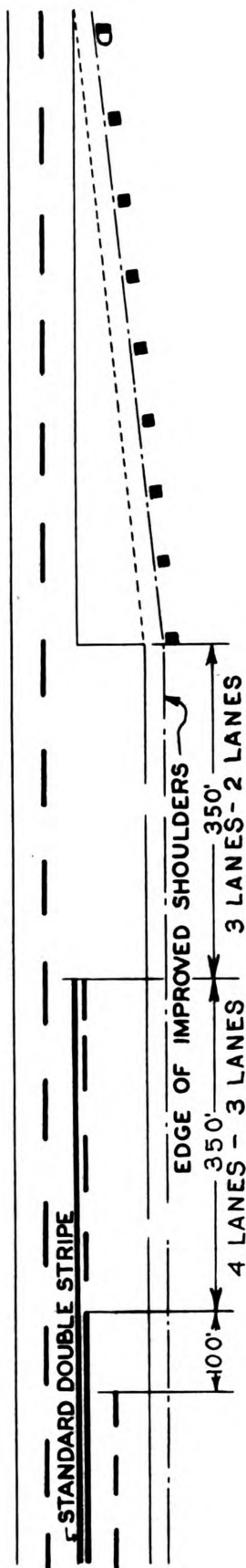
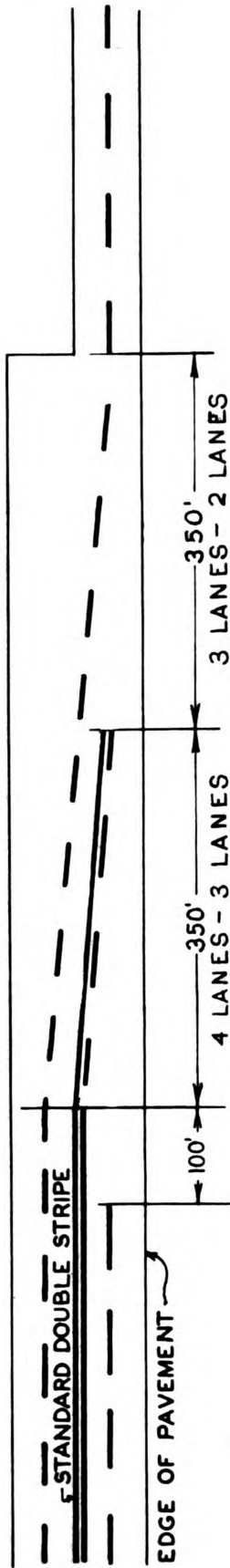
NO SCALE

NOVEMBER, 1948



TRANSITION MARKINGS - 4 LANES TO 3 LANES





LEGEND

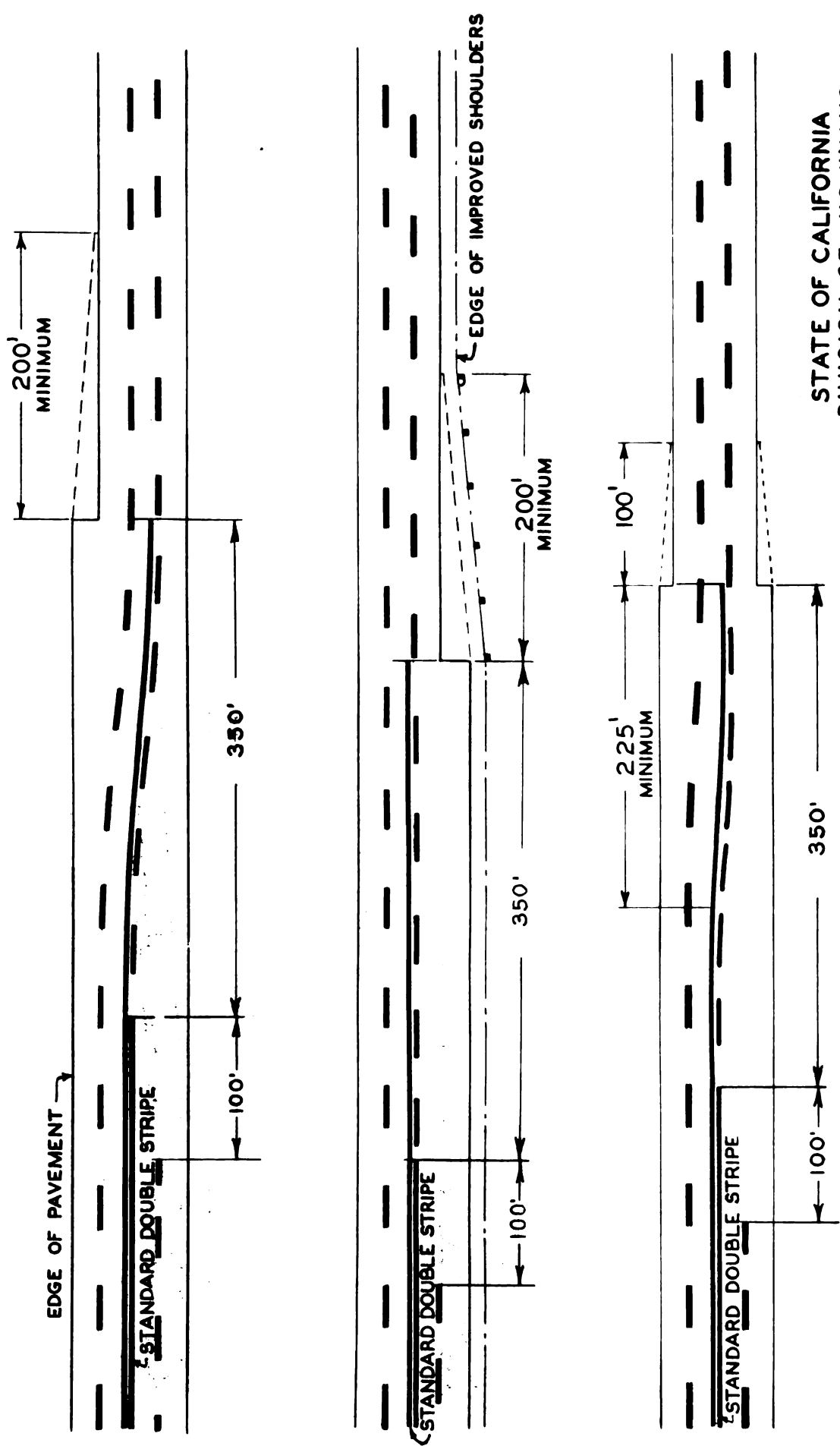
■ SIGHT POST

□ SIGHT POST WITH 3 - 3" RED REFLECTORS. (CODE W22R)

MAINTENANCE DEPT.

NOT TO SCALE

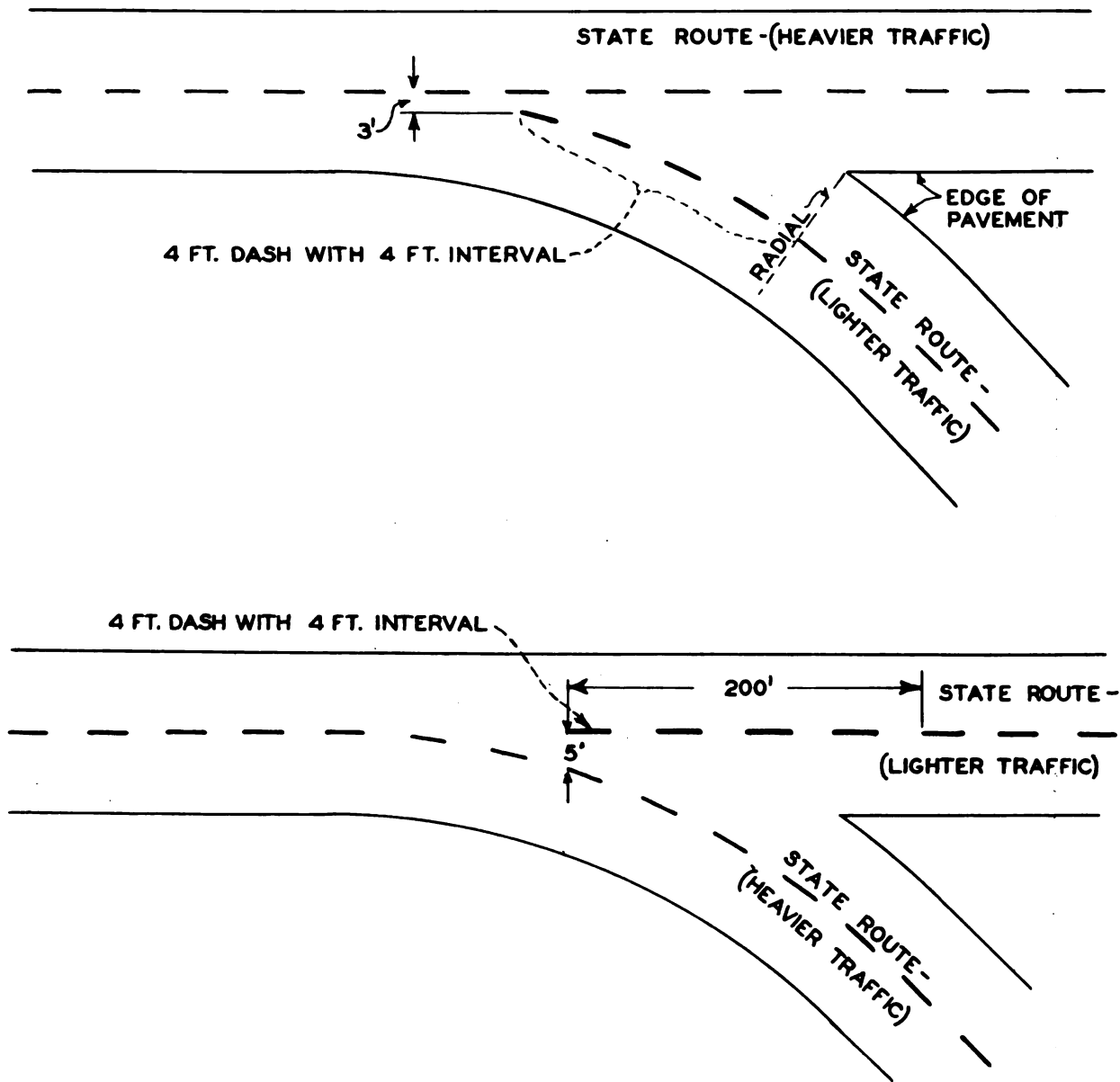
STATE OF CALIFORNIA
DIVISION OF HIGHWAYS
TRAFFIC STRIPE TRANSITION -
4 TO 2 LANE.



STATE OF CALIFORNIA
DIVISION OF HIGHWAYS
TRAFFIC STRIPE TRANSITION
4 TO 3 LANE.
NOT TO SCALE.

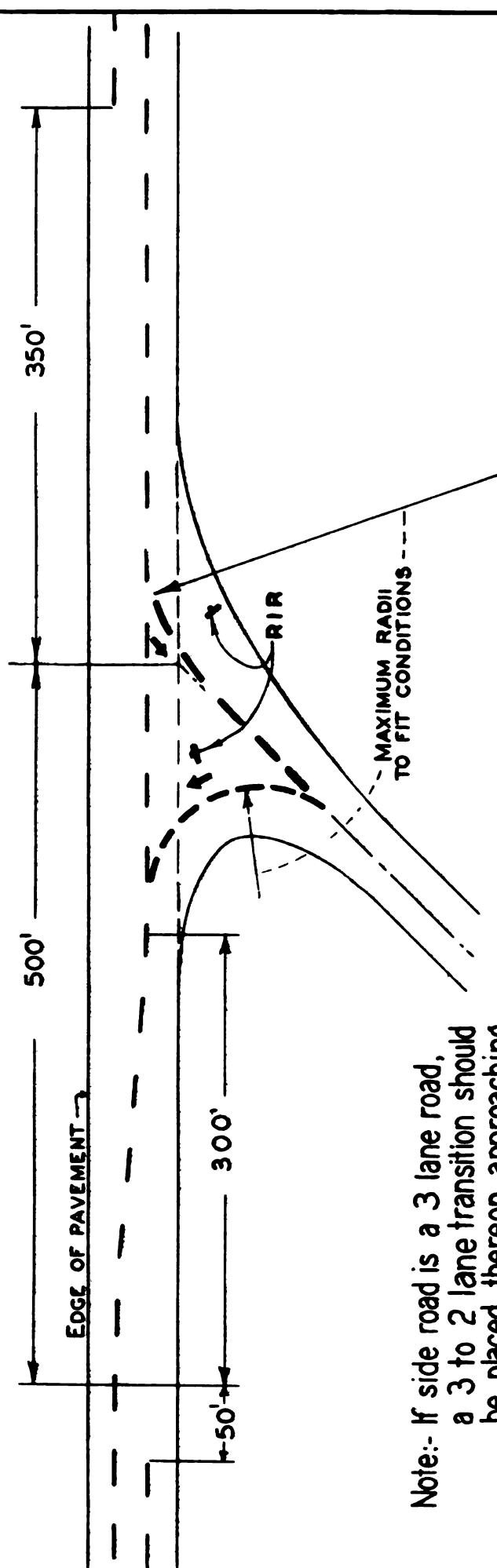
LEGEND

- SIGHT POST.
- SIGHT POST WITH 3-3" RED REFLECTORS-(CODE W 22 R)



PROPOSED TRAFFIC STRIPING
AT JUNCTION OF STATE ROUTES
HAVING HEAVY & LIGHT TRAFFIC.
(TWO LANE)

STATE OF CALIFORNIA
DIVISION OF HIGHWAYS
MAINTENANCE DEPT.
NOT TO SCALE.



