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Bulletin 72

Directional Channelization and Determination of Pavement Widths

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Directional Channelization and Determination of Pavement Widths

PRESENTED AT THE

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1953
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Preface

THE two papers on highway channelization included in this bulletin were presented at the open meeting of the Committee on Channelization at the Highway Research Board's Thirty-Second Annual Meeting.

The paper presented by W. R. Bellis, chief of the Traffic Design and Research Section of the New Jersey State Highway Department, "Directional Channelization Design," describes unique methods for the efficient movement of traffic through high-volume intersections at grade by the use of channelization. With continued rapid increases in motor-vehicle traffic, it is apparent that grade separations cannot be provided at all major intersections. The methods which have been developed by the New Jersey State Highway Department for reducing traffic accidents and congestion at high-volume intersections through the use of channelization offer a challenge to those courageous designers who are seeking a solution to severe traffic conditions where funds may not be available for the construction of costly grade separations. The techniques described by Bellis will receive wider application in highway design in the coming decade.

The paper presented by L. F. Heuperman, urban designer, Idaho Department of Highways, entitled "Determining Widths of Pavements in Channelized Intersections," describes in detail a practical method for designing pavements at channelized intersections by checking the design through the use of scaled models of typical motor-vehicle types. The design data developed and assembled by Heuperman .will prove of inestimable value to highway and traffic engineers.

Precise principles of functional channelization design have not been developed nor generally accepted. The contributions of Bellis and Heuperman represent an important supplement for the highway designer in the application of recognized principles of geometric highway design to the design of the channelized highway intersection at grade.

— EUGENE B. MAIER, Chairman,
Committee on Channelization

Contents

Directional Channelization Design

W. R. BELLIS, Chief, Bureau Traffic and Safety Research,
New Jersey State Highway Department

IN January of 1950, the New Jersey State Highway Department reconstructed the intersection of Routes 1 and 25 (Communipaw Avenue) in Jersey City by a unique design which, although it did not use a bridge, proved to serve traffic as well as could have been done with a cloverleaf design. The design includes separate direct roadways short-cutting the center of the intersection. Traffic at the points of crossing is controlled by traffic signals. The locations of the points of cross traffic are designed for normal travel time between points and the best traffic signal synchronization. The number of lanes at each signal is a function of the traffic volume to be served and the signal capacity per lane.

As demonstrated by four intersections constructed by the New Jersey State Highway Department, an entirely new field has been opened to the designer. It is the purpose of this paper to submit proven evidence of the new design technics, to illustrate traffic behavior suggesting more advanced application and to present untested but probable ultimate designs.

The existing intersections do not express freedom of design. They were limited severely by restrictive right-of-way costs and the revisions were adopted as measures to improve existing conditions. Nevertheless, there are design features which are taken advantage of by a few drivers, thereby, increasing the efficiency of the intersection. If these features are refined so that all drivers can use them, the efficiency is increased still more.

A study of these features and accompanying traffic behavior suggests an ultimate design, without the use of bridges, which would permit the free flow of all streams of traffic without the need for stopping and without the need for deviating from reasonable, normal vehicle speed.

● DIRECTIONAL channelization is that at-grade-intersection design which provides for all traffic movements being made without deviating from a normal short-cut path and in which separate roadways (or channels) are provided for turning movements in order to localize the points of conflict between cross movements. At a four-point intersection there are twelve basic traffic movements and sixteen basic cross movements of traffic. Figure 1 shows these movements and conflicts. In this figure all movements are shown directionally.

All of these movements and crossings must be made at any four-point intersection, but the manner of crossing is different for each type of design.

At simple intersections at grade, all of these crossings are made within a small area which has no more capacity than one of the roads with no turning movements. The capacity of the intersection can be increased by pavement widening adjacent to the intersection and easing the turning radius for right turns. However, the capacity for left turns is not improved.

At traffic circles the crossings are made by first merging the movements and then separating the movements. That is, the crossings are made by cross weaving with the crossing vehicles traveling in the same direction. Although the capacity of a traffic circle is no greater than the capacity of a simple intersection having the same approach widths, it can handle larger volumes without the aid of traffic signals. Volumes in excess of the capacity of a traffic circle can be passed through a simple intersection at grade with traffic signals.

At grade separations of the cloverleaf type, the straight-through movements are separated by a bridge, but each left turn must cross weave with two of the other

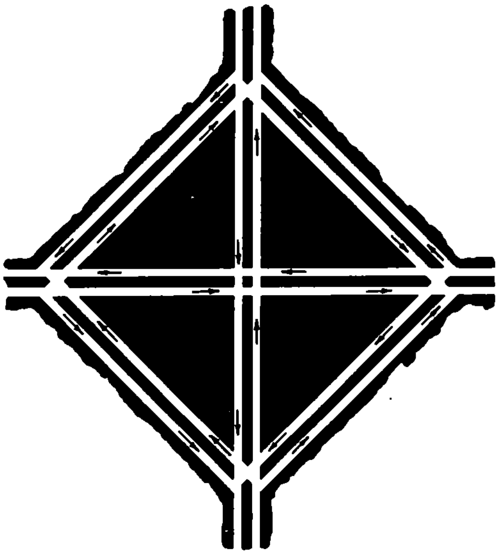


Figure 1.

left turns, in addition to traveling a long, indirect path. The traffic demand at existing well-designed cloverleafs has exceeded the capacity where heavy left turns occur.

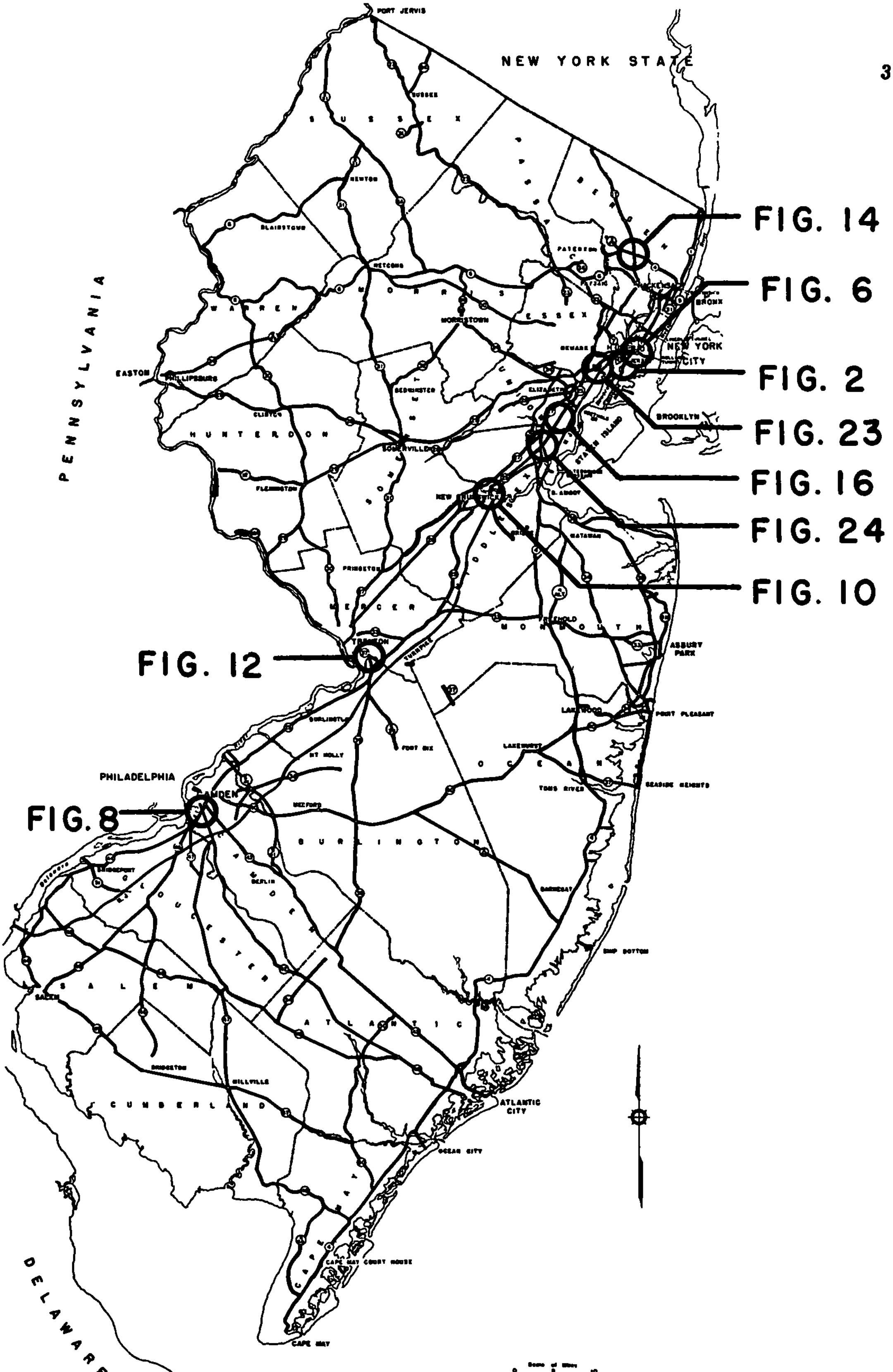
At a directional interchange all crossing movements are separated by bridges. Except for three-point intersections, complete directional interchanges have not been used. The four-level interchange in California is sometimes referred to as a complete directional interchange, but this is not completely directional in that the left-turning movements leave the main roadway on the right. The capacity of a true directional interchange is unlimited, it merely being necessary to increase the number of lanes to provide for greater capacity.

The absolute capacity of a four-point traffic circle with equal traffic on all approach roads and even distribution for right turns, left turns, and straight through is reached when the total traffic using the intersection is 6,600 cars per hour. Volumes of this magnitude have been approached at existing circles. The absolute capacity of a cloverleaf for the same conditions is reached at 13,200 cars per hour. This volume has not been approached in actual practice, although the traffic demand on one part of the cloverleaf has exceeded the capacity. Cloverleafs have not been designed up to their full capacity, probably because the cost would then be greater than a directional interchange or a special grade separation with directional interchange principles used in part of the intersection.

The capacity of directional channelization in its ultimate development, like directional interchange, is unlimited, and this design could eliminate the need for stopping any vehicles, even though there are no bridges provided. Despite these possibilities, highway designers have been guilty of shunning the use of channelization and traffic signals. Since it appeared that the grade-separation principle was the pinnacle of intersection design, efforts were concentrated on exploring the possibilities of applying bridges and ramps or interchange connections. Traffic engineers have used traffic-signal control and channelization as measures to increase capacity of existing intersections, mostly as simple alterations within existing right-of-way or curb lines. As a result of this restrictive application, there has been some misuse of both traffic signals and channelization, resulting in an accelerating general dislike for both. Actually, the use of traffic signals and channelization provides a great opportunity for the economical solution of many traffic problems, provided that joint use is made of design and traffic engineering. A good designer must also be a good traffic engineer and vice versa.

Despite the tendency to consider traffic signals and channelization as a low type of intersection design, sufficient applications have been provided to allow observations of traffic behavior and an analysis of such design in a manner suitable for reliable comparison with other forms of intersection design.

The New Jersey State Highway Department has used a combination of channelization and traffic signal control at four major intersections where traffic volumes were far in excess of the capacity


NEW YORK STATE
PENNSYLVANIA
DELAWARE
FIG. 14
FIG. 6
FIG. 2
FIG. 23
FIG. 16
FIG. 24
FIG. 10
FIG. 12
FIG. 8
NEW YORK CITY
BROOKLYN
BRONX
PHILADELPHIA
CAMDEN
EASTON
TRENTON
ATLANTIC CITY
ASBURY PARK
S U S S E X
W A R R E N
M O R R I S
E S S E X
H U N T E R D O N
M E R C E R
M O N M O U T H
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B U R L I N G T O N
S A L E M
A T L A N T I C
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Figure 1-A.

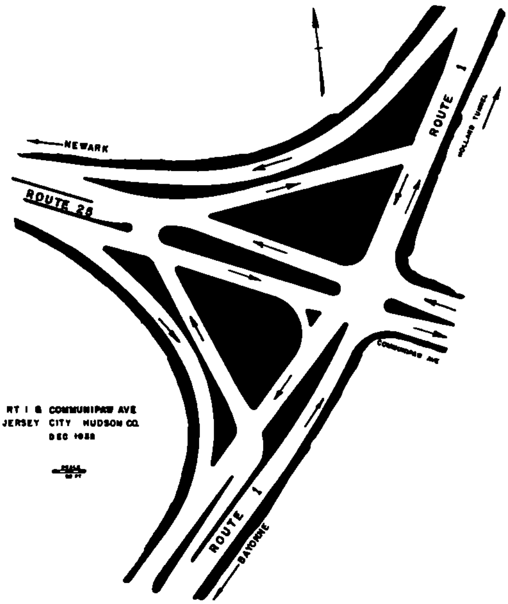


Figure 2.

intersection. These intersections, plus a fifth which does not utilize traffic signals, are shown in the illustrations. None of these intersections provide complete directional channelization, but all do illustrate practical applications of the principle.

Figure 2 shows the intersection of Routes 1 and 25, Communipaw Avenue, in Jersey City. This intersection has been

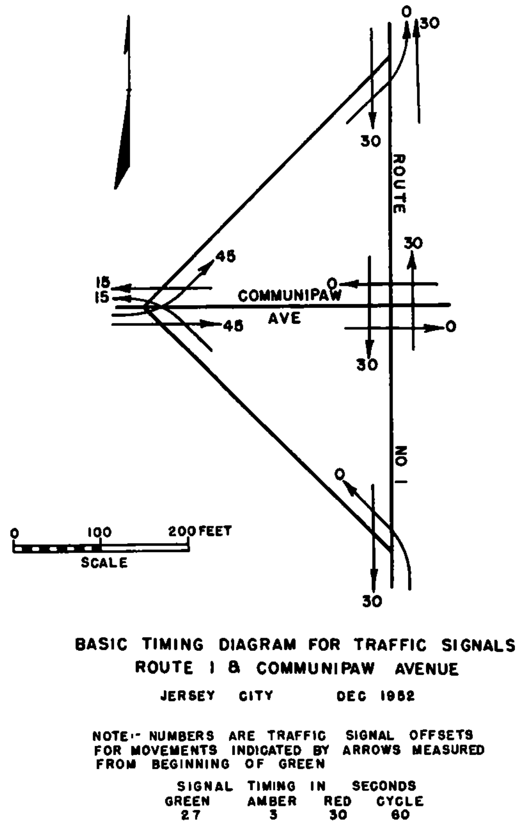


Figure 4.

of the then-existing intersection and where, at each location, it had been planned to construct a grade separation to overcome the congestion. The average saving was more than $1,000,000 per

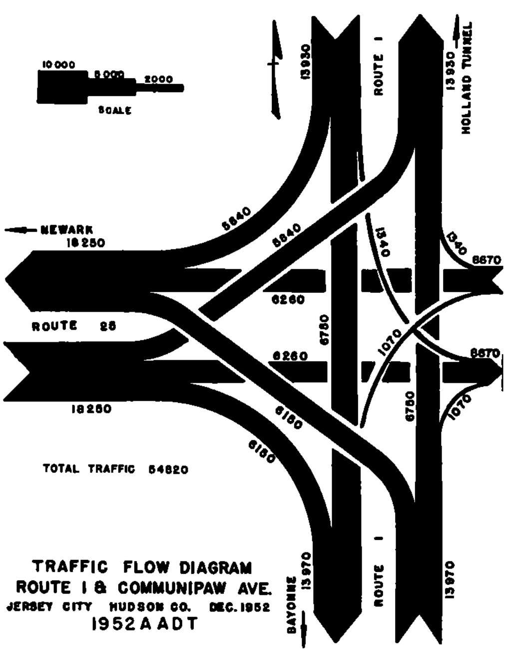
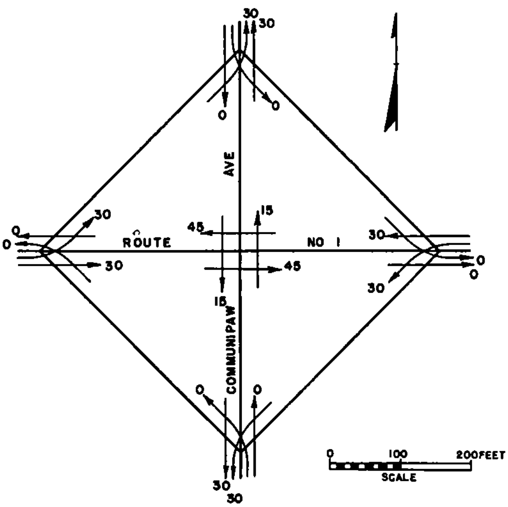


Figure 3.

in use since January 1950, and was described in a previous report. At this location there are two very-heavy left-turning movements, so directional channelization has been provided in two quadrants.