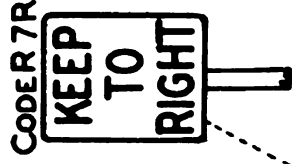
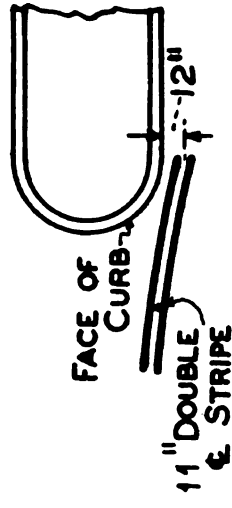
Note:- If side road is a 3 lane road, a 3 to 2 lane transition should be placed thereon approaching the intersection.

Series 3 3 2
(Also 3 3 3)

For side roads having sufficient importance.

STATE OF CALIFORNIA
DIVISION OF HIGHWAYS
TRAFFIC STRIPE TRANSITION-
FOR 3 LANE HIGHWAY AT
SIDE ROAD JUNCTION.

NOT TO SCALE



3" Dia. Red Reflectors in Curb.
Amber Flasher Optional.

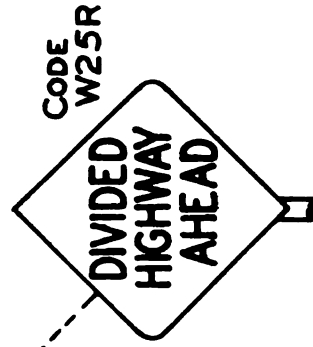
Edge of Pavement

P.C.C. Curb

Edge of Pavement

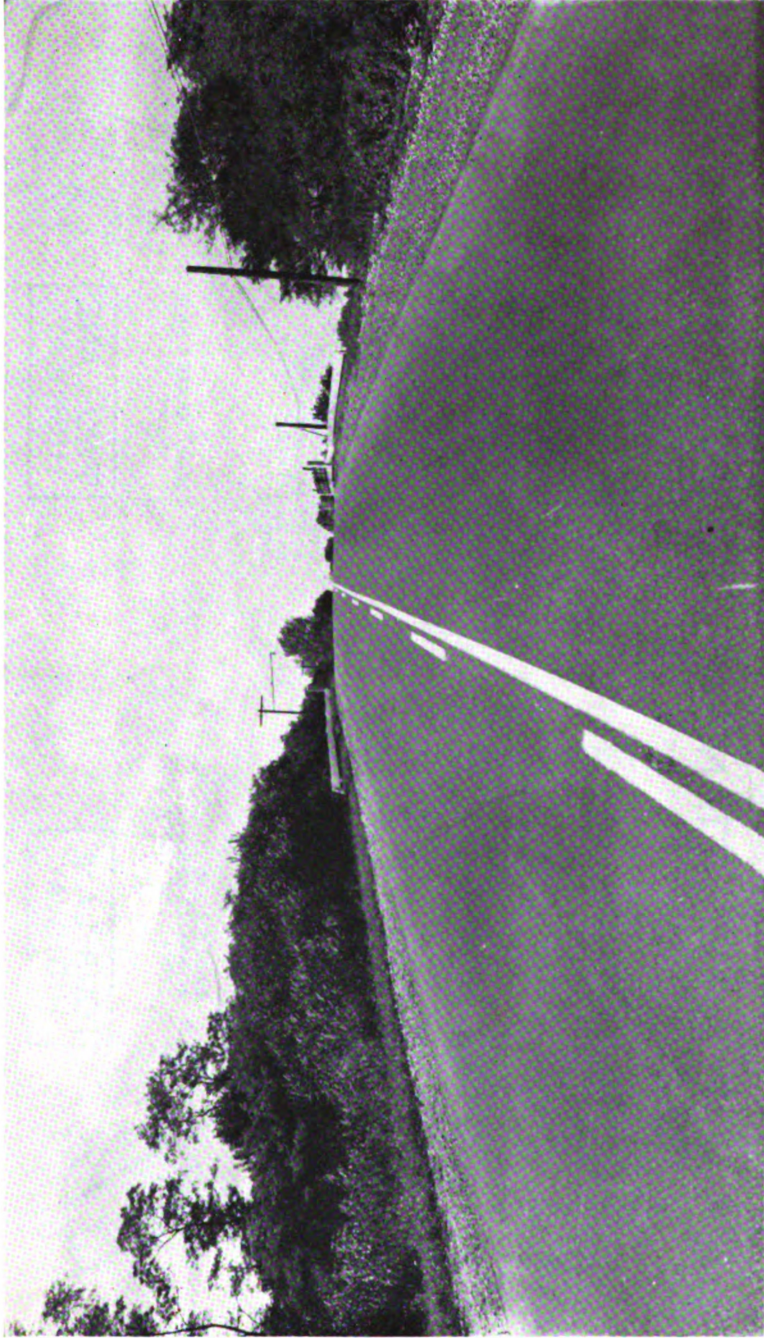
Length of Transition Variable in
Proportion to Width of Divisional Island.

Also Standard Striping
for Any Obstruction in Traveled Way.

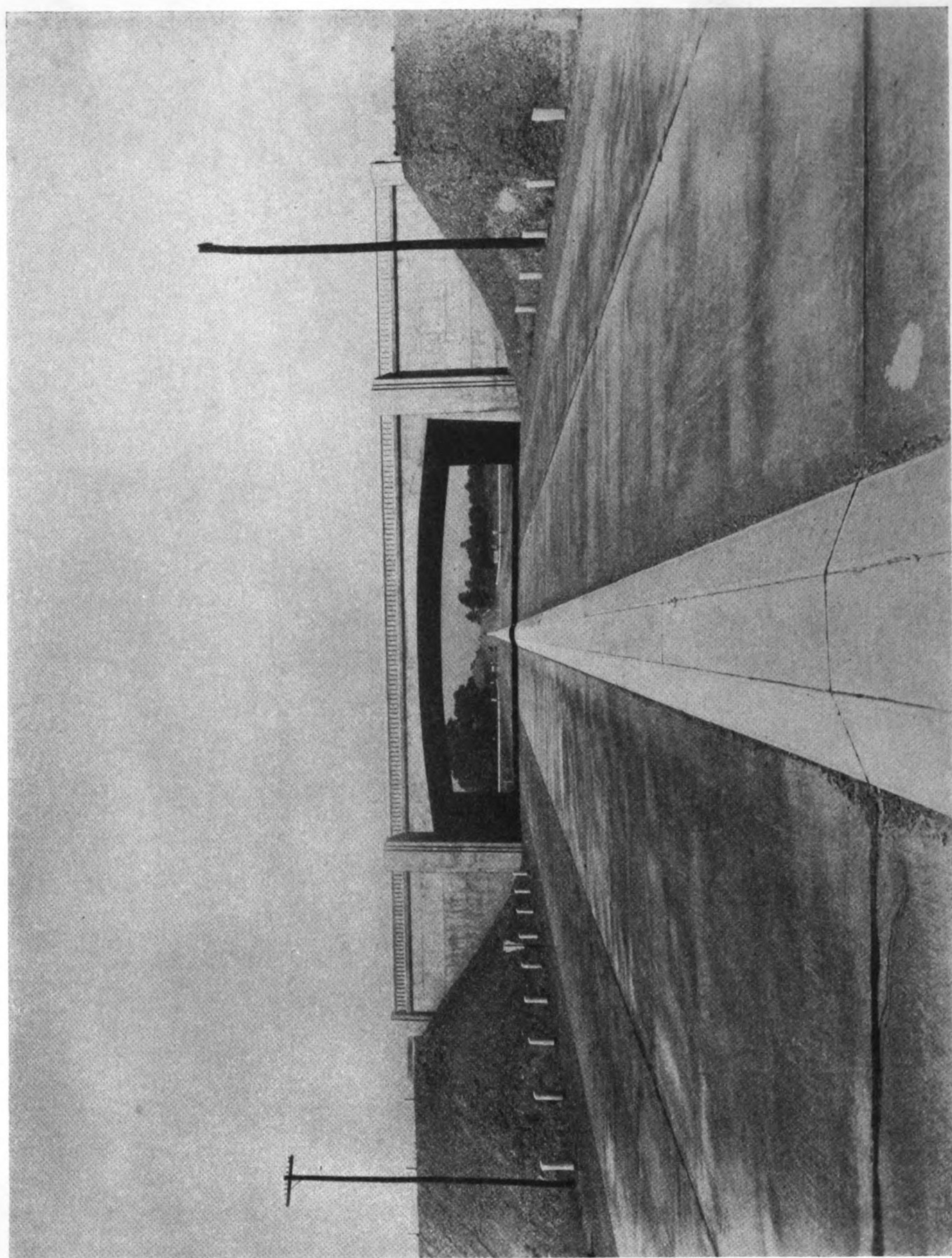


STANDARD TRAFFIC STRIPE FOR DIVIDED HIGHWAY

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS



Typical centerline stripes on New York State highway



used the paint with glass beads exclusively."

Over a period of years, it has been found that the greatest safety value in center lane separation of a four lane highway can be obtained from physical barriers. This virtually eliminates the most serious type of accident - the-head-on-collision. There has been a great deal of research on this particular method of separation. Michigan has about 300 feet of medial barrier designed by the Yale Traffic Bureau under test. Many four lane highways are constructed with a boulevard type of separation. The value of this type of barrier is increased if low planting is done to eliminate glare from on coming cars. Woodward Avenue is an excellent example of a multiple lane highway with low planting.

Other features of highway design considered from the standpoint of safety are crowns and superelevations of curves. Although, crowns are not of major importance in comparison with other phases of design with safety in mind, it must be noted, however, that if the surface of a roadway were made level across the road, rain water and melting snow would not run off, thus causing the highway to be slippery and dangerous when wet. The crown or difference in elevation between the center and the edges of a road depends on the type of surface used. It is obvious that water will run off more readily from a smooth concrete surface than from a rough one. For high type surfaces a crown of 1/8th of an inch per foot has been found to be sufficient. The crowned surface is generally curved to the shape of a parabola. In laying out the crossection of a highway it is necessary to obtain elevations of the surface at different

points, using a parabolic surface, this verticle distance of any point below a horizontal line tangent to the roadway surface at the center is computed as follows:

$$Y = \frac{4CX^2}{W^2} = C\left(\frac{X}{\frac{W}{2}}\right)^2$$

Y = verticle distance of point below tangent at center of road in inches.

C = crown of road in inches.

X = horizontal distance to point from center line of roadway in feet.

W = width of roadway in feet.

Example: the concrete pavement 40 feet wide is to have a crown of 1/8 inch per foot of half-width. If a parabolic crown is used, to find the ordinate from the tangents at the center surface at a point 5 feet from center.

Solution: $C = 1/8 \times 20 = 2.5$ in at 5 feet from center.

$$Y = \frac{4CX^2}{W^2} = \frac{4 \times 2.5 \times 5^2}{40^2} = \frac{4 \times 2.5 \times 25}{1600} = 0.156 \text{ in}$$

The ideal alignment for safe design would be a perfectly straight road between two points at grade. This would eliminate all vertical and horizontal curves and the resulting dangers they entail. Of course this is not only impossible but not desirable because it would be tiresome to drive. Therefore, the radius of the numerous curves that are necessary to fit a highway line into its natural surroundings has an important bearing on the safe driving speed and sight-dis-

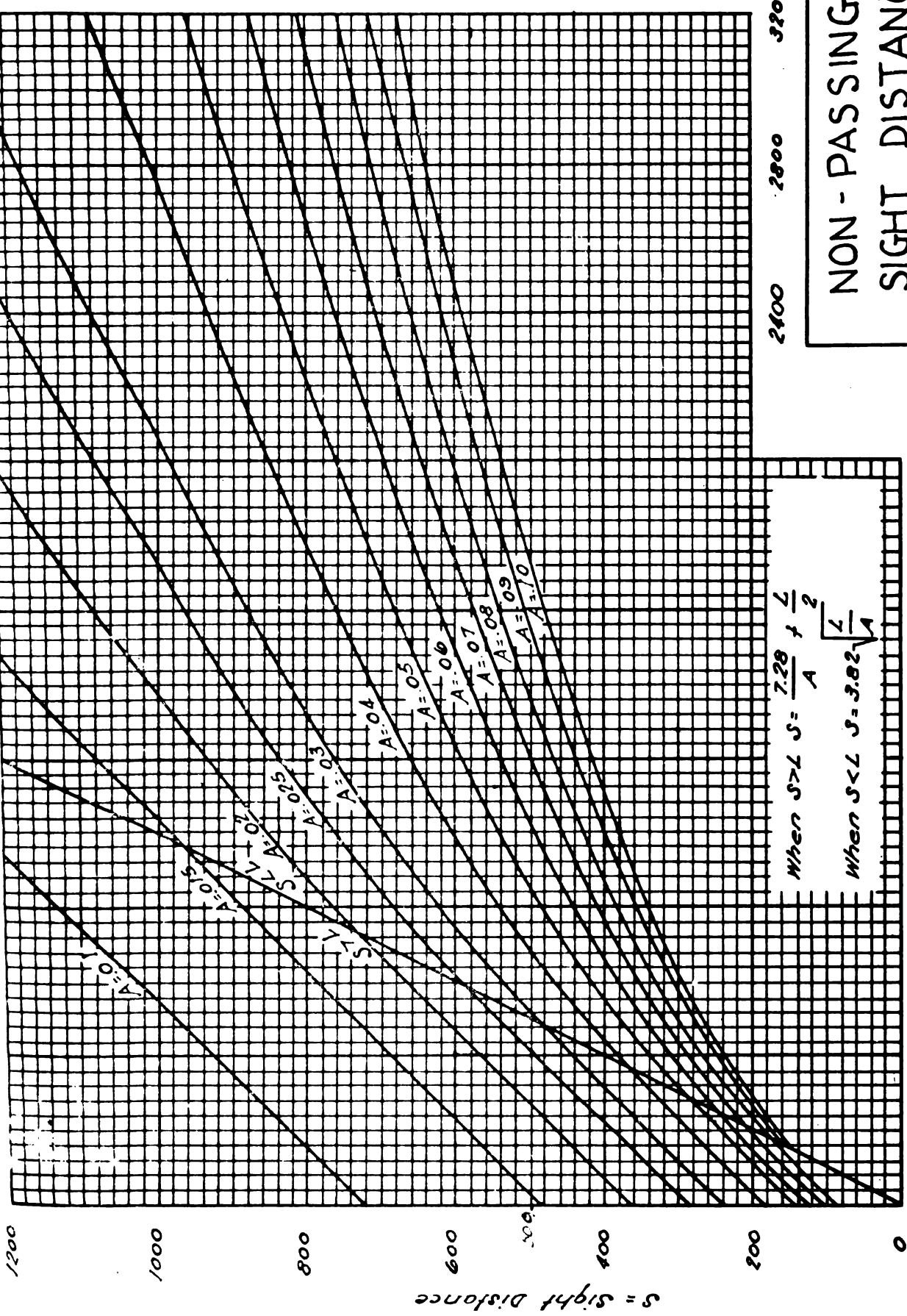
tances of the road. The present standards set limiting, minimum radii for curves that are, for the most part, greater in length than previously used. The outer edge of the pavement itself is elevated in varying degrees depending on the length of radius of the curve. If this relationship is worked out carefully it will actually facilitate steering around the curve, eliminate the need for a quick recovery coming out of the curve, and cause only a very slight awareness of any superelevation. The degree of superelevation must not be so great as to cause lateral slipping toward the center when a slower speed is used during rainy or icy weather. The following computations and illustrations will serve as examples to the reader on how vertical and horizontal curves, and sight-distances are worked out in design. A word should be said about sight-distances. Vertical sight-distance is the distance at which a driver, who is sitting in a vehicle with his eyes assumed to be about 5 feet above the pavement, can see a corresponding point on another car. This distance on a straight level road is about eleven miles, and is limited by the earth's curvature. Horizontal sight-distance is a similar measure in which the limiting obstruction would be found along the side of the highway on the inside of the curve. This could be the shoulder of a hill, a building, or trees. Vertical and horizontal sight-distances are computed for every foot of highway constructed.

TO AVOID THE APPEARANCE OF A KINK IN THE HIGHWAY
FOR SMALL DEFLECTION ANGLES THE FOLLOWING
MINIMUM LENGTHS OF CURVES SHOULD BE USED:

Central Angle Δ	Min. Length Curve L
1°	900'
2°	800'
3°	700'
4°	600'
5°	500'

Recommended by A.A.S.H.O. in
their policy on "Geometric Design
Standards For Highways" in 1940.

MINIMUM LENGTH OF CURVE
FOR
SMALL DEFLECTION ANGLES



0 400 800 1200 1600 2000

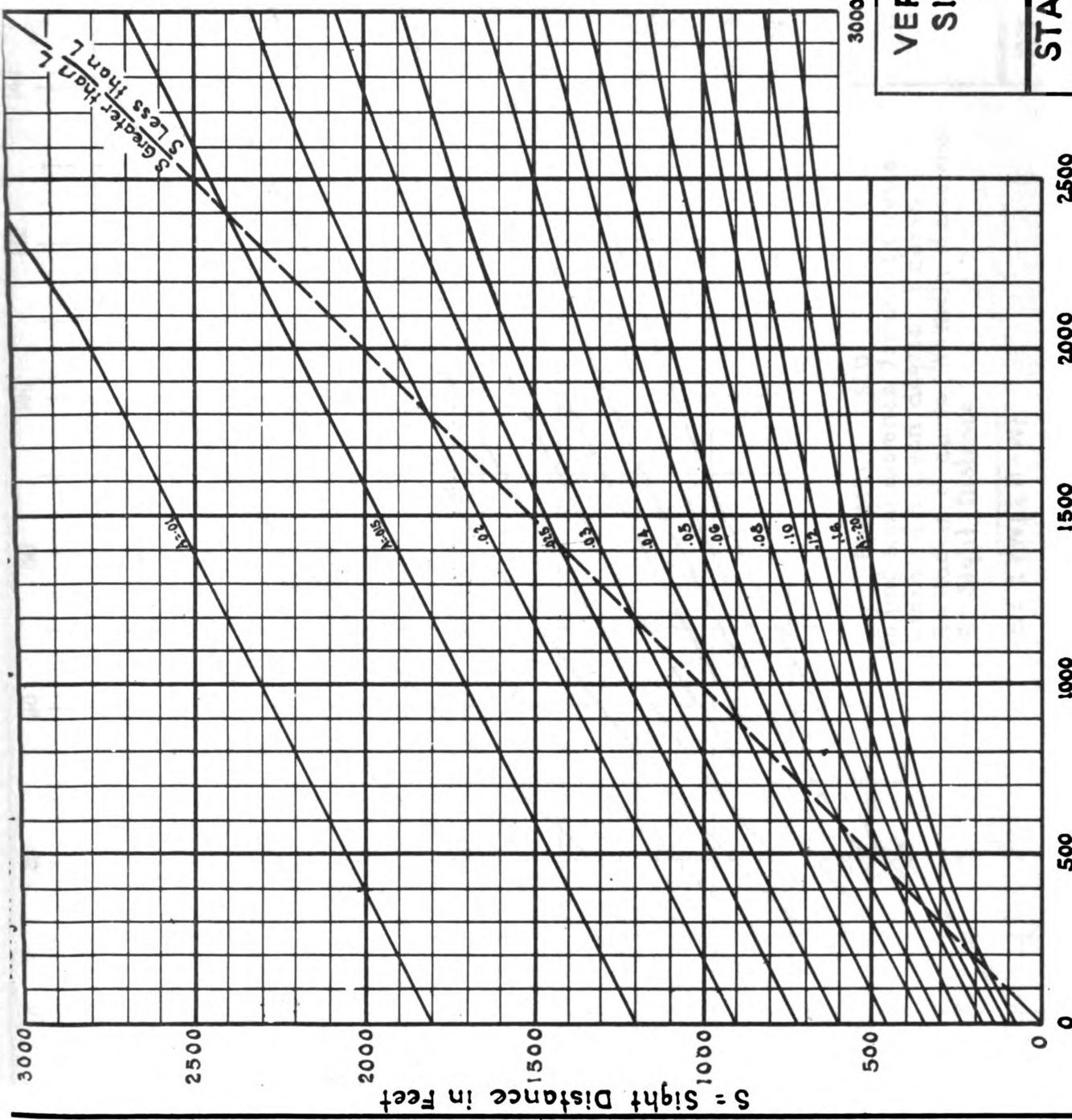
L = Length of Vertical Curve - Feet
 A = Algebraic Difference of Grades - % + 100
 Height of eye 4.5 ft. Height of Object 4 in.

2400 2800 3200

NON - PASSING SIGHT DISTANCE

STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS

Designed: Paschal	Traced: S.A.B.
Checked: Burke	Checked:



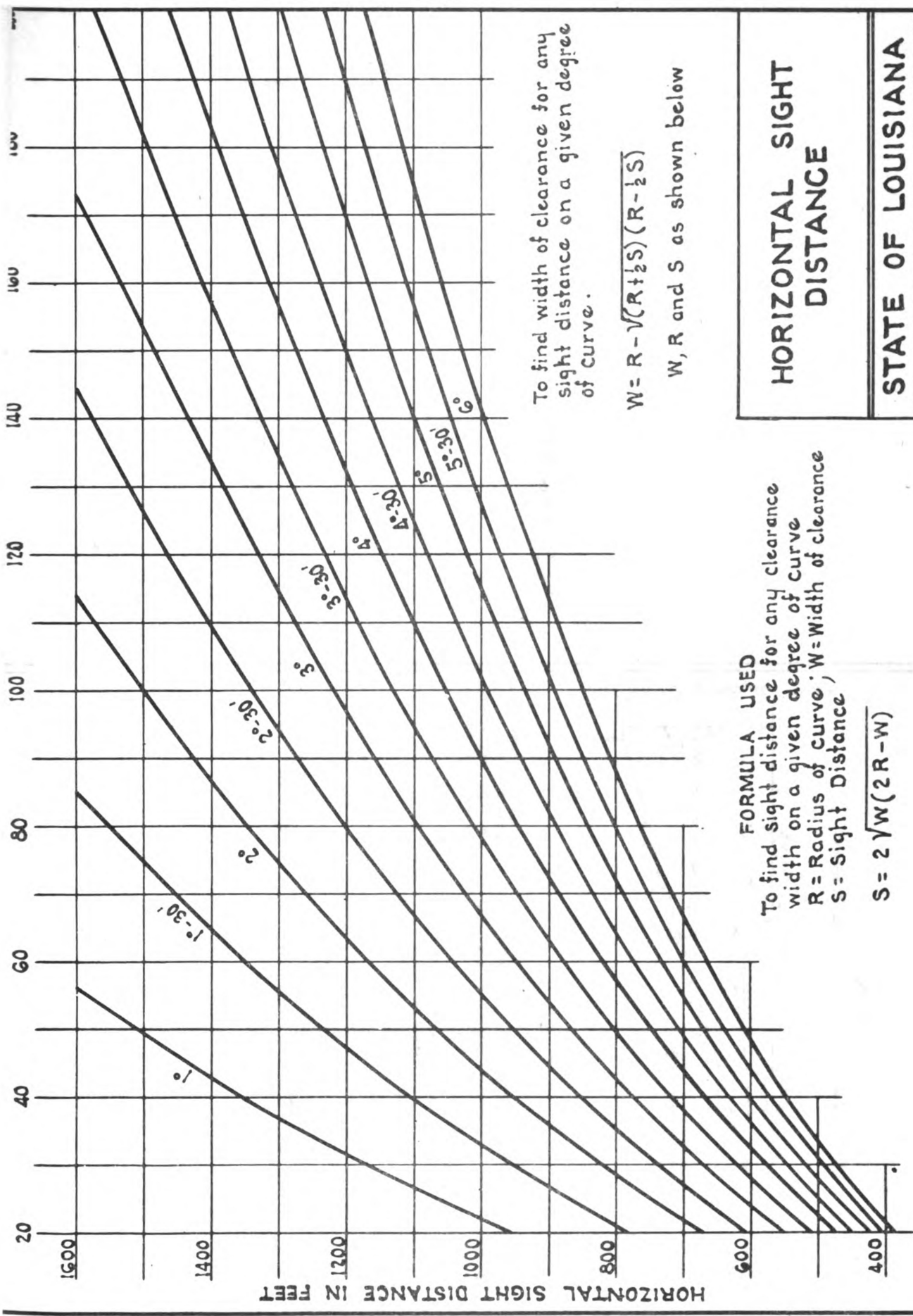
A = Algebraic difference
of grades in percent
divided by 100

Formula Used:
When S is less than L
 $S = 6\sqrt{\frac{L}{A}}$

When S is greater than L
 $S = \frac{18}{A} + \frac{L}{2}$

**VERTICAL PASSING
SIGHT DISTANCE
(OVERCREST)**

STATE OF LOUISIANA DEPARTMENT OF HIGHWAYS	
Detailed: D.J. Daigle	Traced: D.J. Daigle
Checked: A.J.L.	Checked: A.J.L.



HORIZONTAL SIGHT DISTANCE IN FEET

To find width of clearance for any sight distance on a given degree of Curve.

$$W = R - \sqrt{(R + \frac{1}{2}S)(R - \frac{1}{2}S)}$$

W, R and S as shown below

FORMULA USED

To find sight distance for any clearance width on a given degree of curve
 R = Radius of curve; W = Width of clearance
 S = Sight Distance

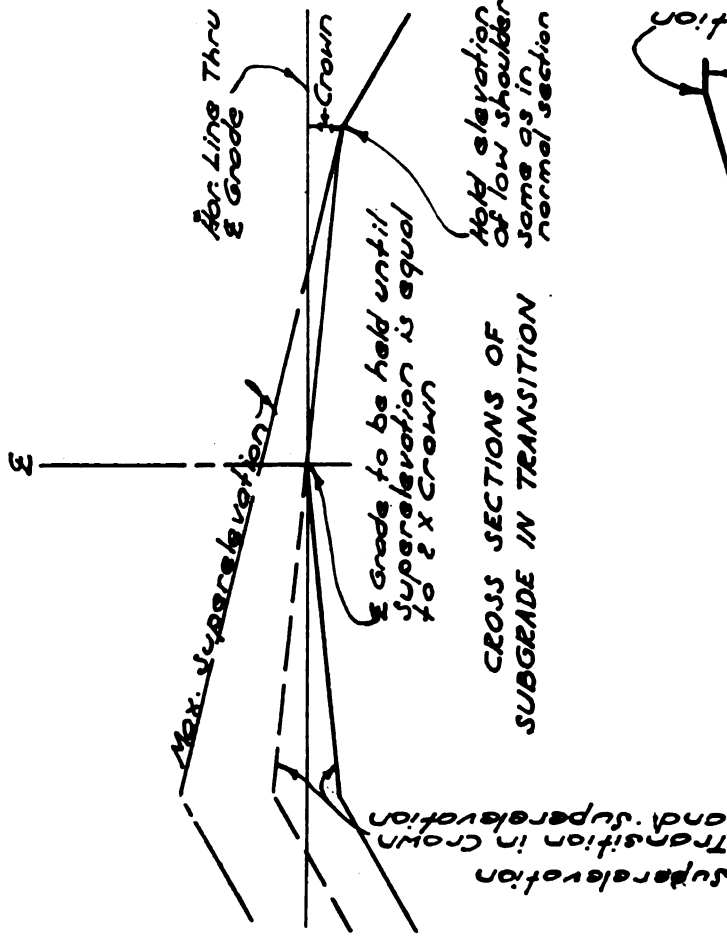
$$S = 2\sqrt{W(2R - W)}$$

* Based on clear horizontal sight thru a point 4½ Feet above E Elevation.