It is readily seen that the intersection shown in Figure 2 could be modified to provide diagonal roadways in the other two quadrants to further increase the efficiency of the intersection. It would then be the type as illustrated in Figure 1. Expensive gas stations occupy the two quadrants in question. Figure 3 shows the A. A. D. T. volumes at this location. Note that the left turns in the two undeveloped quadrants are each about 1,000 cars per A. A. D. T., which are not small left-turn volumes, but the other two left turns are over 5,000 vehicles A. A. D. T. Figure 4 shows the existing signal offsets.

At this location the signals are on a 60-sec. cycle with an even distribution of green time for conflicting movements. Numbers 0, 15, 30, and 45 indicate the relative beginning of the green signal



BASIC TIMING DIAGRAM FOR TRAFFIC SIGNALS
ROUTE 1 & COMMUNIPAW AVENUE
POSSIBLE MODIFICATION
JERSEY CITY DEC 1952

NOTE:-NUMBERS ARE TRAFFIC SIGNAL OFFSETS FOR MOVEMENTS INDICATED BY ARROWS MEASURED FROM BEGINNING OF GREEN

SIGNAL TIMING IN SECONDS

GREEN	AMBER	RED	CYCLE
27	3	30	60

Figure 5.

for the movements illustrated by the arrows at the points of cross traffic indicated. The offsets with the added roadways would be as shown in Figure 5.

Note that progressive offsets are provided for the straight-through movements and simultaneous offsets for the left turns.

At the Communipaw Avenue intersection, nearly all drivers are familiar with the intersection by virtue of repeated use, and there are no high speeds such as experienced in rural areas. High speed here is 40 mph. with 50 mph. rarely experienced on the adjacent roadways.

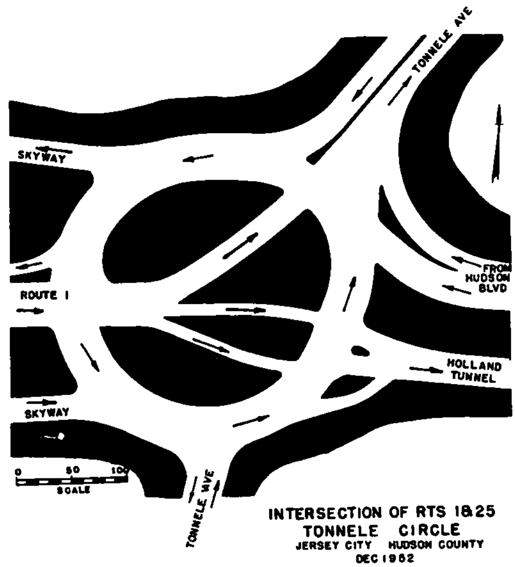


Figure 6.

These two factors, familiarity and reasonably slow speed, tend to make it relatively easy to control traffic with traffic signals. As the speeds become faster, it is more difficult to stop the vehicles, not because of the driver but because of the controlling devices. Drivers will respond to signal control at high speed just as readily as at low speed if the regulatory message is clearly legible.

Lane marking has not been used fully at this intersection, tending to reduce

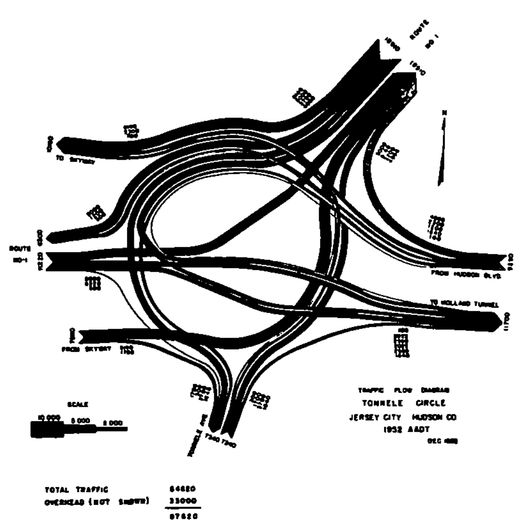


Figure 7.

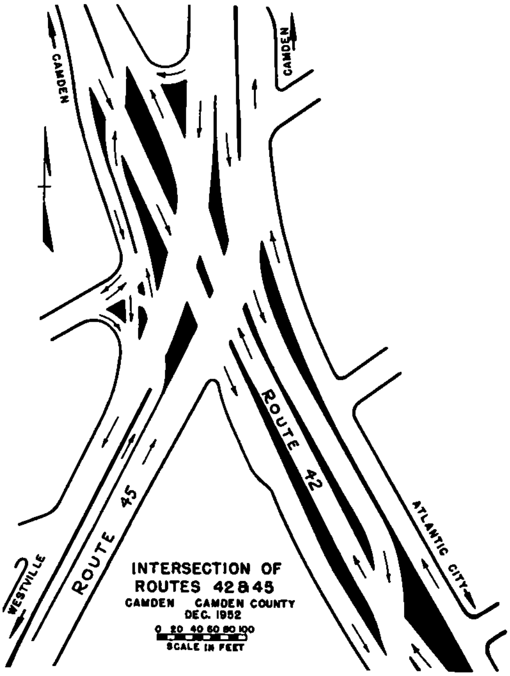


Figure 8.

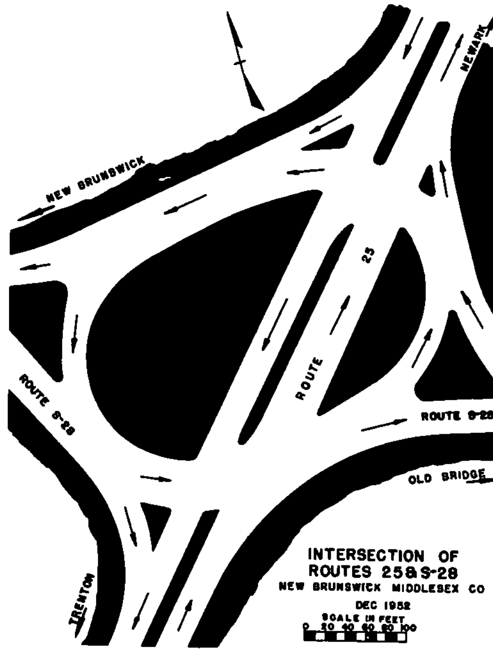


Figure 10.

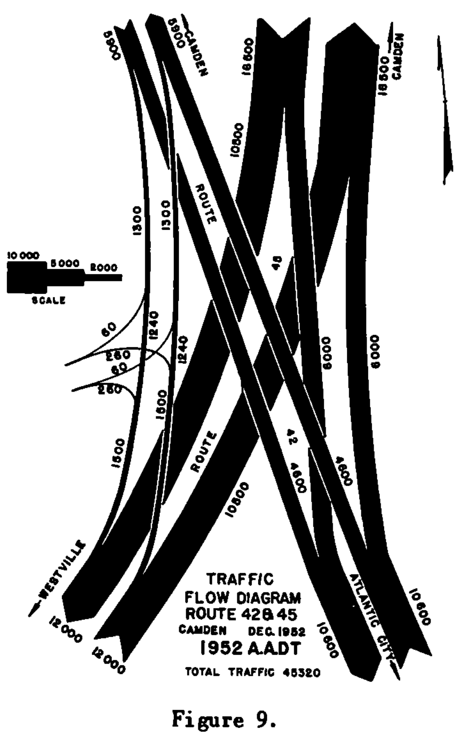


Figure 9.

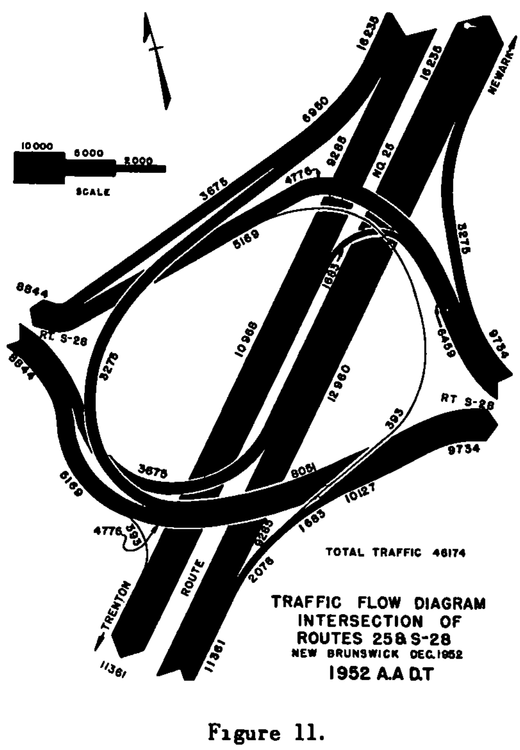


Figure 11.

efficiency. On roadways where two and three lanes in one direction are provided, some drivers overlap lanes and, on curves, cut corners into adjacent lanes. Proper lane marking would reduce this and improve efficiency still more.

Figure 6 shows the Tonnele Circle revision at the intersection of Routes 1 and 25 in Jersey City. This revision proved that channelization with signals, even though there seemed to be many signals, had a much greater capacity than the former traffic circle. It also proved

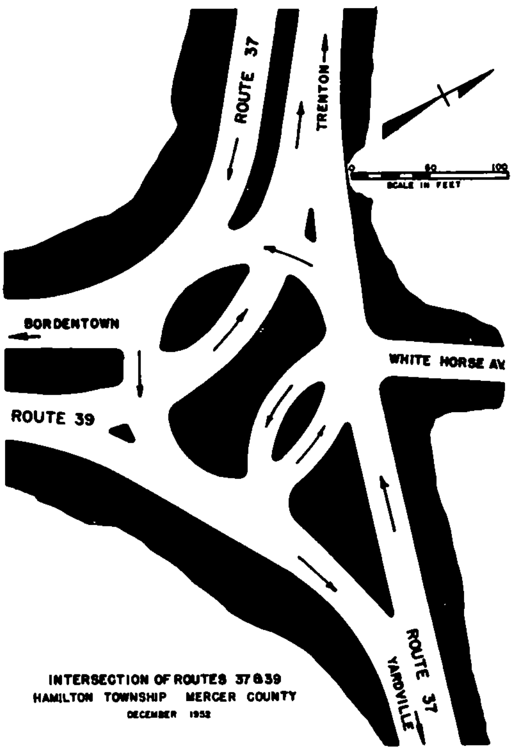


Figure 12.

that traffic-signal timing and coordination and lane requirements could be predetermined and designed to adequately serve the traffic to be expected. Lane marking was used extensively and drivers respect it admirably, even though most of it is on difficult curvature. Illustrated here is the driver's obedience to the stop signal, even at locations where it is desired that he continue. At some locations, because of the compactness of the intersection, drivers see signals that are meant to control other movements. Prop-

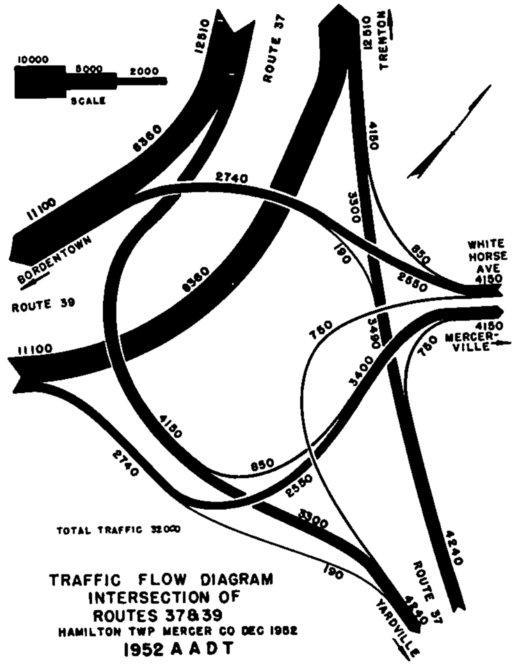


Figure 13.

er shielding has not yet been placed. At this location speeds are also relatively slow. A normal high speed is 30 mph., and 40 mph. is rare on the approach

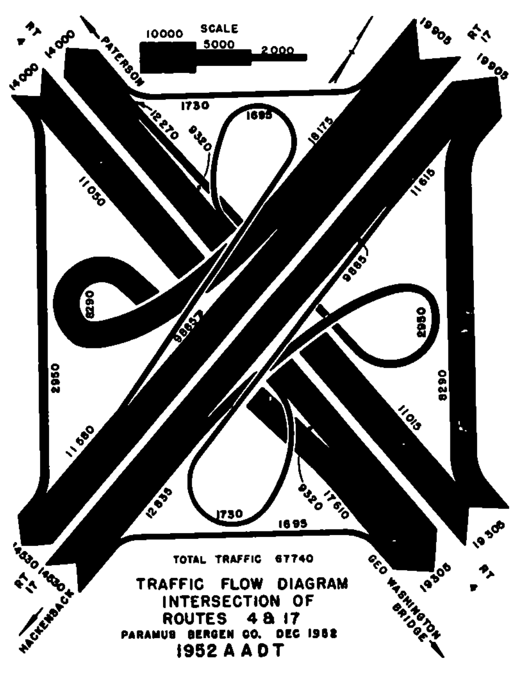


Figure 14.

roads. Most drivers are repeaters, although strangers are not uncommon.

Figure 7 shows the A. A. D. T. volume at this location. Note that the volumes shown do not include the overhead structures.

At the intersection of Routes 42 and 45, in Camden (Fig. 8), further support of the directional-channelization design principle was furnished. Lane marking was used extensively and effectively. Traffic behavior has responded favorably at this intersection, which is admitted to be quite complicated because of the many parallel roadways in a minimum overall width. The speeds are noticeably faster than at the two intersections in Jersey City. Speeds of 40 mph. are common, and 50 mph. can be expected on approach roads and even through the intersection. Higher speeds would be rare, although probably experienced along Route 45.

Figure 9 shows the A. A. D. T. volumes at this location. It should be noted that one left-turn movement is 6,000 cars per day. The plan illustrated provides ample capacity for the left-turn movement, which could not be obtained by conventional designs at grade.