HORIZONTAL SIGHT DISTANCE

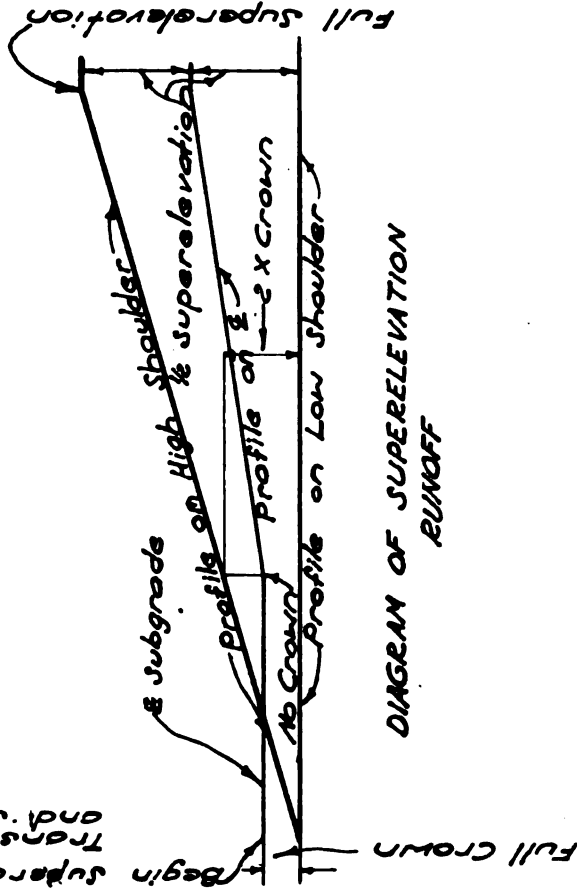
STATE OF LOUISIANA
 DEPARTMENT OF HIGHWAYS

Traced: Landry	Checked: A.D.J
Traced: D.J. Daigle	Checked: A.J.L

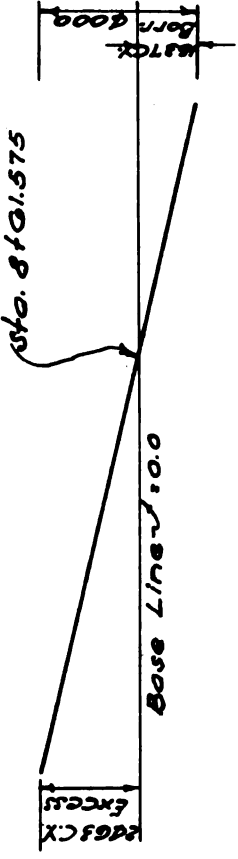


CROSS SECTIONS OF SUBGRADE IN TRANSITION

DIAGRAM OF SUPERELEVATION RUNOFF



Summation of Earthwork to Sta. 8+00
Exc. = 22,863 Cu. Yds.
Emb. = 15% = 20,000 Cu. Yds.



Earthwork from Sta. 8+00 to 9+00
Exc. = 8000 Cu. Yds.
Emb. = 15% = 8000 Cu. Yds.

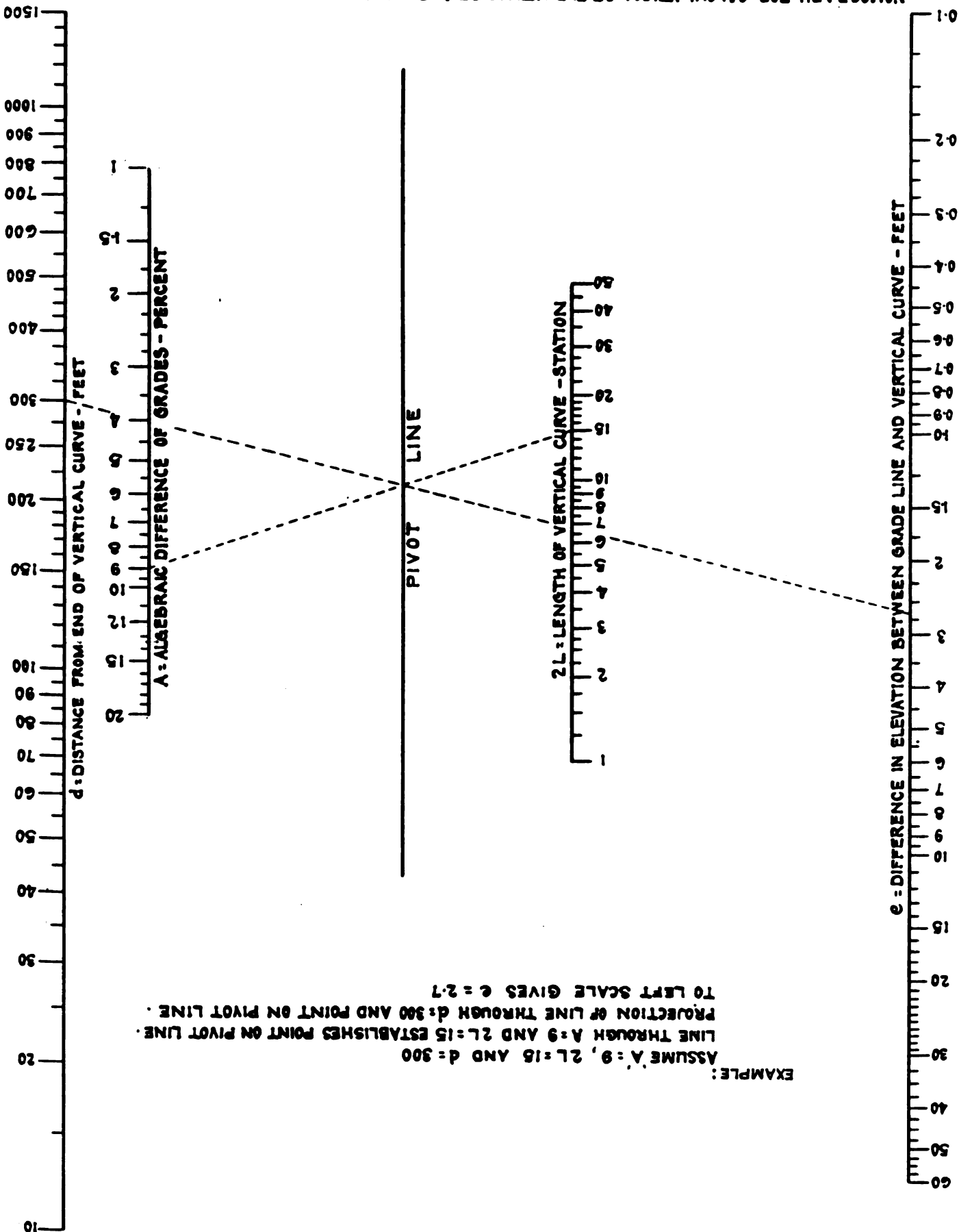
$$\begin{array}{r} \textcircled{1} \quad 22,863 \\ - 20,000 \\ \hline 2,863 \end{array}$$

$$\textcircled{2} \quad \begin{array}{r} 8000 \\ - 8000 \\ \hline 0 \end{array}$$

$$\textcircled{3} \quad \frac{2863}{8000} = 0.3575$$

Compiled by:- H.A. Lowler
3-14-34

NOMOGRAPH FOR CALCULATION OF ELEVATION OF A POINT ON A PARABOLIC VERTICAL CURVE



Chapter Eight

Minor Points of Design

The degree of safety of a highway is not only determined by the actual design, but also is dependent on such things as guard rails, retaining walls, traffic control devices, snow fences and fences, and illumination. These several mentioned points of design will now be taken up separately.

Guard rails may be typed according to the material they are constructed from: wood, cable and wire tape, wire mesh, steel plate, and masonry. However, no matter what material they are made from, they must be a protection and act as a warning. To be effective and lend safety to the motorist, they are used wherever the highway is on an embankment and the side slopes are steeper than 1 vertical to 3 horizontal, or on any section of a highway where the motorist needs this added protection. Their main function is to prevent a vehicle from leaving the highway in case the operator loses control of the machine.

The ideal guard rail should deflect the vehicle back toward the roadway rather than check its speed or stop it. Also the guard rail should be constructed in such a manner as not to entangle the vehicle, but to allow it to slide freely along the face of it. It is impractical to construct a guard rail with sufficient strength to stop a fast-moving car quickly. If the guard rail stopped, within 1 or 2 feet, a vehicle that struck it at high speed, the damage caused would be almost as great as if the vehicle had gone over the embankment. Other

design features of a guard rail should include low enough height so as to come in contact with the bumper and the wheels of the car, any other part of the vehicle, such as the hood, would crush easily under impact. They should be highly visible and not be constructed so as to cause snow to drift in their locality.

Wooden guard rails were used extensively during the horse and buggy days. They still are used to some extent where lumber is plentiful. The disadvantage of the wood type is that lumber of small cross-sectional area has a low resistance to shock and when struck will damage the vehicle. However, if heavy planks are used, say 3 x 10 inches and larger, this disadvantage will be overcome to a great degree.

Steel cable railings usually consist of $3/4$ inch wire tape mounted on wood posts, steel posts, and masonry posts. Although low in cost to build, they are difficult to see. Also they sag with weather changes; and they actually don't give too much protection when struck. If spring tightening devices and off-set lugs, to hold the cable away from the post, are used, this decreases the last two mentioned disadvantages to some degree, while durable white paint will increase their visibility.

Wire mesh guard rails are usually from 14 to 22 inches wide and are usually placed on wood posts. They have several advantages; they don't cause too much damage when hit; they are strong and tend to deflect cars back to the roadway when struck; and when painted white they are very easily seen. The disadvantage of using them is when struck the section must be

replaced, also they tend to act as snow fences in snowy regions.

There are several types of steel plate guard rails used today. Some are directly connected to posts, while others have spring connections giving greater deflection. They cause little damage to the vehicle when struck and are easily seen. However, they too act as snow fences in snow areas.

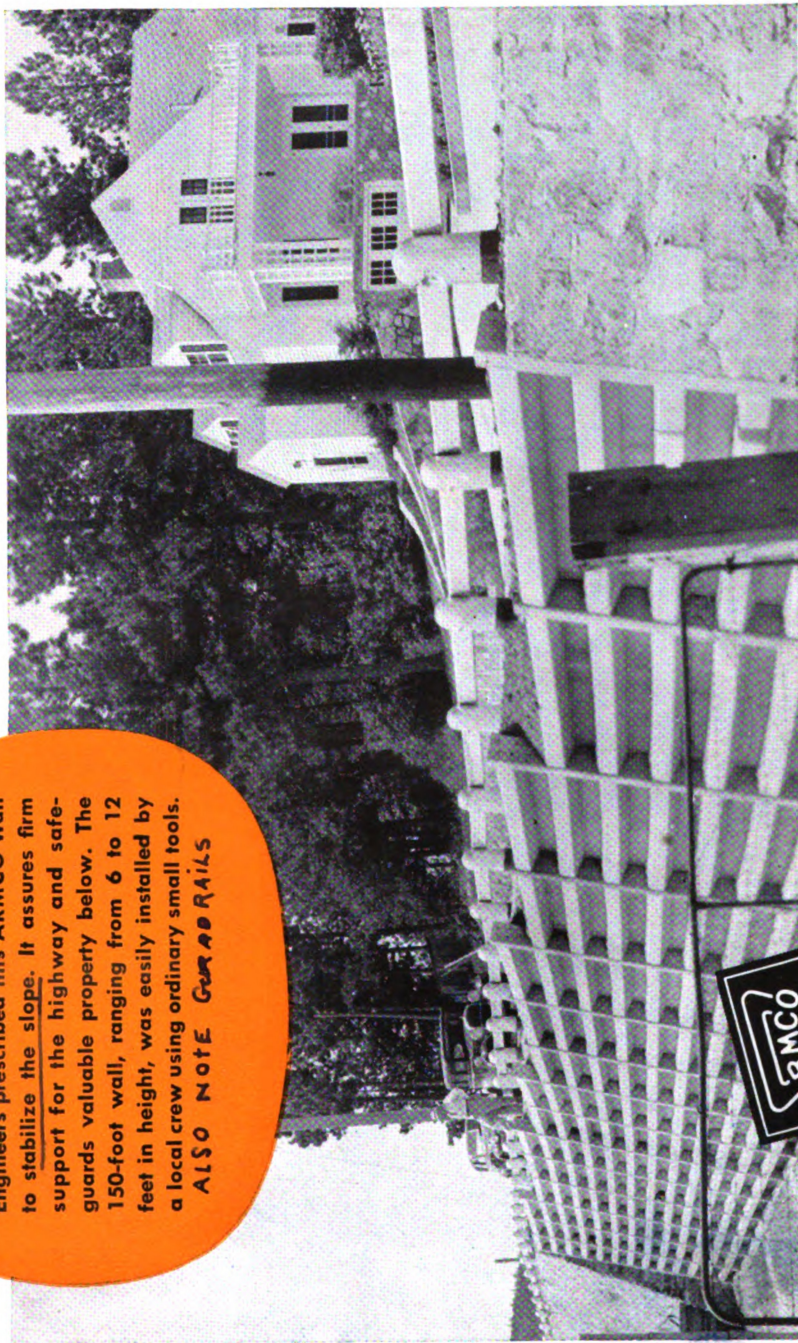
Masonry railings are not used very often, except where appearance is important. They make a very neat looking rail, and need not be painted.

Guard rails demand special treatment. They must be kept painted to maintain their visibility effectiveness; and they must not be placed so as to become hazards themselves. Since guard rails make parking on the shoulders impossible and since guard rails make mowing and maintaining the shoulders difficult, sometimes other construction would be better employed, such as making the slope 4 horizontal to 1 vertical.

In unusual cases gravity retaining walls, which depend on their own weight for stability, are needed in highway construction. However, they are rarely needed over 18 feet in height. They provide safety by stabilizing the slope and thus keeping the soil off the road surface. This of course would lend safety by preventing skidding caused from mud from the slope, and losing control of the vehicle by striking rocks and other such objects that had rolled onto the highway. Retaining walls are usually built in monolithic sections of 20 to 25 feet in length; expansion joints are provided between these sections. The expansion joints may consist simply of a plane of weakness

Engineers prescribed this ARMCO Wall to stabilize the slope. It assures firm support for the highway and safeguards valuable property below. The 150-foot wall, ranging from 6 to 12 feet in height, was easily installed by a local crew using ordinary small tools.

ALSO NOTE GUARDRAILS



between the sections, produced by allowing one section to set before building the adjacent wall; or it may be a key joint.

Another phase under minor points in design is signs and signals which is an important part of any highway system. Signs and signals have an essential place in the safety of a highway. Their design and installation has become quite well standardized through the efforts of the American Association of State Highway Officials. Highway signs may be classified as: route markers; guide series; informational series; regulatory series; warning series; and caution series.

As the speed of the vehicle has increased and as the volume of traffic has increased, traffic control devices have become more necessary for warning and guiding traffic. Intersections are the most critical points in traffic control, especially where two primary routes cross. However, excessive use of signs to warn of hazards, signs to indicate traffic regulation, and the misapplication of control devices not only wastes the public's money, but has in many cases accomplished the reverse of the intention, causing delay, confusion, and disrespect for and disregard of all control devices.

Traffic control requirements in any specific case cannot be determined by guess work. They should be based on sound engineering principles established by factual studies of accidents, speeds, physical conditions, and delay. In this way the problems can be understood and subsequently solved with the result of safety to the motorist.

Modern highway speeds and complex intersections require signs which can be seen at long distances and understood in-

stantly. This calls for simple standardization. The following characteristics of signs have been standardized and made simple to provide uniformity of significance in the signs themselves, and to make familiarity with them easy to acquire even by the most casual driver:

- | | | |
|-----------------|----------------|------------------|
| (a) application | (d) location | (g) wording |
| (b) shapes | (e) dimensions | (h) lettering |
| (c) colors | (f) symbols | (i) illumination |

The first series to be discussed is route markers. The great advantage to tourists in having continuous route numbers across the states is quite obvious. At the time this system was established, each of the numerous trail associations had its own distinctive marker and, in many cases, several such associations used the same highway throughout varying distances. A situation demanding correction was thus created. Some of these trail associations made very fine contributions to the highway improvement program. Others did much more harm than good, for sometimes one section of a road might carry as many as eight different sets of route markers. Over 25,000 miles of uniformly marked roads in the United States highway system has done away with all this confusion.

The standard route marker for all U.S. highways is a shield bearing the name of the state across the top and below the lettering U.S., followed by the route number. The design is black on a white background. These shields are used only in marking U.S. highways. In general, highways marked with odd numbers run north and south, while those with even numbers run east and west.

Various types of markers are used for state routes in the different states. Several states, including Arkansas, Illinois,

GUIDE

FEDERAL MARKER SERIES



M-1



M-2



M-4



M-5



M-3

M-1 U. S. ROUTE *Shield*

Regulation shield for marking of all federal routes. Mount on one steel post, or special steel frames. (Refer to "Sign Assemblies—Standard Types" for details of erection.)

M-2 U. S. ROUTE *Shield*

Special shield for limited use in urban areas where space does not permit use of regulation size. Approval for use must be granted by main office. Mount on one steel post, or special steel frames.

M-3 U. S. ROUTE *Shield*

Special shield for limited use in urban areas where space is restricted. Approval for use must be granted by main office. Mount on one steel post, or special steel frames.

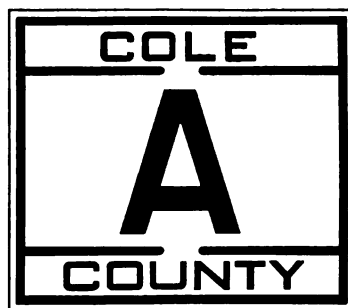
M-4 FAS *Marker*

Use at beginnings and ends of Federal Aid road projects off the regular Federal Aid System, such as NRS, WPS, WPGS and FAGS projects. It is necessary that the project number be shown but not the prefix letters. Indicate directions by use of the small arrow. Mount on one wooden post on the north side of East-West highways and on the east side of North-South routes. (Refer to "Sign Assemblies—Special Types" for details of erection.)

M-5 FAP MARKER

Use at beginnings and ends of Federal Aid road projects on the regular Federal Aid System, such as FAP, NRH, WPGH and FAGH projects. It is necessary to show the project number but not the prefix letters. Indicate directions by use of the small arrow. Mount on one wooden post on the north side of East-West highways and on the east side of North-South routes. (Refer to "Sign Assemblies—Special Types" for details of erection.)

GUIDE
STATE MARKER SERIES



M-10 STATE ROUTE *Marker*

Use on all State numbered routes. Mount on one steel post, or special steel frames. (Refer to "Sign Assemblies—Standard Types" for details of erection.)

M-15 SUPPLEMENTARY ROUTE *Marker*

Use on all supplementary lettered routes. At county lines erect supplementary markers for each direction of travel indicating the county to be entered. Mount on one steel post, or special steel frames. (Refer to "Sign Assemblies—Standard Types" for details of erection.)

Missouri, Ohio, and South Dakota use the state outline bearing the route number as a distinctive marker. Some states use markers such as a covered wagon in Nebraska, the conventional sunflower in Kansas, the indian head in North Dakota, and the triangle in Wisconsin.

The U.S. markers should always be placed at intersections where a motorist is likely to become confused, such as: at all right angle intersections; at all intersections where the route turns; at all irregular intersections, such as a "T" or "Y"; at all intersections where the type of road surface changes. On straight, open stretches of a U.S. numbered highway, additional markers placed at one and one-half mile intervals help the motorist considerably. State route markers should be used in similar cases.

Informational signs are used to give locations, distances, speed limits, cities on a route, etc. They are of value to the motorist, but do not relate to the immediate or detailed control of the vehicle. The standard shape is rectangular. They are usually black symbols or letters on a white background and are bordered in black for higher visibility. (see illustrations)

Directional signs are those which give information necessary to the operation of the vehicle. There are two groups of this type; those requiring readiness to act, for example: school zone. These are square in shape and are usually black on a federal yellow background. The second group includes conditions for definite action, for example: curve. The standard

GUIDE
DESTINATION SERIES



G-1 Right Fingerboard

G-2 Left Fingerboard



G-3 Right Directional Guide

G-4 Left Directional Guide



G-5 Right Business District

G-6 Left Business District



G-7

G-1 RIGHT FINGERBOARD**G-2 LEFT FINGERBOARD**

Use at Class B junctions to inform traffic of the direction and distance to various destinations (See "Sign Assemblies—Fingerboard Erection" for details). For restricted use at important intersecting roads with marked routes, by indicating directions only towards points along intersecting roads. A maximum of two fingerboards for any given direction will be permitted. Fingerboards with black arrows shall be used to indicate numbered lake roads in the Lake of the Ozarks region. Mount on wooden post.

G-3 RIGHT DIRECTIONAL GUIDE**G-4 LEFT DIRECTIONAL GUIDE**

Use at junctions, intersections, or other locations to indicate towns, scenic views, historic sites, or other points of importance that are in close proximity to the highway, generally not more than one mile away. For restricted use at junctions to supplant "Fingerboards" when greater legibility is desired, or to guide the traveler at confusing locations. Mount on single wooden post.

G-5 RIGHT BUSINESS DISTRICT *Sign***G-6 LEFT BUSINESS DISTRICT *Sign***

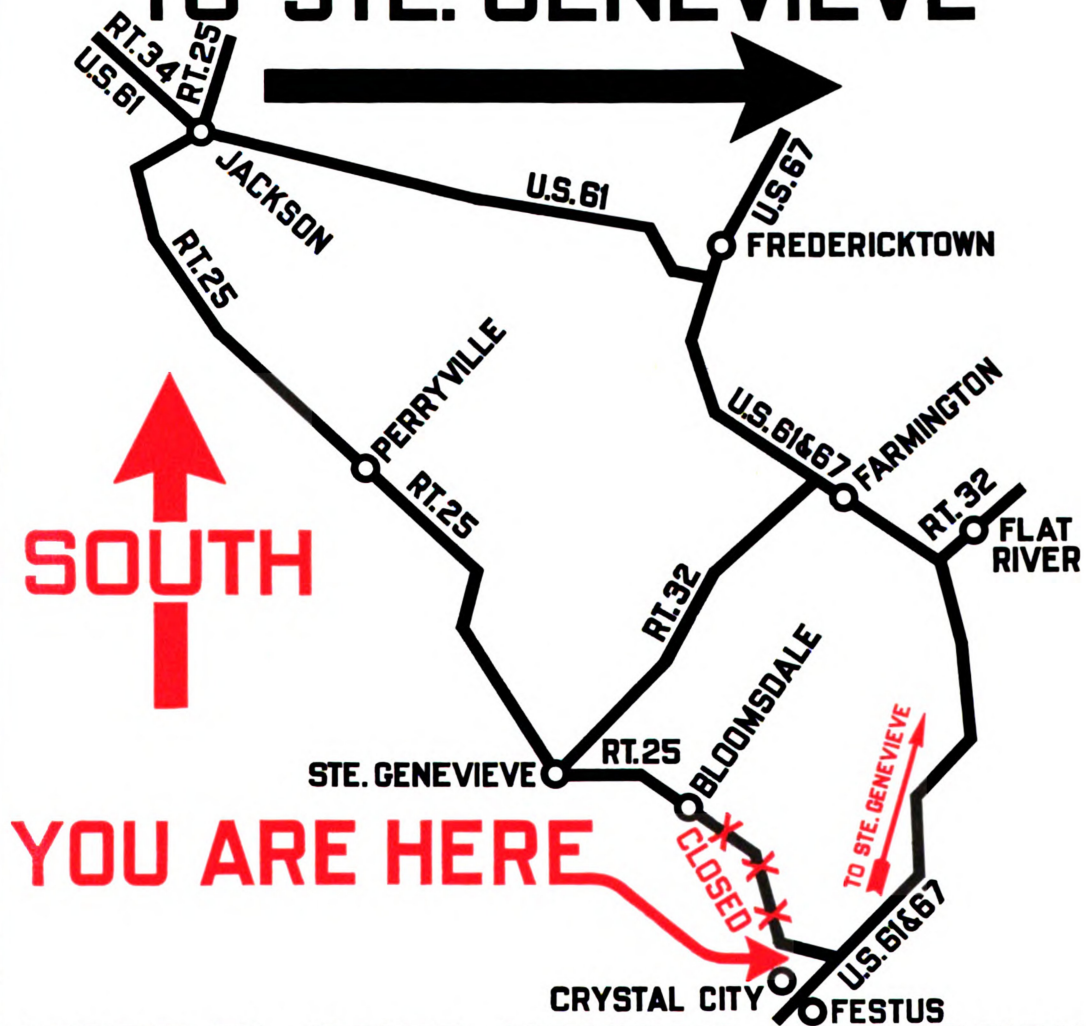
Use at principal intersections, within city or town limits leading to the business district. Mount on single wooden post.

G-7 MULTIPLE-LINE MILEAGE *Sign*

Use on major through highways designated by the main office. Use 400 to 1000 feet beyond junction of Federal or State numbered routes. Use at city or town limits on the opposite side of the road from the "City Limits" sign for traffic leaving the city or town. Do not use at unincorporated villages. Word-
ing is limited to a maximum of three lines which shall include the name and distance to the nearest community where motor or personal services may be obtained, the nearest important city within fifty to one hundred miles on the route, and the terminal city, or sometimes, the most important city on the route which is near the terminal point. Mount on wooden posts.

GUIDE
INFORMATION SERIES

ROAD INFORMATION
ROUTE 25 CLOSED
FOLLOW ROUTES 61 & 32
TO STE. GENEVIEVE



MISSOURI STATE HIGHWAY COMMISSION

DETOUR ROAD INFORMATION MAP Sign

Use when roads are blocked or closed roads where no marked detours are provided. Use as few words as possible to convey necessary information. Use of routing arrow is optional. The map should remain simple and readable with the "You are here" located at the bottom of the sign. The compass arrow should be used in all cases, with the basic directions North, East, South or West changed to meet the requirements. Use of reflectorization is permitted for special cases. (Refer to "Sign Assemblies—Roads" for details of erection.) This sign may be supplemented by "Road Information" and "Road Information—Mileage" signs. Mount on wooden posts.

GUIDE
AUXILIARY MARKER SERIES



M-40



D-81 to 86



D-87

M-40 JUNCTION Sign

Use 400 to 1000 feet in advance of junctions and in conjunction with route markers to indicate points where other routes meet or cross the route being traveled. Mount above markers on one steel post or special steel frames.

D-81 DIRECTIONAL Marker—AHEAD ARROW

D-82 DIRECTIONAL Marker—LEFT ARROW

D-83 DIRECTIONAL Marker—LEFT—AHEAD ARROW

D-84 DIRECTIONAL Marker—RIGHT ARROW

D-85 DIRECTIONAL Marker—AHEAD—RIGHT ARROW

D-86 DIRECTIONAL Marker—DOUBLE ARROW

Use as confirmation markers at junctions or intersections where motorist might be confused as to correct routing, where approach is made at high speeds, or where intersection covers large area requiring larger signs for legibility. May be used in conjunction with "Junction Assembly" when authorized by main office. Mount on one wooden post or in urban areas on one tall steel channel post.

D-87 PULLER Marker

Use as puller marker at junctions or intersections where motorist might be confused as to correct routing, where approach is made at high speeds, or where intersection covers large area requiring larger signs for legibility. Mount on one wooden post or in urban areas on one tall steel channel post.

REGULATORY

SPEED SERIES



R-1



R-4

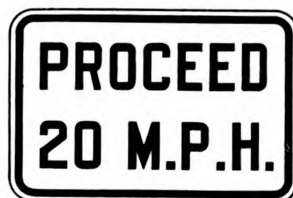


R-2 Speed Limit

R-3 Speed Zone



R-5



R-6

R-1 BEGIN.....MILE ZONE *Sign*

Use at the beginning of speed zones or at points where zone speeds change. It is limited to those areas outside incorporated limits of cities or towns, where the locality is built up and unlimited speeds would prove hazardous. Also it is used at approaches to large cities to step down speeds, serving as a transition between unlimited movement and restricted speeds. Use "Resume Speed" at the end of the zoned or restricted areas. Mount on one wooden post or, in congested areas, on one tall steel channel post.