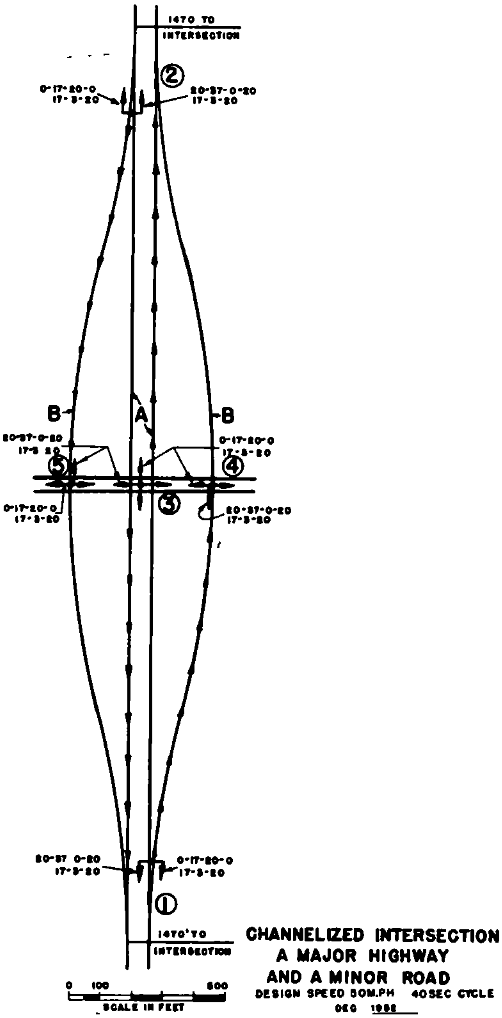


Figure 15.

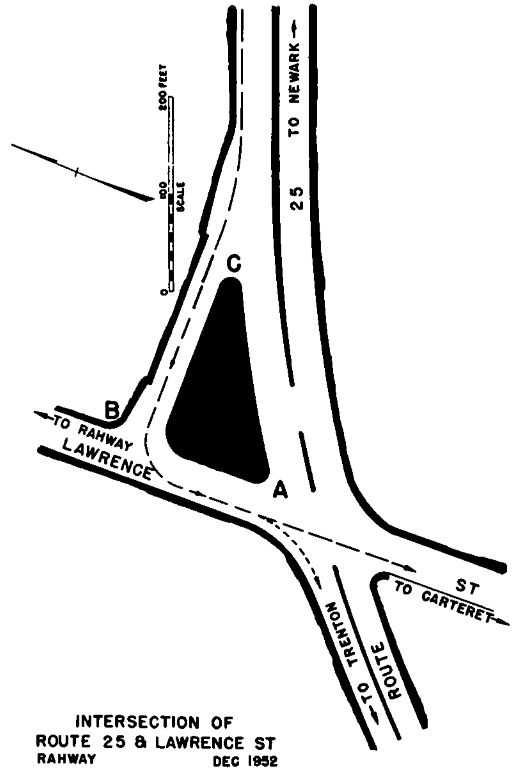
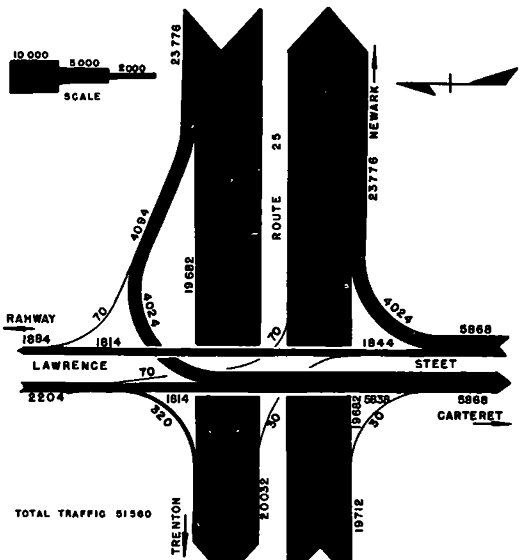


Figure 16.

At the intersection of Routes 25 and S-28 in New Brunswick (Fig. 10) further support has been added for the basic principles of channelization and existing congestion has been removed. The design permits a choice of two routes to go straight through on Route 25. The intended movement is that Route 25 traffic should go straight through, but when the signal is red these drivers can swing to the right on a green arrow, for right turns, and then continue around the circle, bypassing the traffic signals. Many drivers have been observed to take advantage of this opportunity, and if it is practiced during periods of light traffic, there should be no reason to attempt to discourage it; but if it is practiced during peak hours, it may be necessary to alternate the secondary points of crossing by the use of synchronized traffic signals. Observations indicate that about 200 cars per day are using the circle route in place of the straight-through route, compared to 9,000 cars per day using the straight-through route. Figure 11 shows the A. A. D. T. volume at this location.



TRAFFIC FLOW DIAGRAM
ROUTE 25 & LAWRENCE ST
RAHWAY UNION COUNTY DEC. 1952
1952 A.A.D.T

Figure 17.

At this intersection it is also possible to use an alternate route around the circle to make either of the left turns from Route S-28 to Route 25. Observations indicate that about 400 cars per day are using the circle route, compared to 1,200 per day using the direct route on one of these left turns.

The speeds for Route 25 straight through are probably higher than for any of the desired channelized intersections mentioned above. Route S-28 speeds are moderate with a normal speed of about 40 mph., while a high speed of 45 is rare in the vicinity of the intersection. On Route 25, speeds of 50 mph. are common, and 60 mph. can be expected occasionally.

Figure 12 shows an application of directional channelization without use of traffic lights. This is at the intersection of Routes 37 and 39 in Hamilton Township, near Trenton. At this location, the R. O. W. available limited the size of the basic circle, but an adequate facility was provided by adding separate roadways for two of the left-turn movements. Figure 13 shows the A. A. D. T. volumes.

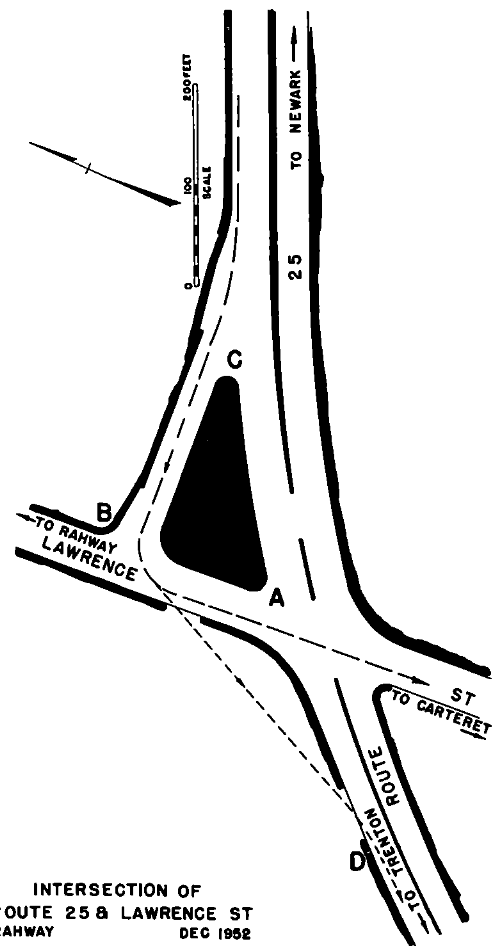


Figure 18.

After completion of the first directional channelization project at the Communipaw Avenue intersection, observations led to

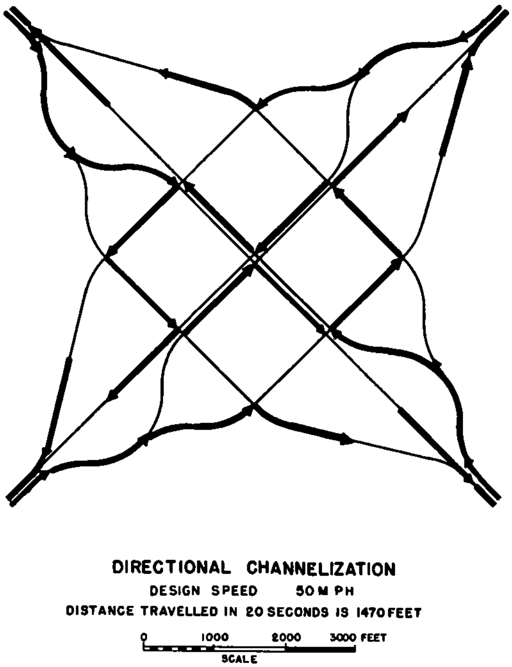


Figure 19.

the conclusion that the directional channelization served traffic better than could have been done by a cloverleaf. To check this conclusion, comparative time studies were made using one quadrant of a heavily traveled cloverleaf at the intersection of Routes 4 and 17 in Paramus (Fig. 14). These studies show that (1) left turns require 13 sec. less time when made directly with signals at the Communipaw Avenue channelization than on the cloverleaf without signals; and (2) for the equal distribution of left turns, right turns, and straight-through volumes, a cloverleaf would be 3 sec. faster per average car than a completed directional-channelized intersection of the Communipaw Avenue type and size. This 3 sec. could be eliminated with further refinements of the directional-channelization principle. Directional channelization, therefore, is a better choice of design than would have been a cloverleaf.

The intersection at Routes 1 and 25, Communipaw Avenue, in Jersey City, and at Routes 42 and 45 in Camden are the two best examples of directional channelization. The one at New Brunswick (Fig. 10) is not directional channelization, because the left turns must first turn right. This type might better be classified as "controlled channelization." It is included here, because it employs the same basic principle used in directional channelization. The basic principle involves the volume of traffic that will use the various parts of the intersection, the traffic distribution per lane and per traffic signal cycle, the capacity per lane per traffic signal timing, the acceleration of vehicles after stopping, the speed of vehicles through the intersection, and the coördination of design to fit these and other traffic behavior factors.

Many of these factors of traffic behavior have been developed into mathematical expressions or applications which are essential to the delicate balance of traffic behavior and design necessary for satisfactory operation. This science of traffic behavior can best be expressed by a coined word "traffodynamics," which would mean that branch of mechanics that treats of forces and laws of traffic. The Tonnele Circle and the New Brunswick Circle revisions are examples of controlled channelization using the technics of traffodynamics. A thorough understanding of traffodynamics is very valuable in a complete treatment of directional channelization, but it will be discussed separately at a later date.

Just as there is a need for coining the word traffodynamics, there is also a need for a better term than directional channelization to include all such especially designed channelizations producing inter-

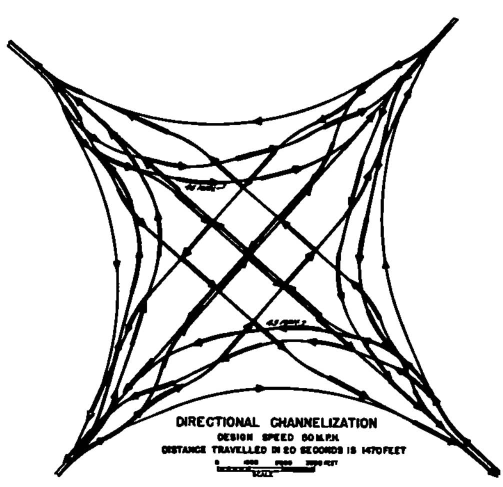


Figure 20.

section types of large traffic-volume capacity without the use of bridges.

Channelization involves the direct crossing at approximately right angles of two streams of traffic, and therefore, the right-of-way at the crossing area must be alternated, generally by the use of traffic signals. The signals must be capable of effectively stopping the moving stream of traffic before the other stream enters the crossing area. This is difficult to do on high-speed roads with the traffic signals that are used as standard today. Nevertheless, with amber signals before the red signals, with the use of all red periods and good coordination at adjacent signals, good results are produced. Probably a strong influence contributing to the reluctance to use traffic-signal control on high-speed roads is the inadequacy of the type signal. There is a need for a more positive signal before directional channelization can be fully applied.

The projects so far completed do not, by any means, indicate the full possibilities in the principle of directional channelization. It is a field where the designer can have wide opportunities for imagination. Figure 15 illustrates a treatment of a major and minor road in which the straight-through traffic on the major highway is never required to stop but, instead, alternates in using Roads A and B. When highway traffic is using Road A,

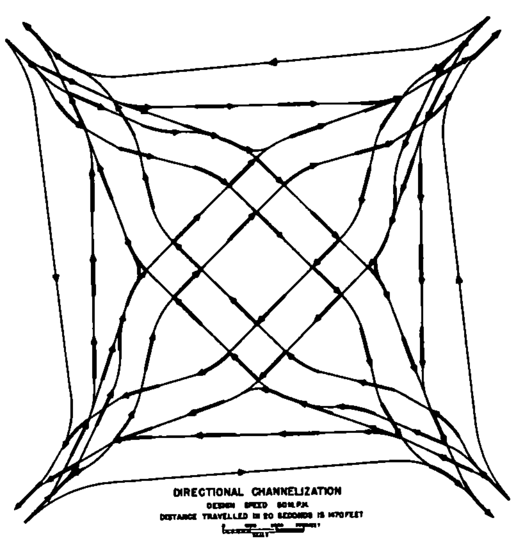
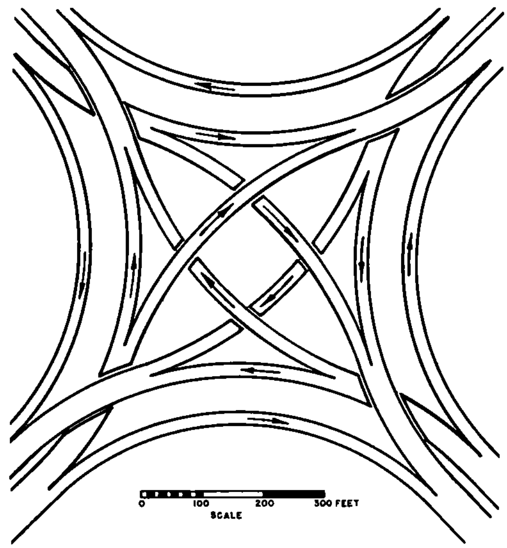


Figure 21.



COMPLETE DIRECTIONAL INTERCHANGE
DEC 1952

Figure 22.

the highway has a green traffic signal along Road A at Points 1, 2, and 3. The minor road has a red signal at Point 3 and a green signal at Points 4 and 5. The highway traffic is kept off Road B by red traffic signals at Points 1 and 2. Red signals also face Road B traffic at Points 4 and 5. If a vehicle approaches on the minor road, it will have a green light at 4 and 5 but a red light at 3. By the use of traffic-actuated detectors at Points 4 and 5, the signals at 1 and 2 are changed to red for Road A and green for Road B. Traffic on the minor road must stop at Point 3, and after sufficient time has elapsed for traffic to clear out of Road A, the minor road will receive a green light at Point 3 and Road A will get a red signal at Point 3. Before the first car from Point 1 or 2 arrives at Points 4 or 5, the signals at 4 and 5 change to red for the minor road and green for Road B. Vehicles on the minor road move from Point 3 to 4 or 5 and wait for the signal system to go back to the original phase. The distance between Points 3 and 4 or 3 and 5 is dependent on the frequency of vehicles on the minor road. A distance of 100 ft. available for storage would satisfy a minor road having an average daily volume of 2,000 if two lanes in each direction were available in the storage area. The distances from 1 to 3 and 3 to 2 are such that the alignment on the B roads will satisfy curvature standards for the design speed.

The success of this type of design depends upon, in addition to the effectiveness of traffic signals, the ability of drivers to make the switch from Road A to B, and vice versa, when so directed by the signals. Observations of traffic behavior indicates that drivers will respond to this type of control. Where the opportunity exists, some drivers can be observed making this movement, even under relatively difficult conditions.