R-2 SPEED LIMIT.....MILES *Sign*

Use within corporate limits of cities, towns or villages having approved speed ordinances. Indicate changes of restricted speeds by erecting the proper "Speed Limit" sign. Repeat this sign at selected intervals for confirmation. Use "Resume Speed" at end of the speed restrictions. Mount on one wooden post or, in congested areas, on one tall steel channel post.

R-3 SPEED ZONE.....MILES *Sign*

Use in a manner similar to the "Begin Zone" sign but to serve as a confirmatory indicator within the zoned area, where it should be placed at selected intervals. Mount on one wooden post or, in congested areas, on one tall steel channel post.

R-4 CURVE SPEED *Plaque*

Use in conjunction with "Curve", "Turn", or "Winding Road" signs on major routes designated by the main office. All curves on these routes shall be tested with a "Ball-type" Bank Indicator to determine, in both directions, the average uniform speed necessary to maintain 10° of bank. The lower speed indication, expressed to the nearest five mile increment, shall be selected for marking the curves. Because of settlements, increased roughness of surface, or other causes, the curves should be rechecked annually and corrections made. Refer to "Sign Assemblies—Standard Types" for mounting details.

R-5 RESUME SPEED *Sign*

Use at the end of any restricted speed limit or zone, as well as to supplement "Slow.....Miles" signs when the succeeding section of road is unrestricted. Mount on one wooden post, portable easel, or temporary steel post.

R-6 PROCEED.....MPH *Sign*

Use only in conjunction with "School Walk Stop" assembly. Refer to "Stop Series" for mounting details. Reverse side of sign may read "Resume.....MPH" or "Resume Speed".

shape is diamond or square with its diagonals vertical and horizontal. One sign in each group has a special shape to give more emphasis and be easier recognized by the driver. The round railroad sign with a cross buck is special in the first group. There are two ways of placing the cross buck, with the diagonals vertical and horizontal, or with the diagonals at a 45° angle. The latter is the better method, for an angle at 45° will cut across most normal objects in range of the driver's vision, thus making it stand out more.

The other group has a special sign- the stop sign, which is octagonal in shape and is black letters on a federal yellow background.

The general position for placing signs is on the shoulder, if they are placed beyond the ditch line, they become practically invisible at night. These should be placed on both sides of the road facing traffic. The angle of placement is very important. It has been found that if the sign is set at about 30° that this will kill glare at night when the car's headlights are on them.

Visibility is important as it is the facility that a sign can be picked out of its surroundings. This is dependent on size, shape, color, height of placement, location, wording, and style of lettering. The size and shape of signs has become quite well standardized by the American Association of State Highway Officials and has been widely adopted by the states (see letters in back) The basic size of signs is 24"x24" with a tendency to using larger sizes because of increased traffic speeds. The size increase is in 6" increments.

WARNING
CAUTION SERIES



C-1



C-2



C-3



C-4



C-5



C-6

C-1 FRESH OIL Sign

Use 400 to 600 feet in advance of freshly oiled surfaces, requiring cautious driving. Remove when condition ceases to exist. Mount on portable easel or temporary steel post and use night torches if conditions justify.

C-2 LOOSE GRAVEL Sign

Use 400 to 600 feet in advance of roads covered with loose gravel which necessitate cautious driving. Mount on portable easel or temporary steel post and use night torches if conditions justify.

C-3 SLIPPERY WHEN WET Sign

Use, temporarily, at points of danger where roadway surface is unusually slippery when wet. Remove when condition is corrected. Mount on portable easel or temporary steel post.

C-4 SCHOOL ZONE Sign

Use 400 to 600 feet in advance of schools fronting along or in close proximity to highway right of way. Erect only during the school season. Mount on wooden post.

C-5 CHURCH Sign

Use 400 to 600 feet in advance of churches, fronting along or in close proximity to highway right of way. Limited use recommended. Issued upon signed contract, and mounted on portable easel.

C-6 HOSPITAL ZONE Sign

Use 400 to 600 feet in advance of hospitals only where highway travel causes undue noises. Limited use recommended. Mount on wooden posts.

WARNING
RAILROAD ADVANCE
SERIES



W-1

W-1 ADVANCE RAILROAD WARNING *Sign*

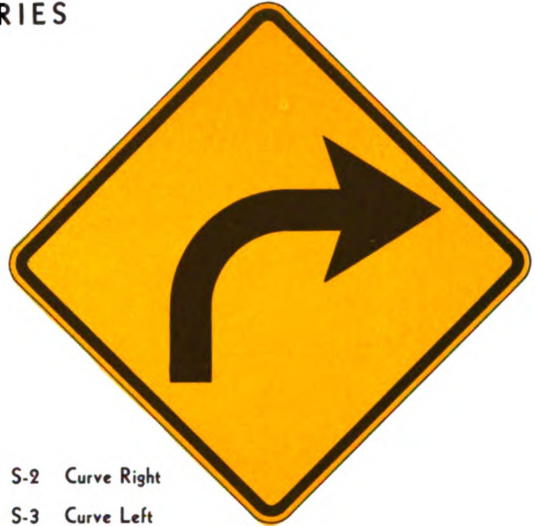
Use 400 to 600 feet in advance of railroad grade crossings. Mount on wooden posts.

WARNING

SLOW SERIES



S-1



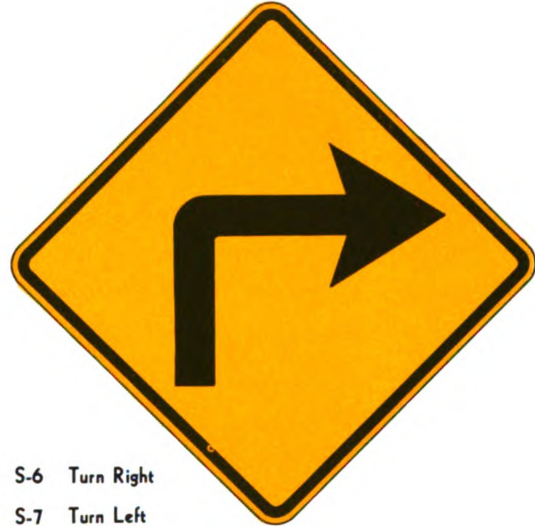
S-2 Curve Right

S-3 Curve Left



S-4 S Curve Right

S-5 S Curve Left



S-6 Turn Right

S-7 Turn Left



S-8 S Turn Right

S-9 S Turn Left



S-10

S-1 HILL Sign

Use 400 to 600 feet in advance of descending grades under the following conditions:

- On a 6 percent grade, more than 2000 feet long
- 10 percent grade, more than 450 feet long
- 15 percent grade, more than 200 feet long
- 16 percent grade, any length.

Use where the percentage or length of grade is less than the above indicated when a sharp curve is located on the grade. Mount on wooden posts.

S-2 CURVE RIGHT Sign**S-3 CURVE LEFT Sign**

For concrete or bituminous pavement, use when the "Ball type" Bank Indicator shows banks of 10° or more at speeds of 31 to 60 miles per hour. For gravel roads use when Bank Indicator shows banks of 10° or more at speeds of 26 to 45 miles per hour. Erect signs 400 to 600 feet in advance of curve and mount on wooden posts.

S-4 S CURVE RIGHT Sign**S-5 S CURVE LEFT Sign**

Use determined in the same manner as for "Curve" signs. Usually confined to a single pair of reverse curves with intermediate tangents not greater than 400 feet. The arrow shall point in the direction of the first curve. Erect 400 to 600 feet in advance of first curve and mount on wooden posts.

S-6 TURN RIGHT Sign**S-7 TURN LEFT Sign**

For concrete or bituminous pavement, use when the "Ball type" Bank Indicator shows banks of 10° or more at speeds up to 30 miles per hour. For gravel roads, use when Bank Indicator shows banks of 10° or more at speeds up to 25 miles per hour. Erect signs 400 to 600 feet in advance of turns and mount on wooden posts.

S-8 S TURN RIGHT Sign**S-9 S TURN LEFT Sign**

Use determined in the same manner as for "Turn" signs. Usually confined to a single pair of reverse turns with intermediate tangents not greater than 400 feet. The arrow shall point in the direction of the first turn. Erect 400 to 600 feet in advance of first turn and mount on wooden posts.

S-10 NARROW ROAD Sign

Use 400 to 600 feet in advance of restriction of width in roadway which permits two lane movement, but necessitates a reduction of speed for safety. Mount on wooden posts.

WARNING
SLOW SERIES



S-11



S-12



S-13



S-14



S-15



S-16

S-11 PAVEMENT ENDS Sign

Use 400 to 600 feet in advance of change in high type road surface to a granular or earth road surface, necessitating a reduction of speed. (Refer to "Gravel Ends" and "Road Ends" signs.) Mount on wooden posts.

S-12 STOP AHEAD Sign

Use 400 to 600 feet in advance of stop signs at hazardous locations. Mount on wooden posts.

S-13 DIP 300 FEET Sign

Use 300 feet in advance of dips or depressions in the roadway, in urban areas, which cause riding discomforts or create driving hazards. Mount on wooden posts, portable easel, or temporary steel posts.

S-14 SLOW DANGEROUS DIP Sign

Use 400 to 600 feet in advance of dips or depressions, in rural areas, which cause riding discomforts or create driving hazards. Mount on wooden posts, portable easel, or temporary steel posts.

S-15 WINDING ROAD Sign

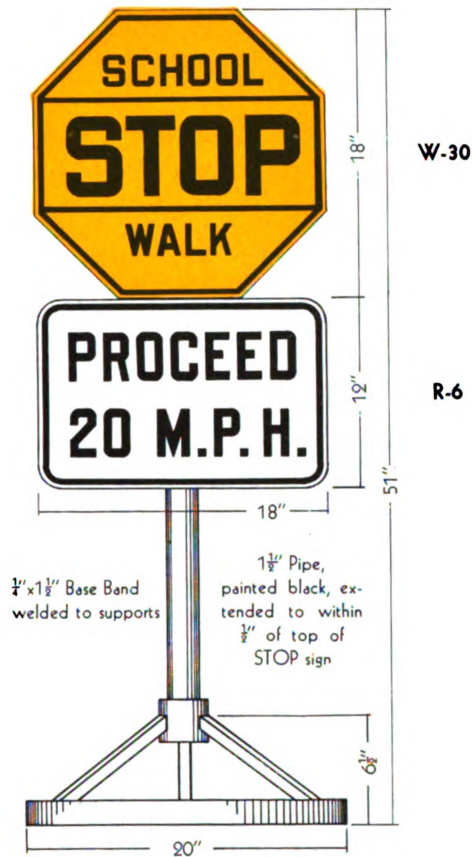
Use 400 to 600 feet in advance of a group of three or more curves with or without short tangents when it would prove infeasible to erect "Curve" signs. Repeat at regular intervals if curves extend over a distance greater than 3 miles. Mark all turns within this zone with "Turn" signs. Mount on wooden posts.

S-16 SLOW.....MILES Sign

Use 400 to 600 feet in advance of unincorporated towns or villages, intersections, or other locations which require, for safety, that vehicles proceed at a speed not greater than that indicated on the sign. Mount on wooden posts, portable easel, or temporary steel posts.

REGULATORY

STOP SERIES



A-1 SCHOOL WALK STOP
ASSEMBLY



W-31



W-32 W-33

SIGNS

Traffic signs are devices mounted on fixed or portable supports whereby notice is given in the form of words or symbols, officially erected for the purposes of regulating, warning or guiding traffic.

The diamond shape sign has the highest general visibility for the reason that it has the largest horizontal and vertical dimensions; also because its boundaries cut across the normal lines of nature. This value is lost, however, since there are over twenty different indications made by word and symbol on this shape.

The square sign is next in line in high visibility value since it has the same area, but its dimensions and position of boundaries is not as good.

The octagonal and round shape lose visibility by a decrease in size, since the area of a octagonal is 83% of a square, and the round is 78½%, but since each bears only one indication, the desirability of the round and the octagonal increase. However, at a distance of a few hundred feet it is very difficult to tell one from the other.

Color combinations are ennumerable and a great many have been tried. The following report of findings by the Bureau of Public Roads and the U.S. Bureau of Standards give the reader some idea of the preference for black on yellow:" Daylight observations on non-luminous signs shows that all evidence points to the definite conclusion that the standard yellow background with black letters or design, under all conditions reasonably to be expected in either urban or rural driving is much superior to black on white or white on black. Yellow has the added value of contrasting with the average natural background or artificial. By the adoption of a definite shade of yellow and prohibiting its use for roadside advertisements or signs other than official highway signs, the value of the color would in-

crease.