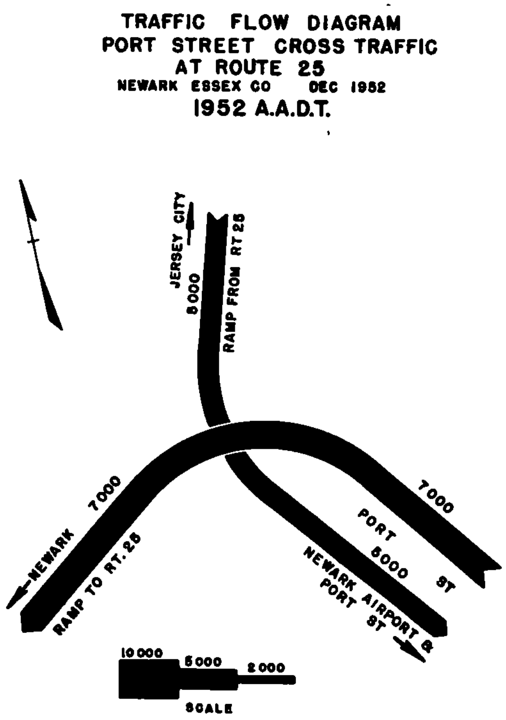


Figure 23.

At the intersection of Route 25 and Lawrence Street in Rahway (Fig. 16), this maneuver has been observed since about 1939. As recounted previously, a similar movement is now found at the New Brunswick Intersection of Routes 25 and S-28. It is quite certain that the movement occurs at many other locations, but the Lawrence Street example can be readily related to design.

Traffic signals control the intersection proper, A, with no signals used at Point B or Point C. The left turn coming from the direction of C is very heavy. Because of this, the one-way roadway from C to B was built in 1930. Left turns at A are prohibited and the heavy left-turn movement is directed to B by signs.

When the amber signal appears, which is 5 sec. long, to be followed by the red signal, vehicles which intend to go straight through on Route 25 can often be observed to swing right, as though to make a left turn, but when arriving at A they turn right. In this way they continue beyond A, whereas other vehicles, which a few seconds before were in front, are now behind, waiting at the traffic signal. This

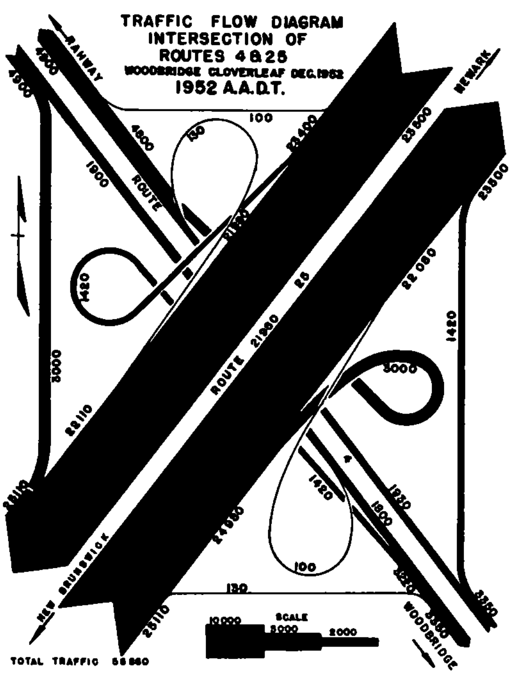


Figure 24.

maneuver depends on quick thinking on the part of the driver. He must be close to Point C but not beyond as the amber first appears. He must be able to do it smoothly, and he must be sure that there are not many vehicles already waiting to complete the left turn, or otherwise he will be caught with a red signal on Lawrence Street, in which case he will lose more time than if he had stayed on Route 25. Through traffic on Lawrence Street is small (Fig. 17) but the Route 25 through traffic is very heavy, so it is essential to separate the left turn.

During the course of these basic observations, the local police erected a sign reading "No Right Turn" in an effort to stop the maneuver, which they claimed was beating the light or evading the intended regulation. The sign was removed after a couple of weeks.

From an engineering viewpoint, one cannot help but imagine what would happen if this maneuver were made physically more inviting, especially since at Lawrence Street there is only an open field where such an improvement would be made.

Figure 18 shows a roadway from B to D, which would make this movement much easier and would not inconvenience any other movement. Traffic signals at B would then be advisable. A further development of this design principle produces the design previously shown in Figure 15, and a still further development produces Figure 19, which will serve an intersection having large straight-through movements and small turning movements. The spacing between points of cross traffic is equal to the distance traveled during the length of a green-signal period.

A still further development of this design principle, which provides for all movements in such a manner that no vehicle needs to stop or slow up below its normal speed, is shown in Figure 20.

Another design providing for all movements without any loss of time is Figure 21.

The capacity of these designs is unlimited. The greater the volume the more the number of lanes needed. Further expansion would involve merely the adding of lanes by widening the roadways. Roadways with 50 lanes in each direction would be no more complicated than roadways with five lanes in each direction.

This type of intersection surpasses all other types, except the complete directional interchange, in capacity and time savings (see Fig. 22). A complete directional interchange has never been built for a four-point intersection, and it is quite probable that a complete directional-channelized intersection may never be built within the lifetime of present-day engineers, but many variations of the basic design principles will be provided. If the ultimate design is clearly understood, better results will be obtained from partial or intermediate designs; and if the intermediate designs are mastered, the problem of the ultimate design becomes simpler.

The capability of designs, such as illustrated in Figures 20 and 21, to serve satisfactorily depends on the designer's ability to pattern the channelized roadways and controls in accordance with natural or normal driver behavior and the ability of drivers to behave or react in accordance with the established design and controls. Existing intersections involving designs and controls applicable to the ultimate design are available for observation and analysis.

Another high-volume example of channelization is at Port Street, Newark, (Fig. 23). For comparative purposes it is also interesting to note the volumes at the famous Woodbridge Cloverleaf (Fig. 24), at the intersection of Routes 4 and 25.

From the projects completed it has been shown that channelized intersections with traffic signals can be designed for some locations which will serve traffic better than other intersection types, with the exception of the directional interchange, in which case the service offered by the directional interchange can be matched. The cost of directional channelization is a small fraction of the cost of the grade-separated intersection in many cases. It might eventually prove that the channelization is less expensive for equal service for all locations.

The greatest deterrent to general application in high-speed rural areas is the traffic-signal control device. It is not effective to the same degree at 60 mph. as it is at 30 mph., although the same signal is used. In this instance, standardization is hampering progress. The existing signal standard is even made a part of the law in some areas. This type of control has been used in Portland, Oregon, (see "Highway Research Abstracts," for October 1952, page 14).

In addition to better signals, it is also possible to utilize advance signals on the high-speed approaches to advise drivers to adjust their speeds so as to arrive at the intersection during the green signal.

With the aid of properly designed channelization, traffic signals can be used to make traffic go instead of stop. In this way, they could be named "Go" signals instead of "Stop" signals.

Determining Widths of Pavements in Channelized Intersections

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IN general the widths of pavements in channelized intersections, or junctions, must be sufficient to provide for the movement of 3 types of vehicles: The 50-ft. semitrailer, the 35-ft. bus, and the passenger car. Larger or smaller vehicles may affect or control the width of some channels.

The design of a channelized intersection is greatly facilitated by the use of vehicle models.

A drawing of the intersection is made on a scale of 1 in. equals 10 ft. The wheels of models of the controlling vehicles, also to a scale of 1 in. equals 10 ft., are inked with a stamp pad and the widths and shapes of the wheel tracks traced on the drawing.

The width of pavement required at any point may now be determined directly from the wheel tracks.

The method is applicable to single-lane or multi-lane channels, and to all forms of curvature, simple, spiraled, compound or reversing.

Illustrations consist of drawings of controlling vehicles, photographs of principal models, and specimen applications of the method of design.

An appendix shows the dimensions of a variety of vehicles with sketches of their characteristic wheel tracks on curves, and tables listing the maximum track widths which can be reached by the vehicles on turns, with the minimum width of pavement required after the maximum track width has been reached for any given radius of curve.

● IN general, the width of pavements in channelized intersections, or junctions, must be sufficient to provide for the movement of three types of vehicles: (1) the 50-ft. semitrailer, (2) the 35-ft. bus, and (3) the passenger car.

Occasionally other vehicles must be considered, such as medium-sized trucks, logging trucks.

50-FT. SEMITRAILER

The track width of a 50-ft. semitrailer on a turn is greater than that of nearly all other vehicles normally using highways, including the 60-ft. full-trailer combination; pavements on turning lanes which will be used by 50-ft. semitrailers must, therefore, be made of sufficient width to accommodate this type of vehicle. The track width of a semitrailer on a tangent is assumed to be 8 ft. (see Fig. 1).

35-FT. BUS

The track width on a turn of the 35-ft. bus with 22-ft. wheelbase is considerably less than that of the 50-ft. semitrailer making the same turn and slightly more than that of a 30-ft. truck with 20-ft. wheelbase. However, the front overhang and rear overhang of the bus are considerable. The effect of the front overhang may influence the width of pavement required on sharp turns, while the effect of rear overhang may need to be considered at the beginning of a turn. The track width of a bus on a tangent is assumed to be 8 ft.

The bus will influence the width of pavement required on a turning lane: (1) when the turn will be used only by busses and smaller vehicles; (2) when the turn is designed for the 50-ft. semitrailer but it is desired to provide sufficient width to allow either vehicle to pass the other in case of a breakdown; and (3) when the turn is designed for one-way, two-lane operation and it is assumed that no vehicle larger than a bus will pass a semitrailer moving in the other lane.

The dimensions of the bus are shown in Fig. 1(B).

PASSENGER CAR

The track width of the passenger car is less than that of any other vehicle used for design.

The passenger car will influence the width of pavement required on a turning lane under the same conditions listed for the 35-ft. bus if the passenger car is substituted for the bus. The track width of a passenger car on a tangent is assumed to be 6 feet.

The dimensions of the passenger car are shown in Figure 1 (C).

OTHER VEHICLES

Semitrailers

Some states permit semitrailers larger than the 50-ft. semitrailer. Such large semitrailers produce a greater track width on turns than the 50-ft. semitrailer, which must be considered in determining the width of pavement, particularly when a turning lane is bordered by curbs or islands. The increase is most noticeable when the radius of the turn is 100 ft. or less.

Single-unit Trucks

Designs based on the track width of a 35-ft. bus are adequate for single-unit, 30-ft. trucks with 20-ft. wheelbase. In some instances the largest vehicles which will use a turn are medium-sized single-unit trucks with a maximum wheelbase of 16 ft. In such cases a truck of this type may be used for design instead of a 35-ft. bus, subject to the same provisions, except that overhang will have very little influence.

Busses

Some busses are larger and have a longer wheelbase than the 35-ft. bus. Where such vehicles are operated they should be substituted for the 35-ft. bus, subject to the same provisions.

Logging Trucks

In the West logging trucks are common. The track width produced by these trucks on a turn varies with the wheelbase of the tractor, the length of logs, and the method of loading.

In general, pavements designed for the 50-ft. semitrailer are adequate for logging

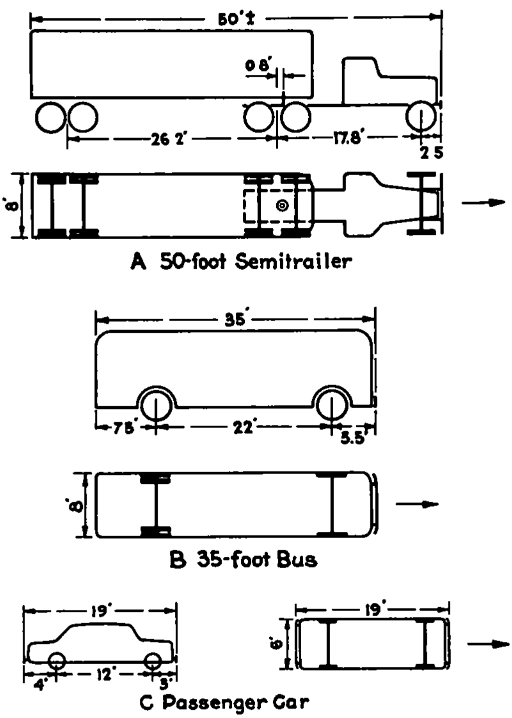


Figure 1. Dimensions of vehicles.

trucks carrying logs up to 60-ft. long when the radius of the turn is 80 ft. or more.

When the radius of the turn is less than 80 ft., the track width produced by a logging truck may be greater than that of a 50-ft. semitrailer.

The trucks are often loaded in such a manner that a portion of the load hangs over beyond the rear axle. In this case one corner of the rear overhang, of a load of 60-ft. logs, may sweep almost 4 ft. outside the path of the outside front

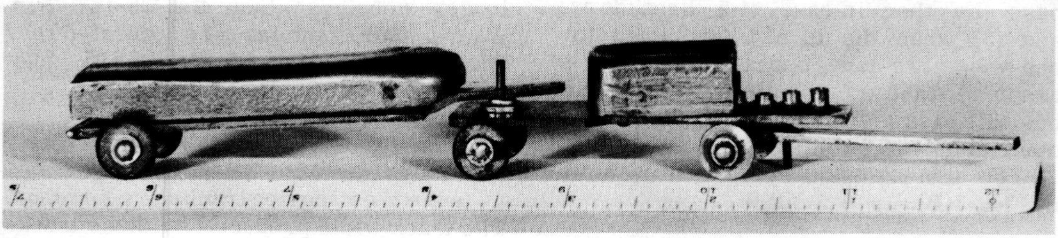


Figure 2. Model of 50-ft. semitrailer.

wheel on entering a very sharp turn (see appendix), and pavements must be designed to provide extra clearance between two lines of vehicles moving in adjacent lanes, where this occurs.

MODELS OF VEHICLES

It occurred to the writer, some years ago, that a drafting tool which could trace the path of the inside rear wheel of a vehicle (the rear wheel nearest to the center of a turn) would be useful for laying out the inside edge of the pavement on a turn. The tool which will accomplish this is an accurate scale model. Models were therefore made of the following vehicles: (1) the 50-ft. semitrailer (Fig. 2); (2) the 60-ft. full trailer combination (Fig. 3); (3) the 35-ft. bus (Fig. 4); (4) the passenger car; and (5) the logging truck (Fig. 5). All of these are to a scale of 1 in. = 10 ft.

Several of these vehicles have some tandem axles. In the models, equivalent single axles were substituted for the tandem axles. To simplify construction of the models, the front wheels are set at right angles to the front axle, which is pivoted at its center (a fifth-wheel arrangement). This does not affect the path of the inside rear wheel.

OPERATION OF MODELS

When a vehicle moves around a turn, it does so most conveniently by steering on a definite curved line. This curved line may be a simple circular curve or a spiraled curve. It may be called the "steering curve" and defined as the curve on which the center of the front axle of a vehicle would move if there were no variations due to fluctuating movements of the steering wheel. The "steering radius" (RS) may be defined as the radius of a circular steering curve or of the circular portion of a spiraled curve.

A sketch is made of the proposed channelized intersection or junction on which the steering lines, consisting of tangents and steering curves, with their radii, are indicated for the various channels and for connecting highway or speed change lanes.

Following this, a plan is drawn on a scale of 1 in. equals 10 ft., on which the steering lines are laid out.

The model of the largest vehicle for which the channels must be designed is now selected (this will, in most cases, be the 50-ft. semitrailer). The inside rear wheel of which the path is to be found is inked by rolling it over a stamp pad, and the model placed in position over

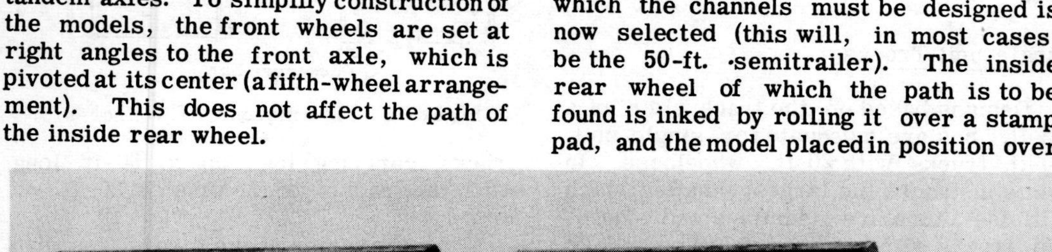


Figure 3. Model of 60-ft. full trailer.

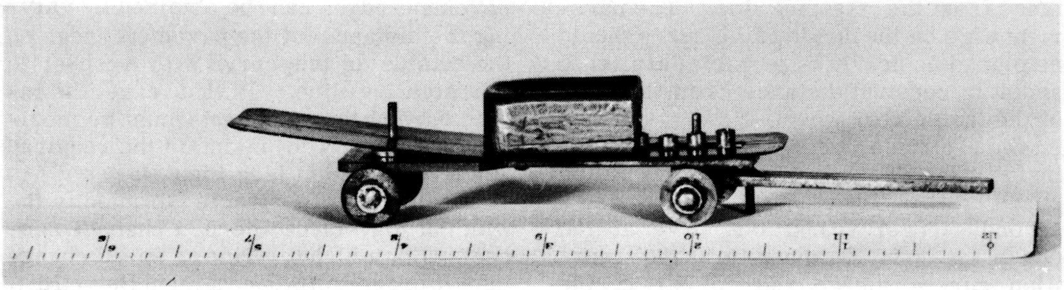


Figure 4. Model of 35-ft. bus.

one of the steering lines on the drawing. The model is provided with a pointer, which theoretically should be directly under the center of the front axle. However, in order to make the pointer visible, it is set just in advance of the front wheels, which has no appreciable effect on the trace of the rear wheel. The pointer is placed accurately over the steering line and the model drawn forward following the steering line carefully with the pointer. The ink trace produced on the drawing will accurately represent the track of the outer face of the inside rear wheel.

On long channels it will be necessary to re-ink the wheel when the trace becomes faint. If the model in use is that of a compound vehicle, the position of the wheels on one side of the model must be carefully spotted on the drawing with a sharp pencil, so the model can be reset in its exact position before the forward movement is resumed. The front and rear overhang can be observed and spotted on the drawing with a sharp pencil.

The forward movement of the model along the steering line in the channel must be continued along the lane to which the channel connects until the rear wheel has reached its normal distance from the centerline of that lane (for trucks and busses, 4 ft. on tangents; for passenger cars, 3 ft. on tangents).

The drawing now shows an accurate trace in ink of the path of the inside rear wheel.

In order to obtain the track width of the vehicle, it will also be necessary to show the path of the outside-front wheel. On many trucks the out-to-out width of the front wheels is less than that of the rear wheels, on some trucks and on busses the width is the same, front and rear. The distance of the outside-front wheel on trucks and busses is therefore assumed to be 4 ft. from the center of the front axle and on passenger cars 3 ft. This distance does not remain constant on a curve, it is least on any given curve when the wheels are fully turned to follow the curve. However, the decrease is small and the path of the outside front wheel may be drawn parallel to and 4 ft. distant from the steering line for trucks and busses and 3 ft. distant from the steering line for passenger cars.

The plan now shows the track width along the entire channel and the pavement edges may be laid out at any desired distance from the wheel tracks. The pavement edge on the outside of a curve will be parallel to and at a constant dis-

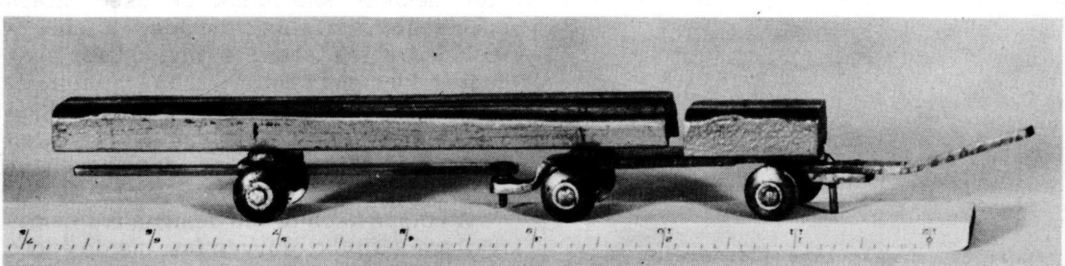


Figure 5. Model of logging truck.

tance from the steering line. The pavement edge on the inside of the curve should be placed as nearly as possible parallel to and at a constant distance from the path of the inside rear wheel.

On a circular or spiraled curve, the inside-rear wheel describes a transition curve at the beginning of a turn and a second, longer transition curve at the end of the turn. On many turns the transition curves merge and no part of the path of the inside-rear wheel is circular. (For a 50-ft. semitrailer this path is entirely transitional on turns with a steering radius less than about 80 ft. and a central angle of 90 deg. or less).

To design a pavement edge which follows the path of the inside-rear wheel as nearly as possible, a circular curve is selected which nearly fits the central portion of the wheel path. This curve is then connected with unsymmetrical or symmetrical compound curves or with unequal or equal spirals to the edges of the pavement on the approach lanes.

Sometimes a better alignment of the pavement edges can be obtained by varying the distance of the pavement edge on the outside of the curve with respect to the steering line. In that case the inside edge of the pavement must be modified accordingly to maintain the required width of pavement (see Fig. 7).

It is often desirable to modify the width of pavement where a channel connects with a highway lane or speed change lane in order to produce a funneling effect.

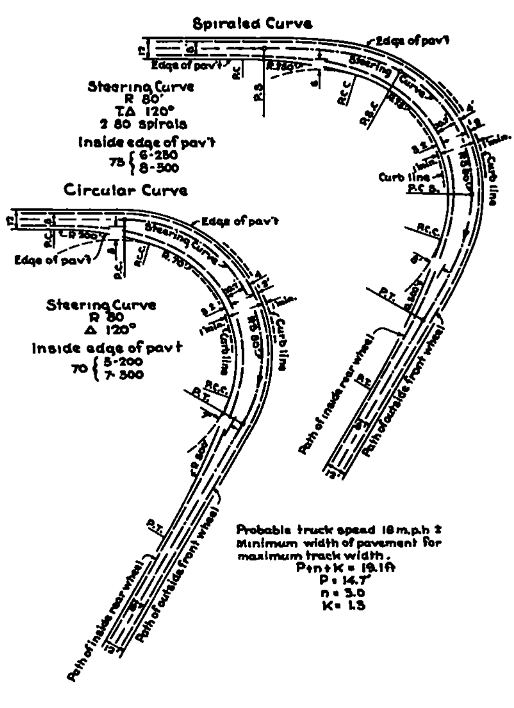


Figure 6. Single-lane channel for 50-ft. semitrailer, steering radius, 80 ft.; central angle, 120 deg.

DESIGNS FOR EDGE OF PAVEMENT, CALIFORNIA 1949

The California Division of Highways published a report entitled "Truck Paths on Short Radius Turns" in August 1949. This report describes a series of tests made to determine the track widths of trucks, including the 50-ft. semitrailer, on short radius turns. The wheel tracks of full size trucks were marked on a pavement, measured and platted. From these wheel tracks a table was prepared showing "Curve Data for Inside and Outside Edges of Lanes Which will Accommodate large Semitrailer Combinations."

DESIGNS FOR EDGE OF PAVEMENT, OREGON 1949

The writer prepared a paper for the Oregon State Highway Department in January 1949 entitled "Minimum Designs for Edge of Pavement and For Curve Radii for Intersections at Oblique Angles of Highways and Streets." This paper shows a series of minimum designs for edge of pavement on the inside of turns for intersection angles from 20 deg. to 160 deg. and of corresponding curb radii when parking is permitted on the intersecting roads but not on the turn. Since minimum designs should not be used unless such designs are unavoidable, a table is included which shows a method for producing designs better than minimum. The designs were developed from wheel tracks drawn by models, and cover turns for semitrailers, busses, and passenger cars.

A comparison of the designs for semitrailers with the curves for inside edges of lanes developed by the California Division of Highways shows close agreement.

MODELS USED FOR DESIGN OF CHANNEL PAVEMENTS UNDER ANY CONDITIONS

The channel pavements thus far mentioned are planned in each instance to follow a simple curve connecting two tangents. In practice however conditions are often not so simple. A channel pavement may be required to provide width sufficient for: (1) a single lane, (2) a single lane with added provision for emergency passing, (3) two lanes for traffic moving in one direction, (4) two lanes for traffic moving in opposite directions.

apart to allow the desired clearance between passing vehicles. When pavements are designed as one lane with extra width for emergency passing or for two-lane movements, the controlling vehicles occupying the lanes may be identical or of differing types. (Data on track width and amount of front overhang for a variety of vehicles and on the rear overhang of logging trucks may be found in the appendix. These data are useful for estimating the required distance between steering lines.)

A great advantage of the vehicle model as a design tool is that the width of chan-

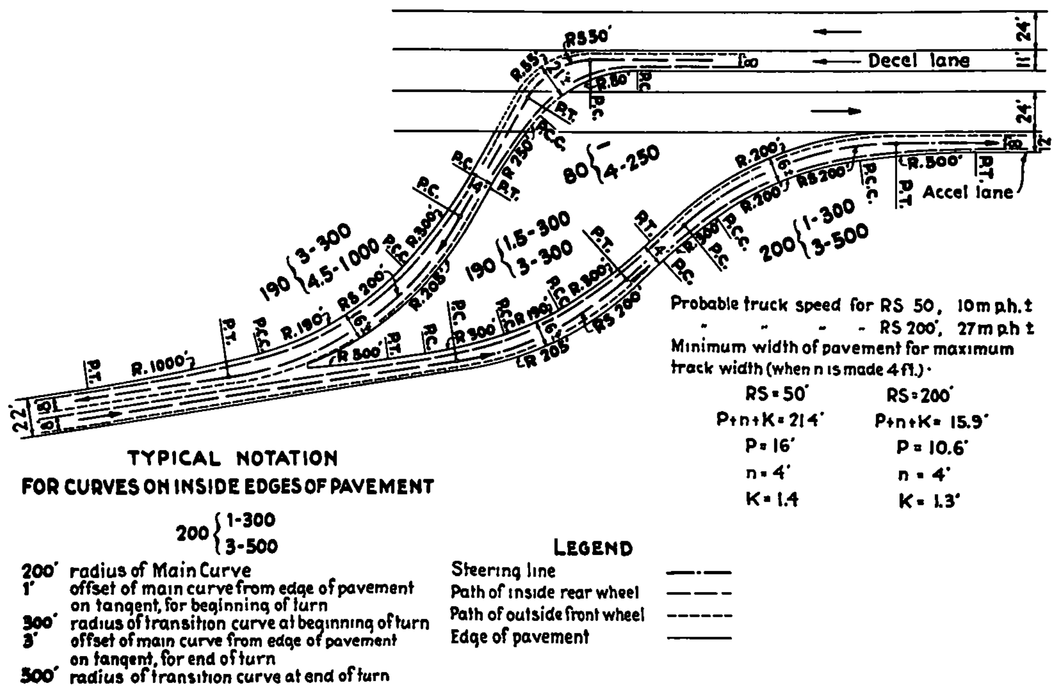


Figure 7. Single-lane channels for 50-ft. semitrailer; reversing curves separated by short tangents.

The steering line may consist of a simple curve, a spiraled curve, compound curves, reverse curves, curves separated by short tangents, and it may meet highway alignment on a tangent or on a curve.

If the channel consists of more than one lane, separate steering lines must be platted for each lane, and these lines will generally not be parallel throughout the length of the channel. These steering lines must be platted far enough

nel pavement required to meet all these conditions can be readily determined after tracing the wheel tracks of the controlling vehicles with the models (Fig. 6 and 7).

FORMULAS FOR DETERMINING WIDTH OF PAVEMENT FROM TRACK WIDTHS

1. Single-Lane Channels

Formula (1) $W = P + n + K$

W = Width of pavement in feet.
P = Track width at any point.
n is the excess of lane width over track width on a tangent.

When the lane width on a tangent is 11 ft:
n = 5 feet for passenger cars.
n = 3 feet for trucks and busses.

When the lane width on a tangent is 12 ft:
n = 6 feet for passenger cars.
n = 4 feet for trucks and busses.
K is a variable which increases the width of pavement to allow for the greater difficulty of maneuvering a vehicle on a curve.

$K = \frac{V}{2\sqrt{RS}}$ where RS is the steering radius of a curve and V is the speed in miles per hour.

K = 1.4 ft. when RS is 100 ft. or less.
K = 1.3 ft. when RS is 150 ft. to 250 ft.
K = 1.2 ft. when RS is 300 ft. to 450 ft.
K = 1.1 ft. when RS is 500 ft.

2. Single-Lane Channels With Extra Width for Emergency Passing

Formula (2) W = P + P' + FO + 3

W = Width of pavement in feet.
P = Track width of the controlling vehicle at any point.
FO = The encroachment of the larger front overhang.
3 = 3 ft., a constant used by the AASHO in "A Policy on Intersections at Grade" (page 21) to determine emergency passing widths.

3. Two-Lane Channels

Formula (3) W = P + n + P' + n' + FO + K

W = Width of pavement in feet.
P = Track width of the controlling vehicle at any point in one lane.
P' = Track width of a controlling vehicle at a corresponding point in the second lane.
n for the vehicle in the first lane has any of the values shown for formula (1).
n' for the vehicle in the second lane has any of the values shown for n, selected for that vehicle.
FO = The encroachment of the larger front overhang.
K has the values shown for formula (1), and is applied to the entire width of the pavement and not to each separate lane.

After scaling P, P', and FO from the platted paths (FO may be estimated from the tables in the appendix), the pavement width, at any point, determined from the formulas will provide a check on the width determined graphically on the plat.

Frequently it is found difficult to maintain a sufficient width between edge of pavement and nearest wheel track where the beginning or end of a turn connects with a highway lane or speed change lane when the edge of pavement is defined by an unsymmetrical or symmetrical three-centered compound curve. It may also be difficult to maintain the required clearance between vehicles moving in adjacent lanes of a two-lane channel at the beginning and end of a turn. These difficulties may be overcome or greatly reduced by flaring the lane to which the turn connects to more than its normal width.

The minimum lane widths on tangents considered suitable by the AASHO are: 11 ft. for passenger cars, 11 ft. for trucks at speeds up to 40 mph. and 12 ft. for trucks at speeds more than 40 mph. (Policy on Intersections at Grade, page 21).

APPENDIX

A paper prepared by the writer in 1951 for the Oregon State Highway Department entitled "Path of Vehicles on Curves and Minimum Width of Turning Lanes" follows as an appendix. This paper gives the dimensions of a variety of vehicles with sketches showing the characteristic wheel tracks of those vehicles on curves.

"Track width" is referred to as "width of wheelpath" in this paper.

The maximum track width which can

be reached by a vehicle turning on steering radii from 25 ft. for the passenger car, and 42 ft. for other vehicles, to 500 ft. was calculated and shown in the columns headed "P" in the tables.

The track widths which will be reached by the 50-ft. semitrailer on circular curves and on spiraled curves when the central angle of the curve is less than that required to produce the maximum possible track width for a given steering radius are also tabulated. These track widths have been scaled from wheel tracks made by a model.

The widths of pavement for turning lanes shown in the tables are the minimum widths required after the track width for a given steering radius has reached its maximum. They have been derived from the calculated width of wheel track by the methods used by the AASHO in a "Policy on Intersections at Grade."

APPENDIX

Path of Vehicles on Curves and Minimum Width of Turning Lanes

Tables of the "Path of Vehicles on Curves and Minimum Width of Turning Lanes" were first prepared by the Oregon State Highway Department in 1946, the present tables differ from these earlier tables in several respects:

1. THE RADIUS OF TURNS.

In the earlier tables the radius of the circular curve RC described by the inside rear wheel of a vehicle was used for the calculation of the width of the wheel path.