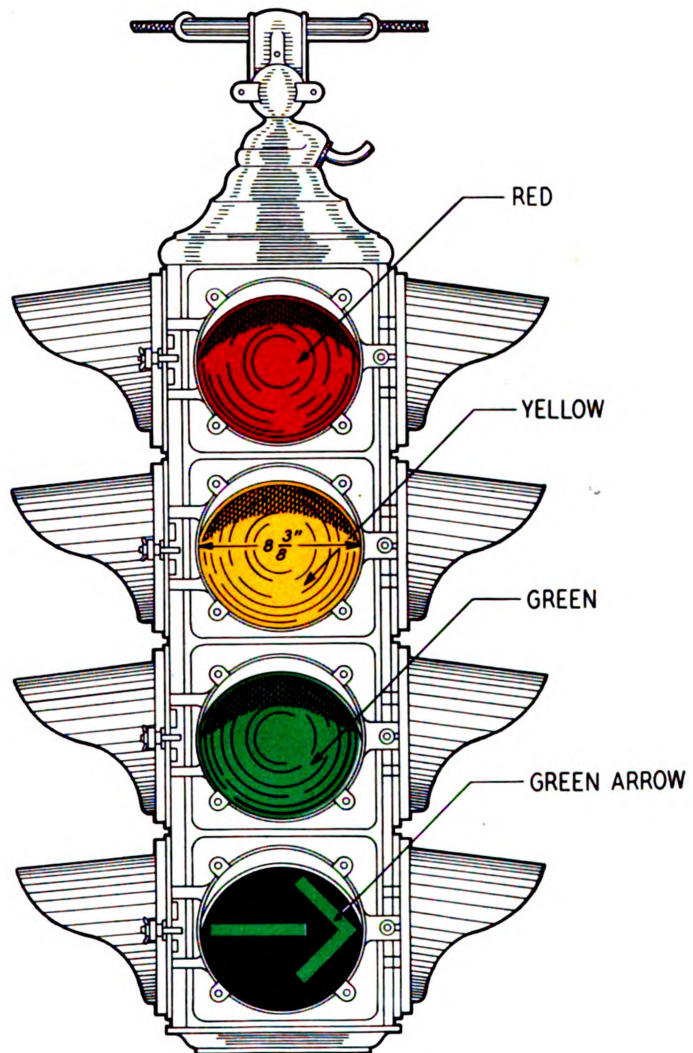
Traffic signals, although of more importance to urban traffic control than rural, do have a place in the study of highway safety. "Traffic signals include all power operated devices using light, by which traffic is warned or directed to take some specific action." They are not the same as illuminated or reflectorized signs. The three main factors determining the justification of placing a signal are as follows: to minimize delays; minimize accidents; and to promote orderly movements of traffic. There are two general groups into which signals falls:

- | | |
|-----------------------------------|---------------|
| (a) Traffic control (stop and go) | (b) Flashing |
| 1. fixed time | 1. slow |
| a. independent | 2. stop |
| b. simultaneous | 3. train r.r. |
| c. alternate | |
| d. progressive | |
| 2. Traffic actuated | |
| 3. Manually operated semaphores | |

It is unfortunate that, due to the effectiveness of signals, they have been placed in many cases where there is no need for them. The reason for such indiscriminate installation is due to the belief that signals are a cure for all traffic problems. Analysis has proved that unwisely installed and poorly operated traffic control signals have actually increased accident rates at certain intersections. Thus it is very important that before undertaking to install a control signal at a proposed location, every possible means must be used to determine the advisability of the installation. This also applies to group (B), the flashing group. According to the manual

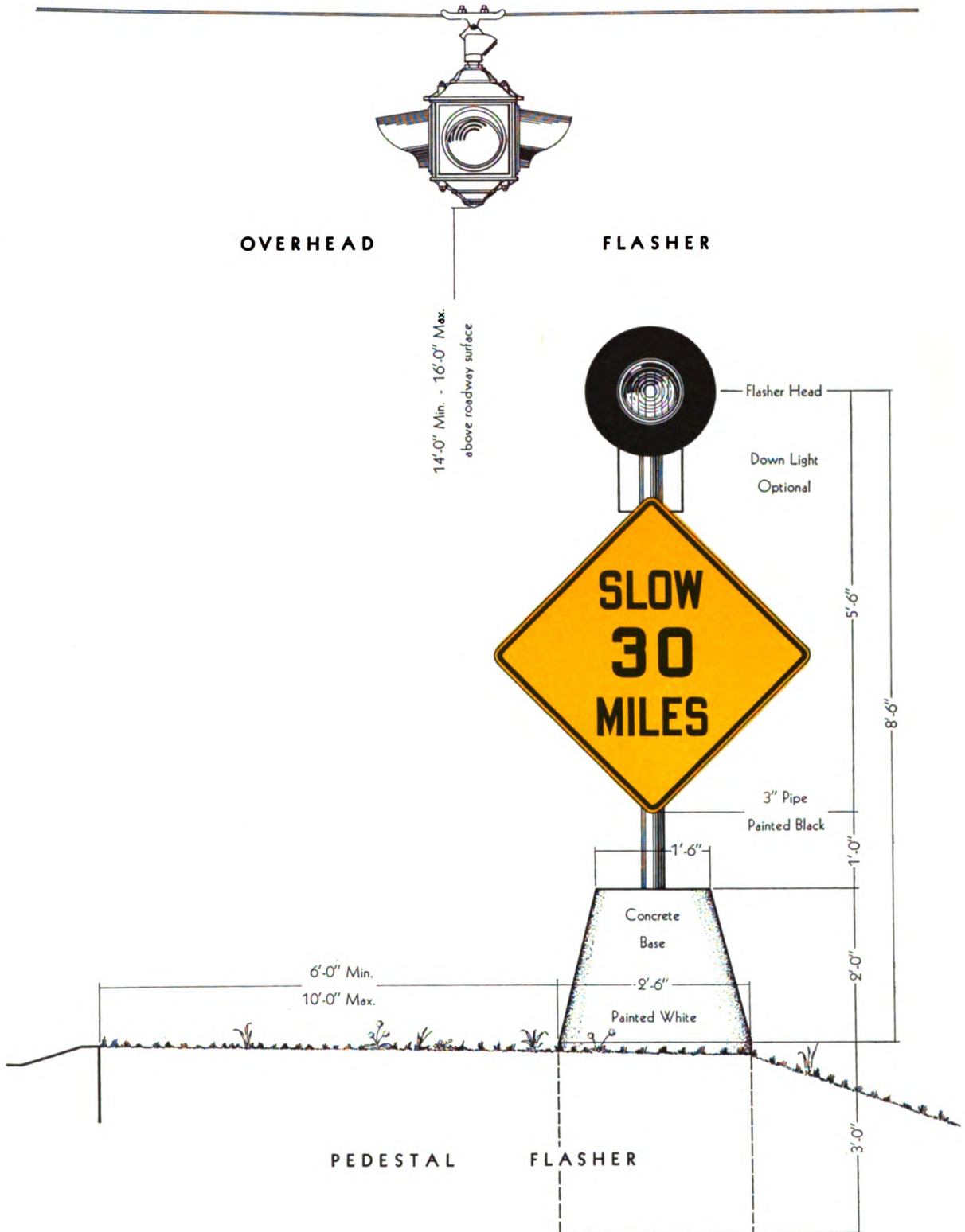
STANDARD TRAFFIC SIGNALS

STANDARD VERTICAL ARRANGEMENT OF SIGNAL LENSES



SIGNALS

FLASHER ERECTION



FLASHER ERECTION

Approval for erection or removal of any type of flasher must be given by the main office.

The use of the yellow lens illuminated with rapid intermittent flashes shall mean the motorist is to proceed with caution. The red lens illuminated with rapid intermittent flashes, which is always supplemented by a "Stop" sign, shall require the motorist to stop and not proceed until it is safe to do so.

OVERHEAD *Flashers*

The overhead unit shall be used only at junctions and intersections and is to be mounted directly above the crossing of the centerlines of the intersecting roads. The lowest portion of the unit shall be erected at a minimum height of 14'-0" to a maximum of 16'-0" above the traveled way. The light shall flash at a rate not less than 40 nor more than 70 times per minute.

PEDESTAL *Flashers*

The pedestal unit shall be erected on the right shoulder of the road. It may be placed on the near right side of an intersection, supplemented by a STOP sign, for stopping movements; or it may be placed 800 to 1000 feet in advance of a hazard, supplemented by the proper warning sign, to denote a caution movement. Signs ranging in size from 24" to 48" shall be permitted, but the 36" sign is preferred. The use of the "down" light is optional when the sign is equipped with reflecting buttons. The light shall flash at a rate not less than 20 nor more than 40 times per minute.

" Uniform System of Traffic Control Devices" used by the state of Kansas, traffic controls signals are installed only where the following recurring warrants are found to exist:

- a. minium vehicular volume
- b. Minium left hand turn volume
- c. Minium pedestrian volume
- d. coordinated movement
- e. Through highway
- f. Accident hazard
- g. Combination of warrants or other findings.

Snow fences and fences are two features that have some importance in safety of highways. Anything that causes a reduction in the velocity of wind carrying snow will cause it to drop the snow and thus form a heap or drift. Due to this fact, vegetation, banks on the side of a cut, and other such things will cause snow to drift on the roadway, which in turn will cause hazards to the motorist. If snow drifts could be prevented from forming on the roadways, travel would be greatly aided on these routes. There are two general methods of preventing the formation of drifts, the removal of obstructions which cause them, and the erection of snow fences behind which drifts would form, thus storing the snow before it reached the road. A good procedure to use is to cut weeds and other vegetation, that cause drifts, early in the fall, and where this cannot be done, as in the case of trees and buildings, to erect snow fences.

Snow drifts are more of a problem in the flat sections of the country where wind velocities are high. In some western states, it is a common practice to locate the road surfaces 12 to 18" above the adjoining land and to avoid cuts wherever possible.

The problem of placing snow fences is very involved. Each case must be studied separately. The factors governing the placement include the topography, location of buildings, the location of plantings, and the direction of the prevailing winds. In some places where land is fairly cheap, attempts are being made to purchase enough right-of-way on which to plant hedges and trees to form a permanent drifting agent.

Fences, other than snow fences, should be mentioned too. The fences themselves do not have any bearing on the subject, however, the absence of fences in certain situations result in hazards. Some states, notably Florida, do not require that live-stock be fenced, due to the sparseness of grazing land cows, razor-back hogs, etc. are left free to roam the range. The consequence of this situation is the hazard that the live-stock cause by being on the highways. The danger becomes of a greater magnitude when the point, of the hords of tourists in that state who are not familar with this situation, is brought out.

During recent years, there has been an increasing amount of highway lighting on our more heavily travelled highways for night driving. The shocking total of deaths resulting from poor visibility, glaring headlights, etc. seem to justify the high cost of such illumination.

The main purpose of highway lighting is roadway visibility. The intent is to make the road open and clear to vision without the need of headlight illumination to show the condition of the way. In every case, a degree of roadway visibility should be sought that will enable the driver to distinguish

all the evidence of roadway conditions that would be made visible by daylight. A standard practice of mounting heights has come out of recent experimented work, this being 16 to 25 feet and horizontal spacing of lights should not be over ten times the mounting height.

The most outstanding recent development in the realm of lighting is the manufacture of sodium-vapor lamps by the General Electric Company. Although daylight is composed of all colors, this new light is monochromatic. The light is yellow and appears dim in comparison with other lights in general use, but actually the visibility is better because of the one color of the light and its reduced glare. Photo-electric controls turn on the current as soon as darkness falls. For the same wattage input, these lights are said to yield approximately two and half times the light output of incandescent lamps.

Chapter Nine

Standardization by the A.A.S.H.O.

With the ever increasing number of vehicles on the road, and the ever increasing amount of improved mileage of State and Federal highways, it has become of prime importance to safety to standardize safety features and procedures among the forty-eight states. The value of this becomes apparent when the fact is brought out that the motorist, through constant observation and practice, recognizes the type of safety devices used by his home state, therefore, when he encounters the same type in other states, he is not confused by their meaning, color, or shape and can therefore react quicker to them.

The American Association of State Highway Officials is an organization of highway departments whose roster includes 52 member departments. This includes, not only the 48 states, but also the territories of Hawaii and Puerto Rico, the District of Columbia, and the United States Public Roads Administration. This Association's main function is to standardize the states on the best features of highway design and control measures.

From the replies of the 22 states with which I corresponded, I am able to conclude that most states are conforming to standards set up by this agency. (See letters in back of binding.) A partial list of manuals that this association has in publication and which the states follow are:

- "A Policy on Sight-distances for Highways"
- "A Policy on Intersections at Grade"
- "A Policy on Grade Separations for Intersecting Highways"
- "A Policy on Highway Types (Geometric)"
- "Manual on Uniform Traffic Control Devices for Highways"

This trend toward nation-wide standardization is an encouraging sign, for it is beleived by this writer that, with the exception of the influence of climate and topography on certain aspects of design and control, the greater the standardization and acceptance of the policies outlined and recommended by the American Association of State Highway Officals, the greater the safety value obtained in our vast network of highways.

The following list is comprised of the 29 states corresponded with. They were chosen as representative of locality, climate, topography, and size. It will be noted that 22 of the 29 states answered by letter, 14 states sent various manuals, specifications etc., while three states did not reply by letter, but did sent material. In all cases where material was not sent, with the exception of Maine, an attempt was made to give information and answers to the questions, in my letter, in their reply as to polices on safety in modern highway design.

STATE	REPLIED	SENT MATERIAL
Washington-----	NO -----	NO -----
Oregon -----	YES -----	NO -----
California -----	YES -----	YES -----
Wyoming -----	YES -----	NO -----
Colorado -----	YES -----	NO -----
Idaho -----	NO -----	NO -----
Arizonia -----	NO -----	YES -----
Texas -----	YES -----	YES -----
Louisanna -----	NO -----	YES -----
Kansas -----	NO -----	YES -----
Missouri -----	YES -----	YES -----
Minnesota -----	YES -----	NO -----

STATE	REPLIED	SENT MATERIAL
Wisconsin -----	Yes -----	NO -----
Illinois -----	NO -----	NO -----
Indiana -----	YES -----	NO -----
Ohio -----	YES -----	YES -----
Tennessee -----	NO -----	NO -----
North Carolina -----	YES -----	YES -----
Virginia -----	YES -----	YES -----
Florida -----	NO -----	NO -----
Alabama -----	YES -----	YES -----
New York -----	YES -----	YES -----
Pennsylvania -----	YES -----	YES -----
New Jersey -----	NO -----	NO -----
Rhode Island -----	YES -----	NO -----
Connecticut -----	YES -----	YES -----
Massachusetts -----	YES -----	YES -----
New Hampshire -----	YES -----	NO -----
Maine -----	YES -----	NO -----

I wish to say in conclusion, that the replies that I received from the various state highway departments were very gratifying. For the most part, they all were eager to help and lend aid. I wish especially to point out the letter from the states of Missouri, New York, Connecticut, and Massachusetts in regard to the time and effort that they took to collect material for me.