There are objections to the use of the radius RC as the controlling radius on turns:

A. There is a large difference between the radius RC of the curve described by the inside rear wheel of a compound vehicle, such as a 50-foot semitrailer, and that of a smaller simple vehicle, such as a 30-foot truck or a passenger car, when the outside front wheel of each vehicle describes the same curve on a turn.

B. On many turns the curve described by the radius RC is an imaginary line.

The inside rear wheel describes a transition curve at the beginning of a turn and a second, longer transition curve at the end of the turn. On many turns the transition curves merge and no part of the path of the inside rear wheel is circular. This is particularly true for large compound vehicles, the path of the inside rear wheel of a 50-foot semitrailer moving on turns with a radius less than 80 feet and through central angles of 90 degrees and less is entirely transitional.

In the present tables a "Steering Curve" is used as the controlling line. The steering curve may be defined as the curve on which the center of the front axle of a vehicle would move if there were no variations due to the fluctuating movements of the steering wheel. The steering curve may be circular, or it may be a spiraled curve. It is a definite line which can be staked on the ground. The "Steering Radius," RS, is defined as the radius of a circular steering curve or of the circular portion of a spiraled curve.

2. LANE WIDTHS.

In the earlier tables the widths of a single lane and 2-lane pavements were calculated according to the A.A.S.H.O. method described on page 21 of "A Policy on Intersections at Grade" (1940). The width of pavement for 1-lane and emergency passing was calculated by the same method but was increased by the amount of the front overhang of a vehicle. The resulting pavement widths for pavements more than one single lane wide are sufficiently close for vehicles having a comparatively narrow wheel path such as passenger cars and single trucks.

<u>Compound Trucks</u>. The wheel path of large compound trucks is, however, so wide, when RS is 100 feet or less, that the steering radius in the outside lane, that is the lane farthest away from the center of the turn, becomes considerably longer than the steering radius in the inside lane, with a consequent reduction in the width of the wheel path. In the present tables for semitrailers and the truck-and-trailer the widths of pavements more than one lane wide have been reduced to allow for the reduced width of wheel path in the outside lane, when RS in the inside lane is 100 feet or less,

Busses. Because a bus always has a large front overhang on short radius turns, the width of 2-lane pavements on turns designed for busses has been increased by the amount of the front overhang.

Logging Trucks. On the usual type of logging truck the load is carried by two bunkers, one bunker over the kingpin of the tractor, the other over the rear wheels of the trailer. For any given length of logs and method of loading the distance between the bunkers remains constant as the truck travels around a curve. The rear axle assembly of the trailer slides along the reach which extends from the coupling on the tractor (the end of the "stinger") through the rear axle assembly. In the earlier tables the length of the reach was considered constant for any given load and this length was used in the calculation of the width of the wheel path.

In the present tables the varying length of the reach was used in the computations, this results in a greater width of wheel path on turns with a radius less than about 120 feet.

Also in the earlier tables the length of the front axle of the tractor was taken as 6 feet. On some tractors this axle may be 8 feet long.

In the present tables 8 feet is used for the length of the front axle. This also results in a greater width of wheel path on turns with a radius less than about 120 feet.

Consequently the widths of single lane pavements for logging trucks on turns with a radius less than about 120 feet are greater in the present tables than in the earlier tables.

3. NEW TABLES.

A table has been added showing data for a 35-foot bus with a 22-foot wheel base.

Two tables have been added showing the greatest width of wheel path reached by the semitrailer S-50-18 on turns through central angles of 10 degrees to 270 degrees, one table is for circular curves, the other for spiraled curves.

4. TABLES EXTENDED.

All tables have been extended to a steering radius of 500 feet.

SPIRALING CURVES ON TURNS.

While it is possible for a vehicle to move from a tangent to a circular curve and from a circular curve to a tangent, at slow speeds, a turn can be considerably improved by spiraling. A method for spiraling steering curves is shown on sheet 18.

It is usually necessary to use spirals, or tapers combined with spirals, to connect the center line of the lane on a tangent with the steering curve on the inside lane of a 2-lane turn, in order to provide sufficient clearance between the wheel tracks of the vehicles moving in the two lanes on the transition.

WIDTH OF WHEEL PATH.

The width of the wheel path, P, shown in the tables is the maximum width reached when the outside front wheel and the inside rear wheel are moving in parallel circles.

For large compound trucks, such as 50-foot semitrailers, this does not happen, on very short radius turns, until the vehicle has moved through a central angle of about 180 degrees or over, see sheets 17 and 19.

MINIMUM DESIGN FOR TURNING LANES.

Turning lanes which will be used by compound trucks, such as the 60-foot truck-and-trailer and the 50-foot semitrailer, must meet two minimum requirements:

1. Steering Radius.

The steering radius, RS, must be sufficient for the 60-foot truck-and-trailer. A minimum RS of 42 feet is used in these tables, this is less than 1 foot over the absolute minimum required by the design truck of this type. (The speed on this radius is about 5 m.p.h.)

2. Lane Width.

The lane width must be sufficient for the 50-foot semitrailer, S-50-18, moving on a steering radius of 42 feet. The width of the wheel path of this semitrailer is 22.8 feet, (about 4 feet more than the wheel path of the 60-foot truck-and-trailer moving on the same steering radius) when the central angle is 270 degrees, (see sheets 17 and 19 for width of wheelpath when the central angle is less than 270 degrees.)

Note. The semitrailer S-50-18 is the dominant type. Occasional 50-foot semitrailers S-50-13 have a somewhat wider wheel path but can use lanes designed for S-50-18. (The length of the front axle of S-50-13 was taken as 8 feet for the computation of the width of the wheel path, but the tractor is small and the front axle is usually less than 8 feet long which reduces the width of the wheel path).

Turning Lanes for Smaller Vehicles.

Only when it is definitely known that no large compound trucks will use a turn this may be designed for the largest vehicle which has to be accommodated. The data may be taken from the appropriate table.

It should be noted that a simple 30-foot truck with 20-foot wheel base requires the same minimum RS of 42 feet as the 60-foot truck-and-trailer. The maximum width of wheel path, 12.7 feet, is reached by the 30-foot truck when it turns through a central angle of about 75 degrees or more.

MINIMUM DESIRABLE RADIUS FOR TRUCK TURNS.

Because of the difficulty of turning on a steering radius of 42 feet and the slow speed on such turns, the minimum desirable RS for truck turns is 66.5 feet. If a curb is constructed along the inner edge of the pavement the curb radius, for a pavement designed for the semitrailer S-50-18, on that part of the turn where the inside rear wheel of the vehicle is moving on a circular curve, will be about 50 feet when RS is 66.5 feet. (The speed of trucks on this radius is about 15 m.p.h.)

TRANSITIONS TO WIDTH OF PAVEMENT ON TURNS.

Where the pavement on a turn merges into the pavement on a tangent, or on a curve of different radius, and the width on the turn differs from that of the pavement into which it merges transitions must be designed to connect the edges of pavements of different widths. Compound curves, or spiraled curves, are used for these transitions which must be so designed that sufficient clearance is left between the edge of the pavement or lane on the transition and the nearest wheel track, or overhang.

The method of designing such transitions is not discussed in this paper. The tables are constructed to show only the maximum width of wheel path which can be reached by various vehicles on turns of a number of different radii, and the pavement widths required to accommodate these maximum widths of wheel path.

LOGGING TRUCKS.

The large majority of logging trucks consist of a tractor and a reach of variable length sliding through the rear axle assembly. The dimensions of tractors vary considerably, the wheelbase is usually between 13 feet and 20 feet, the extension, or "stinger", to which the reach is coupled, varies from 6 feet to 20 feet. The length of the stinger is usually fixed but may be adjustable.

The effective length of the reach varies with the length of logs and the method of loading. For any given load this length remains constant on tangents but varies as the truck moves around curves of differing radii.

For the computation of the tables for logging trucks a tractor wheel base of 16 feet with a stinger of 6 feet, and a number of representative lengths of logs and of methods of loading have been selected. Lanes designed for logging trucks with a tractor of 16 foot wheel base are also suitable when tractors of 13 foot to 20 foot wheel base are used.

No widths are shown in the tables for 1-lane and emergency passing and for 2-lane pavements because the width of such additional lanes depends on the requirements of the vehicles using the additional width of pavement. Where a turn is used only by logging trucks the additional width may be required for emergency passing of loaded trucks, or it may be designed only for the use of unloaded returning tractors, especially if additional width for emergency passing is available on rock shoulders.

On turns which do not develop the maximum width of wheel path a reduction in width of wheel path will occur similar to that shown for the semitrailer S-50-18 on sheets 17 and 19.

<u>Rear Overhang</u>. The load on a logging truck often extends well beyond the rear axle. When the truck begins a turning movement one corner of such a load will hang over the path of the outside front wheel (see sketch, sheet 24) and may encroach on an adjacent lane unless extra width is provided between lanes to avoid this danger.

When the steering curve is spiraled the amount of the overhang is somewhat less than on a simple curve of the same RS and the maximum overhang will occur approximately at the P.S. instead of a short distance back of the P.C. as is the case on simple curves.

<u>Turns for Semitrailers may be adequate for Logging Trucks</u>.

Pavements designed for the semitrailer S-50-18 are adequate for logging trucks when RS is 80 feet or more, see Notes on Tables for Logging Trucks. It may however be necessary to provide extra lane width in the area affected by the rear overhang of the load.

Lettered columns show characteristics of path of vehicle, see sketches..

Numbered columns show width of pavement required when the wheel path of a vehicle has reached its maximum possible width for any given steering radius:

1. Minimum width of pavement for 1-lane, 1-way traffic.
1E. Minimum width of pavement for 1-lane, 1-way traffic and emergency passing lane.
2. Minimum width of pavement for 2-lane, 1-way traffic or for 2-lane, 2-way traffic.

Pavement widths in columns 1E and 2 in the tables have been determined on the assumption that the RS shown in the tables is the steering radius of the inside lane, that is the lane nearest to the center of the turn.

Where pavement is planned for emergency passing (col. 1E) or for full 2-lane movements (col. 2) the widths are designed for use by vehicles of the same type as those for which the single lane pavement (col. 1) is designed.

If smaller vehicles only will use the emergency lane, or the second lane, the widths can be reduced to those required by the width of the wheel path of the smaller vehicle.

Width of pavement shown in columns 1, 1E and 2 is for pavement adjacent to shoulders. Where pavement is adjacent to curbs or islands at least 1 foot, preferably 2 feet, extra clearance must be provided from each curb or island.

THE MINIMUM WIDTH for all single lane pavements between shoulders is 14 feet, between curbs or islands 16 feet.

Single lane pavements (col. 1) should not be used except for short turning lanes, particularly in channelized intersections. On all other single lane turns width should be provided for emergency passing (col. 1E) reduced, if desirable, to the width required for smaller vehicles.

Dimensions of vehicles shown are overall dimensions, including bumpers. Dimensions vary considerably, dimensions shown are those of controlling types.

Pavement widths shown for the 30-foot Design Truck are sufficient for occasional use by busses and, when the steering radius RS is 66.5 feet or more, for occasional use by 45-foot semitrailers and the 60-foot truck-and-trailer.

Turns used by 50-foot semitrailers must be designed from the data for the semitrailer S-50-18, with a minimum steering radius, RS, of 42 feet, or a desirable minimum RS of 66.5 feet.

Special attention to the types of vehicles which will use the pavement is required on single lane pavements, on 2-lane pavements with traffic in 2 directions, and on all pavements bordered by curbs or islands.

DESIGN SPEEDS FOR TURNING LANES

Steering Rad. RS feet	① Super elev. ft. ft.	Passenger Cars, Busses and Single Trucks M.p.H. ②	Compound Trucks and Logging Trucks M.p.H. ③
25	0.02	15	
30	"	16	
40	"	18	
42	"	19	5
50	"	20	10
60	"	22	13
66.5	0.02	23	15
80	0.03	25	18
100	0.04	27	20
120	0.05	29	22
150	0.06	32	24
200	0.08	36	27
250	0.10	40	30
300	"	43	32
350	"	45	34
400	"	47	35
450	"	49	37
500	"	51	38

① Where dangerous snow and ice conditions prevail in winter the maximum superelevation should be 0.08 ft : ft.
On turns designed principally for use by logging trucks the superelevation should be held at 0.05 ft. : ft. when RS is 120 ft. or more.

② On curves of RS 60 ft. and over speeds will be reduced from 0% for RS. 60 ft., to 10% for RS 500 ft. If no superelevation is used.

③ Speeds for compound trucks and logging trucks are arbitrary and represent the probable speeds used by the trucks.

FORMULAS
FOR DETERMINING THE MINIMUM WIDTH OF PAVEMENT ON TURNS

VEHICLE	1 Single Lane		1E 1-Lane & Emergency Passing	2 2-Lane	
	RS 250 ft. or less	RS over 250 ft.		RS 250 ft. or less	RS over 250 ft.
	W	W	W	W	W
Passenger Car	P+5+K	P+5+K	2P+FO+3	2P+10+K	2P+10+K
Single Truck	P+3+K	P+4+K	2P+FO+3	2P+6+K	2P+8+K
Bus	P+3+K	P+4+K	2P+FO+3	2P+FO+6+K	2P+FO+8+K
Compound Truck or Logging Truck	P+3+K	P+4+K	P+P'+FO+3	P+P'+6+K	2P+8+K

RS Steering Radius for single lane or inside lane

W Width of pavement

P Width of wheelpath in single lane or inside lane

P' Width of wheelpath in outside lane. P' is always less than P but when RS is over 100 ft. the difference becomes so small that P' may be taken as equal to P

FO Front overhang

K is a variable which increases the width of pavement to allow for the greater difficulty of maneuring a vehicle on a curve.

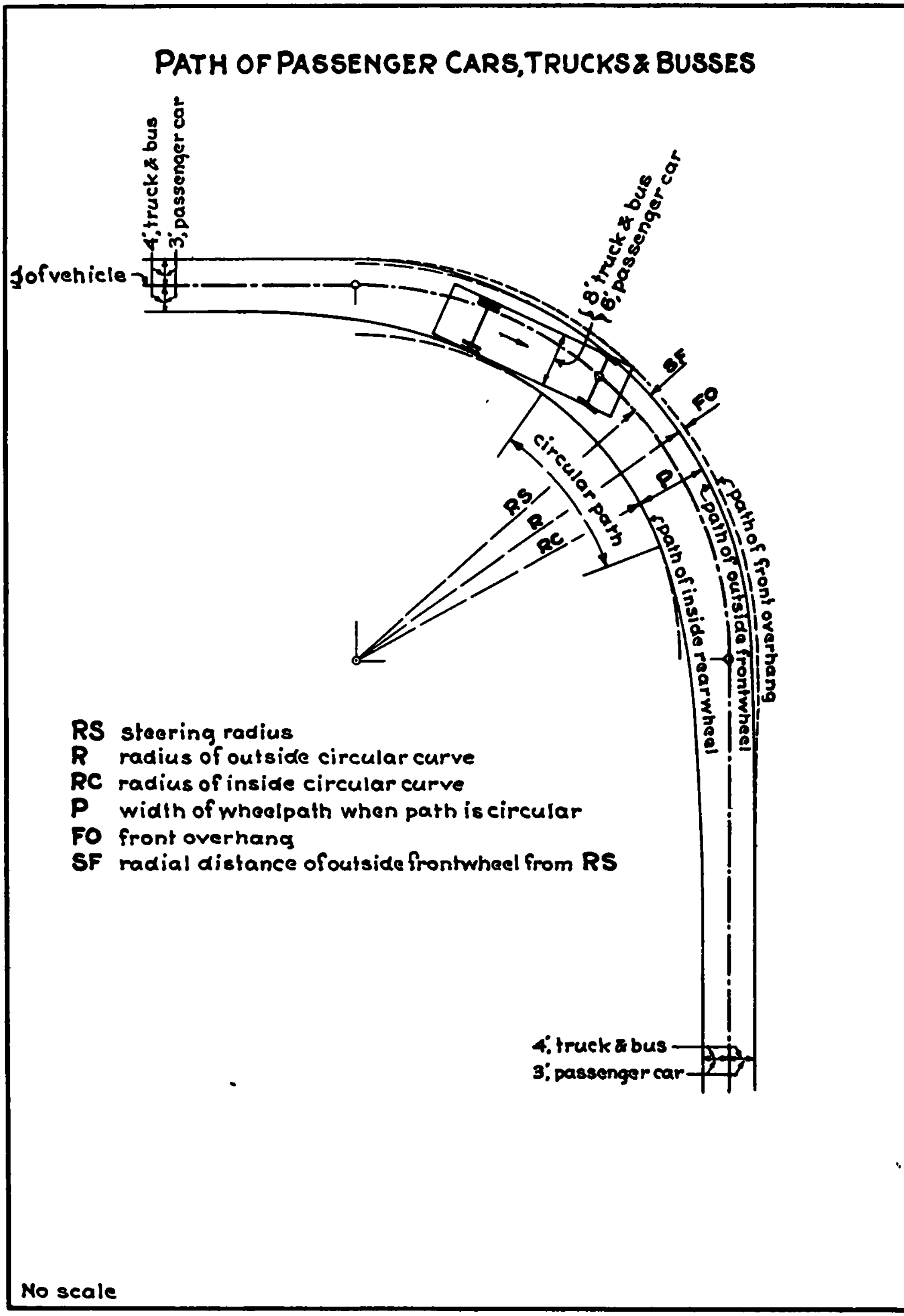
$K = \frac{V}{2\sqrt{RS}}$ where RS is the Steering Radius and V is the speed of a passenger car in M.p.H corresponding to RS. The corresponding speed of a compound truck is less but the difficulty of maneuvering is greater, therefore the speed of the passenger car is used in the formula. K is always small (RS 42'-250', K = 1.3; RS 300'-450', K = 1.2; RS 500', K = 1.1)

NOTE: The speed of single trucks and busses is about 40 M.p.H. when RS is 250 ft., the speed of compound trucks is about 30 M.p.H. for that radius. The formulas for these vehicles provide an increase of 1 foot in the lane width when RS is more than 250 ft., except for emergency passing.

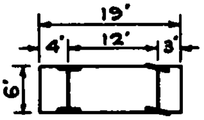
The widths determined from the formulas in this table are for pavement adjacent to shoulders.

Where pavement is adjacent to curbs or islands at least 1 foot, preferably 2 feet, extra clearance must be provided from each curb or island.

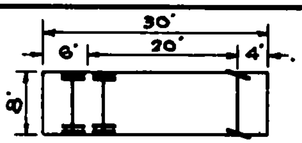
Dimensions in feet


PATH OF PASSENGER CARS, TRUCKS & BUSSES
4', truck & bus
3', passenger car
℄ of vehicle
8', truck & bus
6', passenger car
SF
FO
P
circular path
RS
R
RC
℄ path of front overhang
℄ path of outside frontwheel
℄ path of inside rearwheel
4', truck & bus
3', passenger car
RS steering radius
R radius of outside circular curve
RC radius of inside circular curve
P width of wheelpath when path is circular
FO front overhang
SF radial distance of outside frontwheel from RS
No scale

PASSENGER CAR, 30 FT. TRUCK



(Design car A.A.S.H.O)

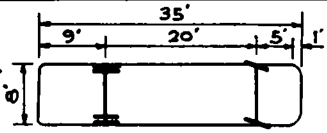


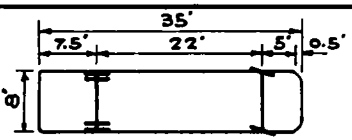
(Design truck A.A.S.H.O.)

	PASSENGER CAR Min.R 28ft.								TRUCK Min.R.45ft.							
	Path					Pavement			Path					Pavement		
RS	RC	R	P	FO	SF	1	1E	2	RC	R	P	FO	SF	1	1E	2
25.3	19.3	28.0	8.7	1.4	2.7	15	21	28								
30	24.5	32.8	8.3	1.2	2.8	15	20	28								
40	35.2	42.9	7.7	0.9	2.9	14	19	27								
42									32.9	45.6	12.7	1.9	3.6	17	30	32
50	45.5	52.9	7.4	0.7	2.9	14	19	26	41.8	53.7	11.9	1.6	3.7	17	28	32
60	55.8	63.0	7.2	0.6	3.0	14	18	26	52.6	63.8	11.2	1.4	3.8	16	27	30
80	76.1	83.0	6.9	0.5	"	13	18	25	73.5	83.9	10.4	1.1	3.9	15	25	28
100	96.3	103.0	6.7	0.4	"	13	17	25	94.0	103.9	9.9	0.9	3.9	15	24	28
120	116.4	123.0	6.6	0.3	"	13	17	25	114.3	123.9	9.6	0.7	3.9	14	23	27
150	146.5	153.0	6.5	0.2	"	13	16	24	144.7	154.0	9.3	0.6	4.0	"	22	26
200	196.6	203.0	6.4	0.2	"	13	16	"	195.0	204.0	9.0	0.4	"	"	22	"
250	246.7	253.0	6.3	0.2	"	13	16	"	245.2	254.0	8.8	0.3	"	"	21	"
300	296.8	303.0	6.2	0.2	"	13	16	"	295.3	304.0	8.7	0.3	"	"	21	"
350	346.8	353.0	6.2	0.1	"	12	16	"	345.4	354.0	8.6	0.2	"	"	21	"
400	396.8	403.0	6.2	0.1	"	"	16	"	395.5	404.0	8.5	0.2	"	"	20	"
500	496.9	503.0	6.1	0.1	"	"	15	"	495.6	504.0	8.4	0.2	"	"	20	"

Dimensions in feet

Busses

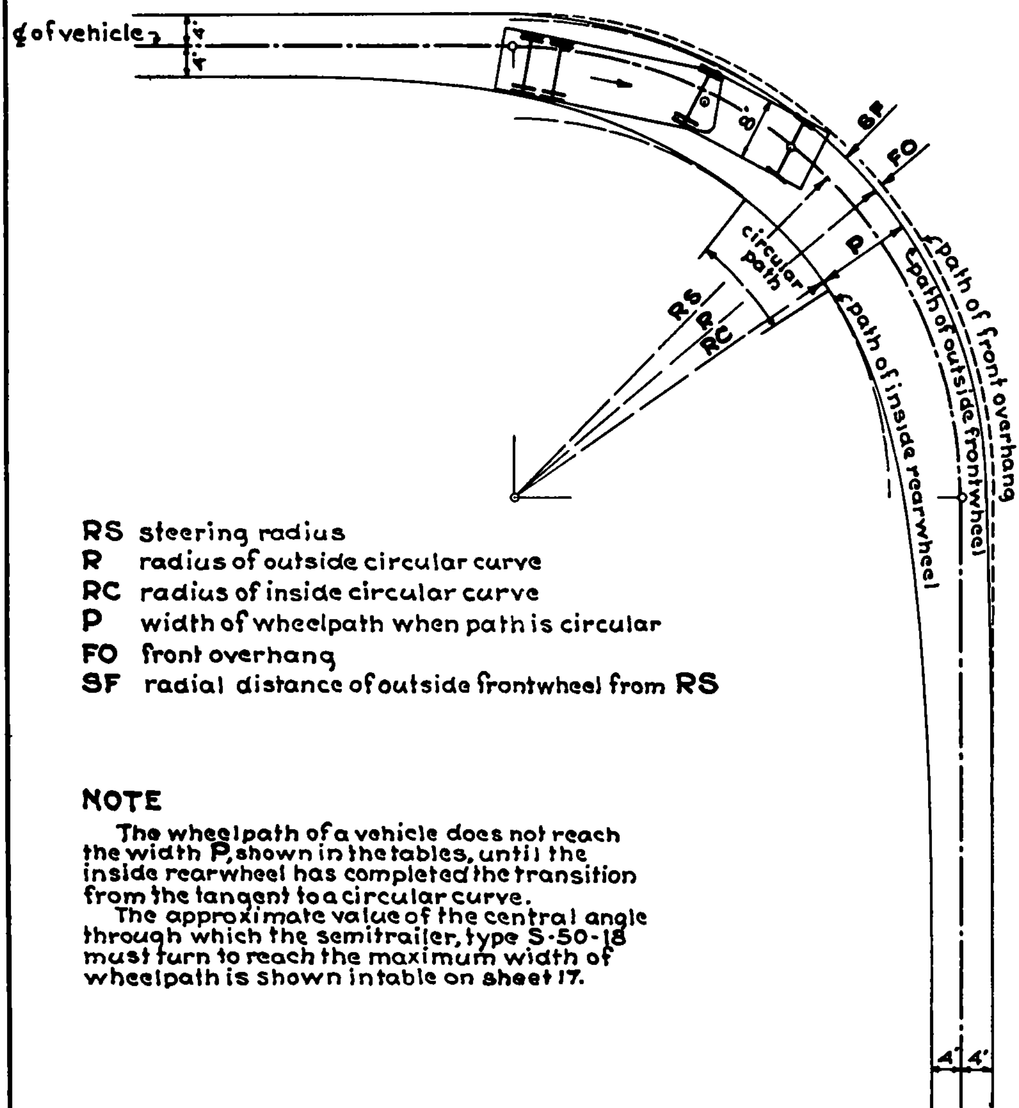




	B-35-20 Min.R. 39ft ±								B-35-22 Min R.43 ft.							
	Path					Pavement			Path					Pavement		
RS	RC	R	P	FO	SF	1	1E	2	RC	R	P	FO	SF	1	1E	2
36	25.9	39.4	13.5	2.7	3.4	18	32	36								
40									29.4	43.4	14.0	2.7	3.4	19	32	37
42	32.9	45.6	12.7	2.4	3.6	17	30	34	31.8	45.5	13.7	2.6	3.5	18	32	36
50	41.8	53.7	11.9	2.0	3.7	17	28	33	40.9	53.6	12.7	2.3	3.6	17	30	34
60	52.6	63.8	11.2	1.8	3.8	16	27	32	51.8	63.7	11.9	1.9	3.7	16	28	33
80	73.5	83.9	10.4	1.4	3.9	15	25	30	72.9	83.9	11.0	1.5	3.9	15	26	31
100	94.0	103.9	9.9	1.1	3.9	15	24	28	93.6	103.9	10.3	1.1	3.9	14	25	29
120	114.3	123.9	9.6	0.9	3.9	14	23	28	114.0	123.9	9.9	1.0	3.9	"	24	28
150	144.7	154.0	9.3	0.7	4.0	"	22	27	144.4	154.0	9.6	0.8	4.0	"	22	28
200	195.0	204.0	9.0	0.5	"	"	22	27	194.8	204.0	9.2	0.6	"	"	22	28
250	245.2	254.0	8.8	0.4	"	"	21	27	245.0	254.0	9.0	0.5	"	"	22	28
300	295.3	304.0	8.7	0.3	"	"	21	27	295.2	304.0	8.8	0.4	"	"	22	28
350	345.4	354.0	8.6	0.3	"	"	21	27	345.3	354.0	8.7	0.3	"	"	21	27
400	395.5	404.0	8.5	0.3	"	"	21	27	395.4	404.0	8.6	0.3	"	"	"	"
450	445.6	454.0	8.4	0.3	"	"	20	27	445.5	454.0	8.5	0.3	"	"	"	"
500	495.6	504.0	8.4	0.2	"	"	20	26	495.5	504.0	8.5	0.2	"	"	"	"

Dimensions in feet

PATH OF SEMITRAILER
(Steering Curve circular)



RS steering radius
R radius of outside circular curve
RC radius of inside circular curve
P width of wheelpath when path is circular
FO front overhang
SF radial distance of outside frontwheel from RS

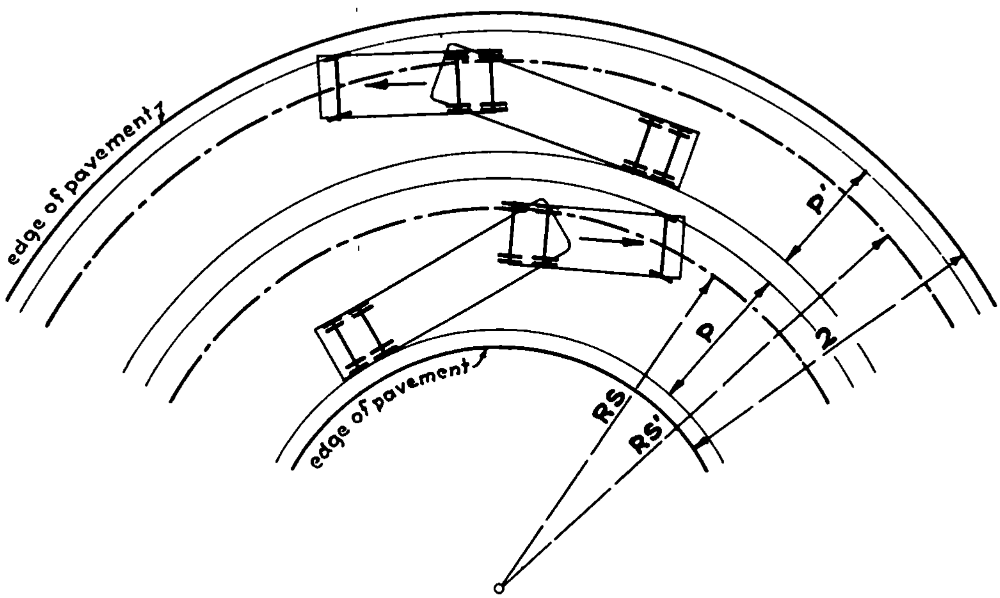
NOTE

The wheelpath of a vehicle does not reach the width P, shown in the tables, until the inside rearwheel has completed the transition from the tangent to a circular curve.

The approximate value of the central angle through which the semitrailer, type S-50-18 must turn to reach the maximum width of wheelpath is shown in table on sheet 17.