Chapter Ten

Conclusion

In conclusion, some facts and figures are presented to show that progress is being made toward improved and safer highways throughout the United States. From the "President's Highway Safety Conference Record for 1948": In the treatment of high accident locations, it is found that in 1947, with 41 states reporting, a total of 41,734 man-days were devoted to this activity, as compared with 22,684, by 38 states in 1946. Progress on correcting design weakness in the stages of preliminary planning, or in original construction stages shows that for 33 states with personnel working on this phase of the problem in 1946, in 1947 there were 39 states.

Construction of grade separations at intersections of principal highways and at railroad-highway crossings, as has been mentioned earlier in this thesis, is a very effective means of reducing accidents. Ninety-seven highway grade separations and 174 rail-highway grade separations were reported built by the state highway departments during 1947. The number of highway grade separations reported existing at the end of 1947 totaled 1,009. For the same date there were a total of 12,648 railway grade separations.

Pedestrian crossings, though rather limited in number, due to high expense of construction, were constructed in 11 cases in a total of 6 states during 1947.

In the matter of pavement markings, the white or colored

line in the center of the highway is invaluable as a driving aid. Nearly 240,000 miles of highway, or nearly one-half of the total mileage under state jurisdiction, now have center lines maintained. Of this total, 20,545 miles were added during 1947.

On two lane and three lane highways where sight-distance is below that required for safe passing, special no-passing zone markings are frequently installed to aid the driver in knowing of the hazard. According to data available 148,227 miles of highways, or 32% of the total mileage under state jurisdiction, now have no-passing zones designated, of which 21,111 miles were added in 1947.

Traffic signals, where properly installed, reduce unexpected conflicts at intersections. Usually, however, not always the accident rate will be improved. At the end of 1947, there were 7,232 traffic signals on highways under state jurisdiction, of which 1,051 were installed in 1947. Twelve states reported the installation in 1947 of 70 special signals for pedestrians. A great aid to safety after dark is afforded by reflectorization or illumination of signs. Out of 45 states reporting, the top 15 had 90-100% of their signs reflectorized or illuminated; the middle 15 had 68-90%; and the bottom from 10-68%.

" The safest highway from the standpoint of operating speed is one which the fewest changes of speeds are required because of roadway or traffic conditions, and where such changes are conspicuously posted". Thus, drivers of vehicles are

especially appreciative of sign speed indications on curves, particularly if the speeds posted are realistic. " These speeds should be carefully worked out from observations of actual operating speeds in normal traffic, by trial runs with ball-bank indicators, and after engineering review of 'curvation data, superelevations, surface type, and similar related factors." During 1947, 4,782 more miles of state highways were marked with safe speeds on curves, to bring the total to more than 60,000.

As for protection at grade crossings, more than 8,000 of the nearly 25,000 rail-highway crossings at grade are now equipped with flashing signals or gates. Each year finds several hundred more being added.

Highway lighting has shown progress too. The states report a total of 466 miles of rural highway lighting, including 38 miles added in 1947. Seven states have installed modern equipment for the illumination of 171 intersections on rural highways during 1947.

Channelization has received much attention by highway engineers in the solution of intersection problems on new roads, and for remedying the defects at existing intersections where large, uncontrolled areas cause the driver confusion and the pedestrian danger. The report for 1947 show that the states have on the highways under their jurisdiction a total of 2,656 channelized intersections. In 1947, 209 of these were added, while in 1946, 369 were added. This indicates recognition of a good means for reducing hazards at intersections.

It has been the intent of this writer to bring under one cover some of the most notable features of safety design of highways used today in the United States, rather than to pioneer in any special phase of safety design. The topic covers a very broad field, therefore, in order to cover the subject, much detail that is readily available to the reader, has been cut down considerably. However, it is felt that some attention has been given to most of the outstanding features.

Much personal value has been gleaned from this study by the writer. Although, much knowledge of highway design and especially control can be derived through observation, many of the whys and wherefores were explained and made tangible through the intensive reading that was required in gathering data for this thesis.

ACCIDENT STATISTICS SUMMARY

Route	Location	Years Included in Analysis	Length of Highway Miles	Average Daily Traffic 1946	Total Accidents	Fatalities	Pedestrian Accidents	Property Damage	Accidents per 100 Million Vehicle Miles	Fatalities per 100 Million Vehicle Miles
TWO LANE AND FOUR LANE HIGHWAYS AT GRADE										
1	Greenwich thru West Haven	5 years, '40-'44	46.0	11,000	4,059	103		\$873,543	440	11.2
1	Orange	6 yrs. 11 mo., '40-'46	2.89	11,100		13				14.5
1	West Haven	6 yrs. 11 mo., '40-'46	2.07	11,150		11				18.8
1	Branford thru Old Saybrook	6½ yrs., '40-'46	30.60	4,400	1,069	33	48	335,372	395	11.9
1	Groton and Stonington	6 3/4 yrs., '40-'46	14.45	3,500	385	7	36	77,260	362	6.6
2	Glastonbury Center to So. to Town Line	5 years, '40-'44	7.07	3,300	120	5	7	22,766	432	18.0
5	Jct. of Parkway in Meriden to Parkway Jct. in Wallingford	1946	5.25	9,800	137	1			730	5.3
6	Rt. 93 in Brooklyn to Rhode Island State Line	6 years, '40-'44	9.33	3,200	187	2	19	24,935	440	4.7
7	Norwalk thru Wilton	6½ yrs., '40-'46	10.30	5,400	299	4	12	67,250	348	4.7
9	Wethersfield to Rt. 160 in Rocky Hill	5½ yrs., '40-'45	4.7	7,500	194	5	8	40,275	284	7.3
12	Groton to Norwich	5 years, '40-'44	11.34	1,600	167	4	5	29,867	615	14.7
12	Rt. 205 (Plainfield) to Rt. 101 Killingly	5 years, '40-'44	7.33	3,720	149	2	12	18,220	305	4.0
15	Glastonbury to East Hartford	5 years, '40-'44	8.44	7,500	387	6	31	47,684	789	12.2
32	New London to Norwich	5 years, '40-'44	10.00	4,530	315	10	30	64,500	505	16.0
33	Wilton	6½ yrs., '40-'46	6.85	1,000	33	1	0	8,285	297	9.0
59	Fairfield thru Easton	5 years, '40-'44	11.4	1,600	60	4	1	12,304	180	12.0
94	East of Glastonbury Center Figuera Street (California)	5 years, '40-'44 4 years, '41-'44	2.20 5.35	1,500 30,000	29 820	4 26	4	8,987	746	10.2
2	Ten Curves - Glastonbury and Marlborough	7 yrs., '40-'46	1.0	2,550	31	0	0	8,489	430	14.0
15	Wilbur Cross Highway - Rt. 74 to Mass.	4 yrs., '43-'46	14.03	4,000	148	4			364	0
									260	7.0
DIVIDED HIGHWAYS AT GRADE										
1	East Haven Cutoff	6½ yrs., '40-'46	1.53	7,400	90	4	7	16,067	432	19.2
15	East Hartford (at Aircraft)	5 years, '40-'44	0.71	20,000	275	0	10	35,443	1,154	
US 5A	Hartford Town Line thru Wilson	5 years, '42-'46	0.80	10,100	88	2			765	17.0
US 5A	Wilson to Windsor Center	5 years, '42-'46	2.77	7,300	97	4			337	14.0
US 5	South Windsor	5 years, '42-'46	4.95	5,700	94	2			238	5.0
EXPRESSWAYS AND PARKWAYS										
Riverside Drive (California Freeway)		1941 to 1944	3.50	27,000	102	4			85	3.0
Merritt Parkway		6 yrs. 11 mo., '41-'47	37.46	12,760	1,872	29			201	3.1
South Meadows Expressway-Hartford		Oct. '42 - Oct. '46	4.24	11,700	36	1	0	32,800	97	2.7
Arroyo-Seco Parkway (California)		1941 to 1944	5.80	27,000	114	8			57	3.9
Pennsylvania Turnpike		1941			501	26	2		206	10.7
Wilbur Cross Parkway										
Housatonic River to Route 34		6 yrs. 11 mo., '41-'47	5.32	7,950	117	0			200	0
Wilbur Cross Parkway										
Route 5, Wallingford to Route 5, Meriden		11 mo. 1947	5.44	3,700	16	0			203	0

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TABLE OF GENERAL DESIGN DATA

			SUPPLEMENTARY				MAJOR SYSTEM				MAJOR AND INTERSTATE SYSTEMS								GENERAL NOTES	
Average daily traffic at the time of construction			Under 100 Vehicles		100 to 400 Vehicles		Under 400 Vehicles		400 to 1000 Vehicles		1000 to 2000 Vehicles		2000 to 3000 Vehicles		3000 to 5000 Vehicles		Over 5000 Vehicles		Minimum and desirable standards as listed apply to design speed only. After design speed is determined other standards listed under design speed are minimum and should be considered for use when they make possible an appreciable reduction in construction cost. In general more desirable standards should be used.	
Minimum & Desirable Speed					M	D	M	D	M	D	M	D	M	D	M	D	M	D		
Design Speed in M.P.H.	Flat		40		45		55	45	55	50	60	60	65	65	70	65	70	65	70	It is permissible to change design speed within a single project if topography indicates such procedure will result in economy in construction.
	Rolling		30		35		45	35	45	40	50	50	55	55	60	55	60	55	60	
	Mountainous		20		25		35	25	35	30	40	40	45	40	50	40	50	40	50	
Non-Passing Sight Dist. (4.5 Ft. & 4 Inch)	Flat				315		415	315	415	350	475	475	540	540	600	540	600	540	600	For supplementary roads carrying over 400 vehicles per day use major system standards.
	Rolling				240		315	240	315	275	350	350	415	415	475	415	475	415	475	
	Mountainous				165		240	165	240	200	275	275	315	275	350	275	350	275	350	
Passing Sight Dist. (4.5 Ft. & 4.5 Ft.; provide at least once every 2 miles)	Flat				1150		1750	1150	1750	1400	2100	2100	2500	2500	2900	2500	2900	2500	2900	On major and interstate systems gradients of 7% may be used in short lengths only.
	Rolling				700		1150	700	1150	900	1400	1400	1750	1750	2100	1750	2100	1750	2100	
	Mountainous				500		700	500	700	500	900	900	1150	900	1400	900	1400	900	1400	
Gradients	Flat		8	5	8	5		8	5	7	5	5	5	5	5	5	5	5	5	Cut and fill slopes are to be modified in stable and semi-stable materials. (See typical sections.)
	Rolling		12	7	10	7		10	6	8	6	6	6	6	6	6	6	6	6	
	Mountainous		15	10	12	9		12	7	10	7	6	6	6	6	6	6	6	6	
Curvature	Flat		14*		11		7	11	7	9	5	5	5	5	4	5	4	5	4	*In special cases such as school house or cemetery in section corner, shorter radius may be used.
	Rolling		25*		18		11	18	11	14	7	7	7	7	6	7	6	7	6	
	Mountainous		56		36		18	36	18	25	11	11	9	11	9	11	9	11	9	
Surface Width (Min. & Range)			12 - 20		16 - 20		18 - 20		18 - 22		22		22 - 24		24		44		Dual Roads:- When average daily traffic at time of construction exceeds 3000 vehicles per day, secure R/W for dual construction. When traffic exceeds 5000 vehicles per day, consider initial dual construction.	
Roadbed Width (Min. & Range)			20		24		26 - 30		26 - 38		≠ 38 - 42		42 - 44		44		80 - 108			
Right of Way Width Min. & Range)			60		60		80		80 - 100		120 - 220		120 - 220		120 - 250		150 - 250			
Cut Slopes (Not steeper than)			1½:1		1½:1		1½:1		3:1 under 10' (M) 2:1 over 10' (M)		3:1 under 10'		3:1 under 10'		3:1 under 10'		3:1 under 10'		Median Strip Widths:- Min. 15'; Desirable 40'. (Rural) Min. 4'; Desirable 12'. (Urban)	
Fill Slopes (Not steeper than)			1½:1		1½:1		1½:1		3:1 under 10' (M) 2:1 over 10' (M)		3:1 under 10'		4:1 under 10'		4:1 under 10'		4:1 under 10'			
In Slopes (Not steeper than)			2:1		2:1		2:1		3:1		4:1		4:1		4:1		4:1			
Depth of Ditch (Min. below shoulder)			1		1		2		2		2		2		2		2		Urban Area Standards:- Min. Design speed 40 M.P.H.; Desirable 50 M.P.H. Max. Curvature 14° Min. Non-Passing Sight Distance 275' Min. Passing Sight Distance 900' Min. Lane Width 12'	
Spiral Curves			None		None		On all curves over 2°-00'													
Bridges (New)			Width		14		22		To be determined by Bridge Bureau											
			Loading		H-10		H-15													
Bridges (Use in place)			Width				15		To be determined by Bridge Bureau										ⓂThese slopes apply for Major System roads only. Steeper slopes permitted for supplementary roads.	
			Loading				6 T													
Box Culvert Standards			C-531 (5'-12' Spans) C-532 (2'-4' Spans) C-31 (Skew)				C-528 (5'-12' Spans) C-530 (2'-4' Spans) C-27 (Skew)				C-529 (5'-12' Spans) C-530 (2'-4' Spans) C-27 (Skew)									
Pipe Culverts			For Cross-Road Struct.		12" to 84" Incl. No Hdws.		15" to 48" Incl. C-230R Hdws.				15" to 48" Incl. C-230 Hdws.								In establishing culvert lengths normal roadbed width and normal slopes shall be used.	
			For Struct. under Appr's.		12" to 84" Incl. No Hdws.		12" to 84" Incl. No Hdws.				12" to 84" Incl. No Hdws.									
Typical Section Dwg.#			1 AC		1 AC		1 AB		1 AB or 1 AA		1 AB or 1 AA		1 AA		1AA or Spec. for Dual Lane		Spec. for Dual			

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