No scale

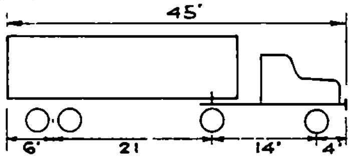
SKETCH SHOWING REDUCTION IN THE WIDTH OF THE WHEELPATH OF A SEMITRAILER IN THE OUTSIDE LANE OF A 2-LANE TURN



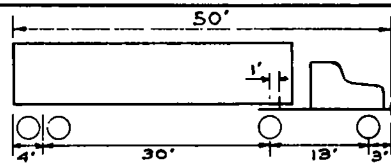
RS Steering Radius for inside lane
RS' Steering Radius for outside lane
P Width of wheelpath in inside lane
P' Width of wheelpath in outside lane
2 Width of 2-lane pavement
NOTE: P' is less than P

No scale

SEMITRAILERS



(Design Semitrailer A.A S.H O)

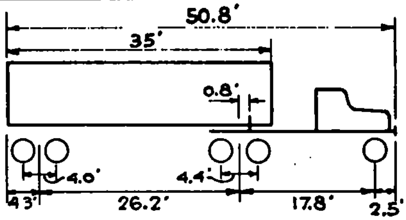


	S-45-14 Min. R. of tractor 31 5 ft ±								S-50-13 Min. R of tractor 29 5 ft. ±							
	Path					Pavement			Path					Pavement		
RS	RC	R	P	FO	SF	1	1E	2	RC	R	P	FO	SF	1	1E	2
28	8.1	31.5	23.4	2.0	3.5	28										
30	12.2	33.6	21.4	1.8	3.6	26										
42	29.6	45.8	16.2	1.4	3.8	21	35	38	21.2	45.8	24.6	1.0	3.8	29		
50	39 2	53.9	14 7	1.2	3.9	19	32	36	33.0	53.9	20.9	0.8	3.9	26	42	46
60	50.4	63.9	13.5	1.0	3.9	18	30	34	45.7	63.9	18.2	0.7	3.9	23	38	42
66.5	57.5	70.4	12.9	0.9	3.9	18	29	33	53.4	70.4	17.0	0.7	3 9	22	36	40
80	71.9	83.9	12 0	0.8	4.0	17	28	31	68.6	83.9	15.3	0.5	4 0	20	33	37
100	92.8	104.0	11.2	0.6	"	16	26	30	90.2	104.0	13.8	0.4	"	18	31	35
120	113.3	124 0	10.7	0.5	"	15	25	29	111.2	124.0	12.8	0.3	"	17	29	33
150	143.9	154 0	10.1	0.4	"	15	24	28	142.2	154.0	11.8	0.3	"	16	27	31
200	194 4	204 0	9.6	0.3	"	14	23	28	193 2	204.0	10.8	0.3	"	15	25	29
250	244.7	254.0	9.3	0.2	"	.	22	27	243.7	254.0	10.3	0.1	"	"	24	29
300	294.9	304 0	9.1	"	"	"	22	"	294.1	304.0	9.9	"	"	"	23	29
350	345 1	354.0	8.9	"	"	"	22	"	344.4	354 0	9.6	"	"	"	23	29
400	395.2	404 0	8.8	"	"	"	21	"	394 6	404 0	9.4	"	"	"	22	28
450	445 3	454 0	8.7	"	"	"	"	"	444.7	454 0	9.3	"	"	"	"	"
500	495.4	504.0	8.6	"	"	"	"	"	494.9	504.0	9.1	"	"	"	"	"

NOTE:
Pavement designed for semitrailer S-50-18 will accommodate S-50-13, although lane widths on the sharper turns will be narrow for S-50-13.

Dimensions in feet

SEMITRAILERS



S-50-18
Min.R Rt.turn 34ft., Lt.turn 44ft.

	Path					Pavement		
RS	RC	R	P	FO	SF	1	1E	2
42	22.8	45.6	22.8	1.0	3.6	28		
50	34.1	53.7	19.6	0.9	3.7	24	40	44
60	46.5	63.8	17.3	0.8	3.8	22	37	40
*66.5	54.1	70.4	16.3	0.7	3.9	21	35	39
80	69.2	83.9	14.7	0.6	3.9	20	32	36
100	90.6	103.9	13.3	0.5	3.9	18	30	34
120	111.6	124.0	12.4	0.4	4.0	17	29	32
150	142.5	154.0	11.5	0.2	"	16	26	31
200	193.4	204.0	10.6	0.2	"	15	25	29
250	243.9	254.0	10.1	0.2	"	15	24	29
300	294.3	304.0	9.7	0.2	"	15	23	29
350	344.5	354.0	9.5	0.1	"	15	22	28
400	394.7	404.0	9.3	"	"	15	22	28
450	444.8	454.0	9.2	"	"	15	22	28
500	495.0	504.0	9.0	"	"	14	21	27

* RS 66.5 ft. corresponds to a curb radius of 50 ft. on the inside of the turn after the wheelpath has reached its maximum width.

Dimensions in feet

SEMITRAILER S-50-18

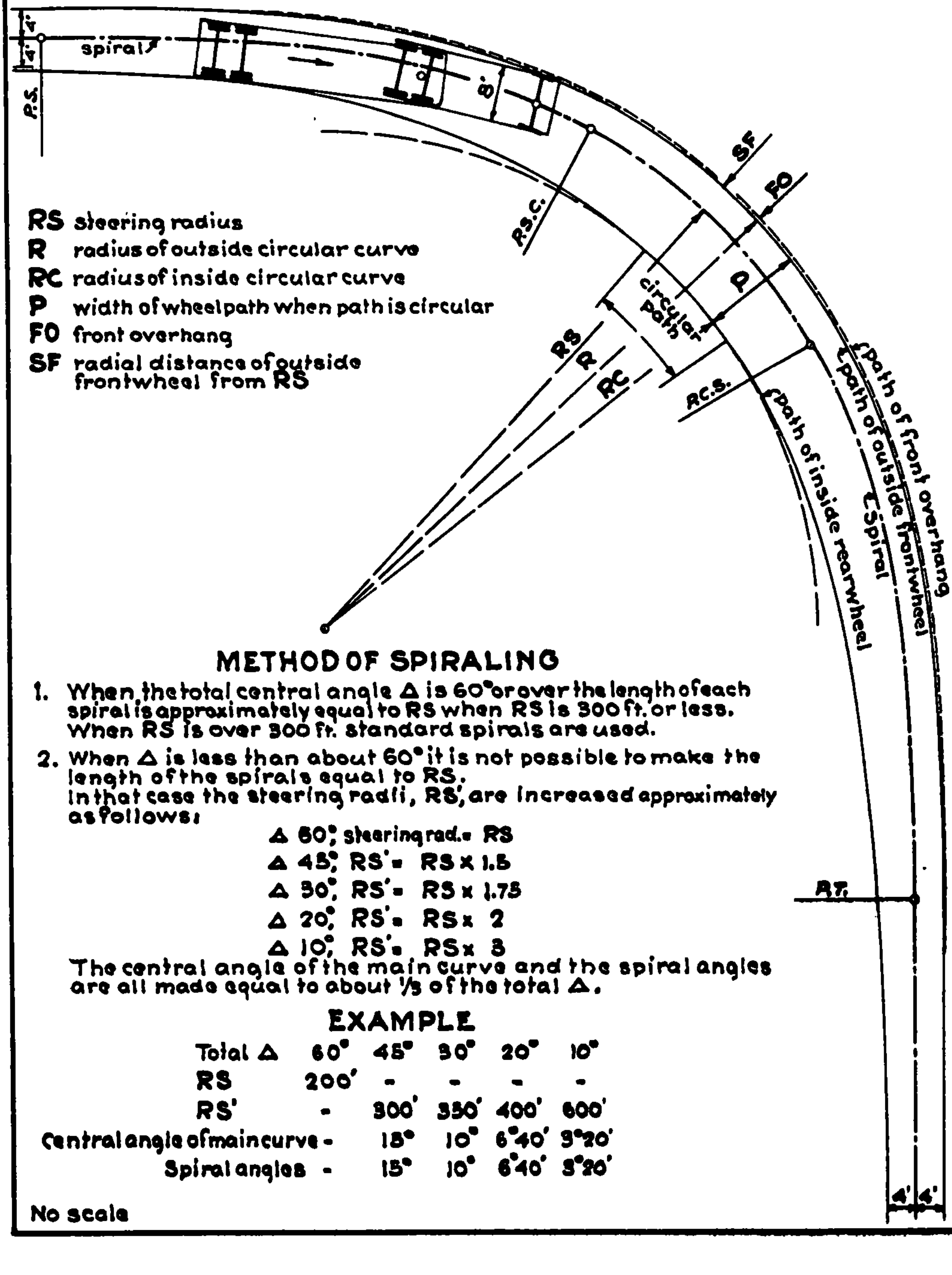
Greatest width of wheelpath reached on Circular Curves on turns through Central Angles of 10° to 270°

RS	Δ, total central angle														
	10°	20°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°	225°	270°
42	10	11.5	13.5	15	17	18	19	19.5	20.5	21	21.5	21.5	22	22.5	**22.8**
50	10	11.5	13	15	16	17	17.5	18	18.5	19	19	19.5	**19.6**		
60	10	11.5	12.5	14	15.5	16	16.5	17	17	**17.3**					
66.5	10	11.5	12.5	14	15	15.5	16	16	**16.3**						
80	10	11.5	12.5	13.5	14	14.5	**14.7**								
100	10	11	12	13	13	**13.3**									
120	10	11	12	**12.4**											
150	10	10.5	11	**11.5**											
200	9.5	10.5	**10.6**												
250	9.5	**10.1**													
300	9	**9.7**													
350	**9.5**														
400	**9.3**														
450	**9.2**														
500	**9.0**														

NOTE:
Widths of wheelpaths are scaled to the nearest 0.5 ft. from wheeltracks made by a model, except the maximum width for each RS which is calculated, and shown in heavy type. After reaching the maximum width this remains constant for all larger central angles.

Dimensions in feet.

PATH OF SEMITRAILER
(Steering Curve spiraled)



RS steering radius
R radius of outside circular curve
RC radius of inside circular curve
P width of wheelpath when path is circular
FO front overhang
SF radial distance of outside frontwheel from RS

METHOD OF SPIRALING

1. When the total central angle Δ is 60° or over the length of each spiral is approximately equal to RS when RS is 300 ft. or less. When RS is over 300 ft. standard spirals are used.
2. When Δ is less than about 60° it is not possible to make the length of the spirals equal to RS. In that case the steering radii, RS', are increased approximately as follows:

Δ 60°, steering rad. = RS
Δ 45°, RS' = RS × 1.5
Δ 30°, RS' = RS × 1.75
Δ 20°, RS' = RS × 2
Δ 10°, RS' = RS × 3

The central angle of the main curve and the spiral angles are all made equal to about ⅓ of the total Δ.

EXAMPLE

Total Δ	60°	45°	30°	20°	10°
RS	200'	-	-	-	-
RS'	-	300'	350'	400'	600'
Central angle of main curve -		15°	10°	6°40'	3°20'
Spiral angles -		15°	10°	6°40'	3°20'

No scale

SEMITRAILER S-50-18

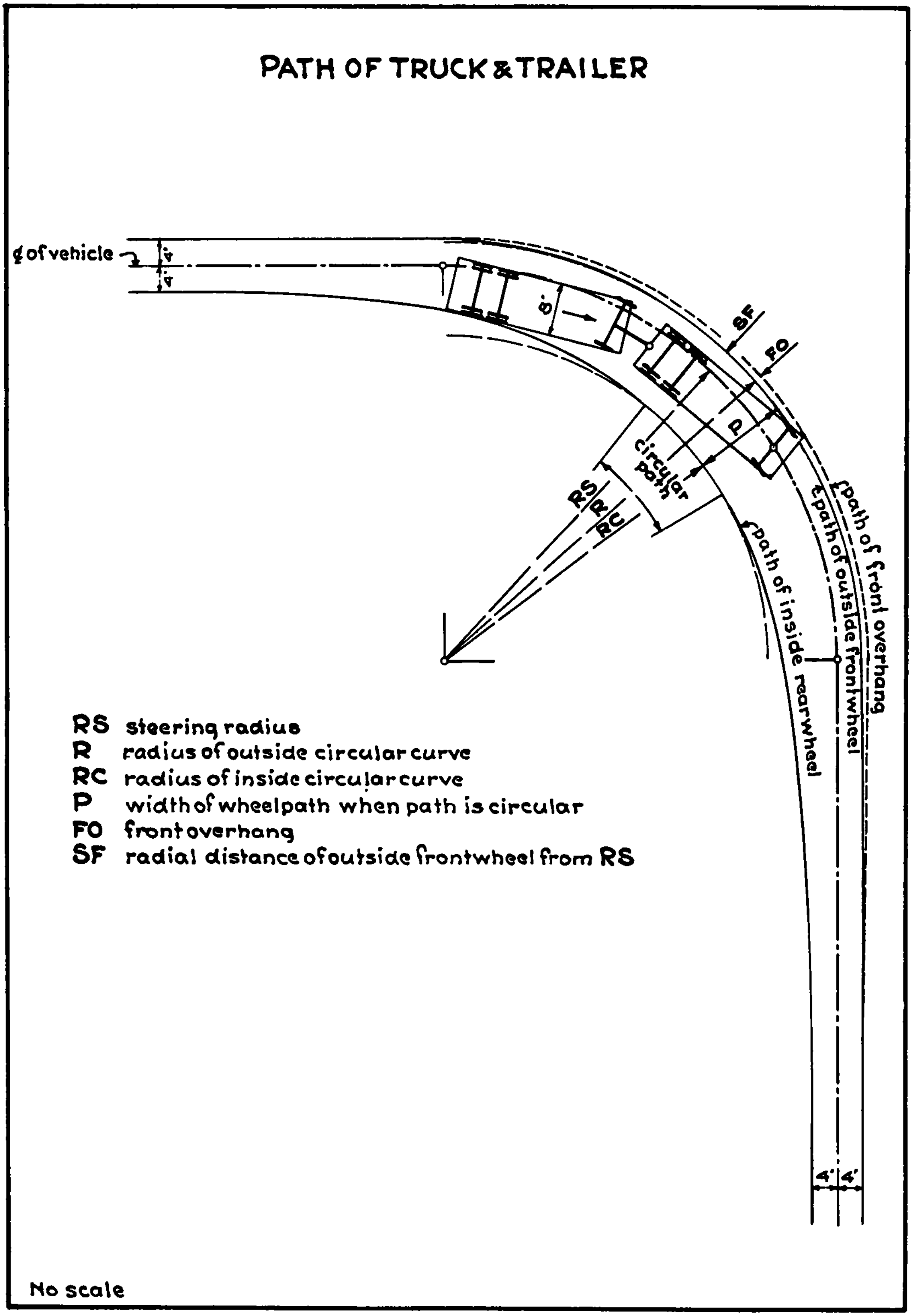
Greatest width of wheelpath reached on Spiraled Curves
On turns through Central Angles of 10° to 270°

Δ, total central angle				RS * for Δ 60° & over	Δ, total central angle										
10°	20°	30°	45°		60°	75°	90°	105°	120°	135°	150°	165°	180°	225°	270°
9.5	11	12.5	14	42	15.5	17	18	19	20	20.5	21	21.5	22	22.5	**22.8**
9.5	10.5	12	13.5	50	14.5	16	17	18	18	19	19	19	19.5	**19.6**	
9	10.5	11.5	13	60	14	15	16	16.5	16.5	17	17	17	17	**17.3**	
9	10	11	12.5	66.5	14	14.5	15	15.5	16	16	16	16	**16.3**		
9	10	11	12	80	13	13.5	14	14.5	**14.7**						
9	10	10.5	11.5	100	12.5	13	13	**13.3**							
9	10	10.5	11	120	12	12	**12.4**								
9	9.5	10	10.5	150	11	**11.5**									
9	9	9.5	10	200	10.5	**10.6**									
8.5	9	9.5	9.5	250	**10.1**										
"	9	9	9.5	300	**9.7**										
"	8.5	9	9	350	**9.5**										
"	"	9	9	400	**9.3**										
"	"	8.5	9	450	**9.2**										
"	"	8.5	9	500	**9.0**										

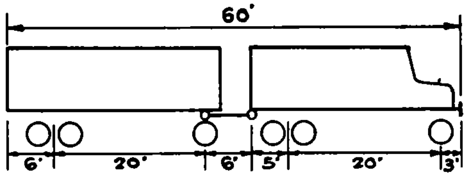
* For Δ less than 60° RS varies, see sheet 18.

NOTE:
Widths of wheelpaths are scaled to the nearest 0.5 ft. from wheeltracks made by a model, except the maximum width for each RS which is calculated, and shown in heavy type. After reaching the maximum width this remains constant for all larger central angles.

Dimensions in feet


PATH OF TRUCK & TRAILER
℄ of vehicle
4'
4'
8'
SF
FO
P
circular path
RS
R
RC
℄ path of front overhang
℄ path of outside frontwheel
℄ path of inside rearwheel
4'
4'
RS steering radius
R radius of outside circular curve
RC radius of inside circular curve
P width of wheelpath when path is circular
FO front overhang
SF radial distance of outside frontwheel from RS
No scale

TRUCK & TRAILER



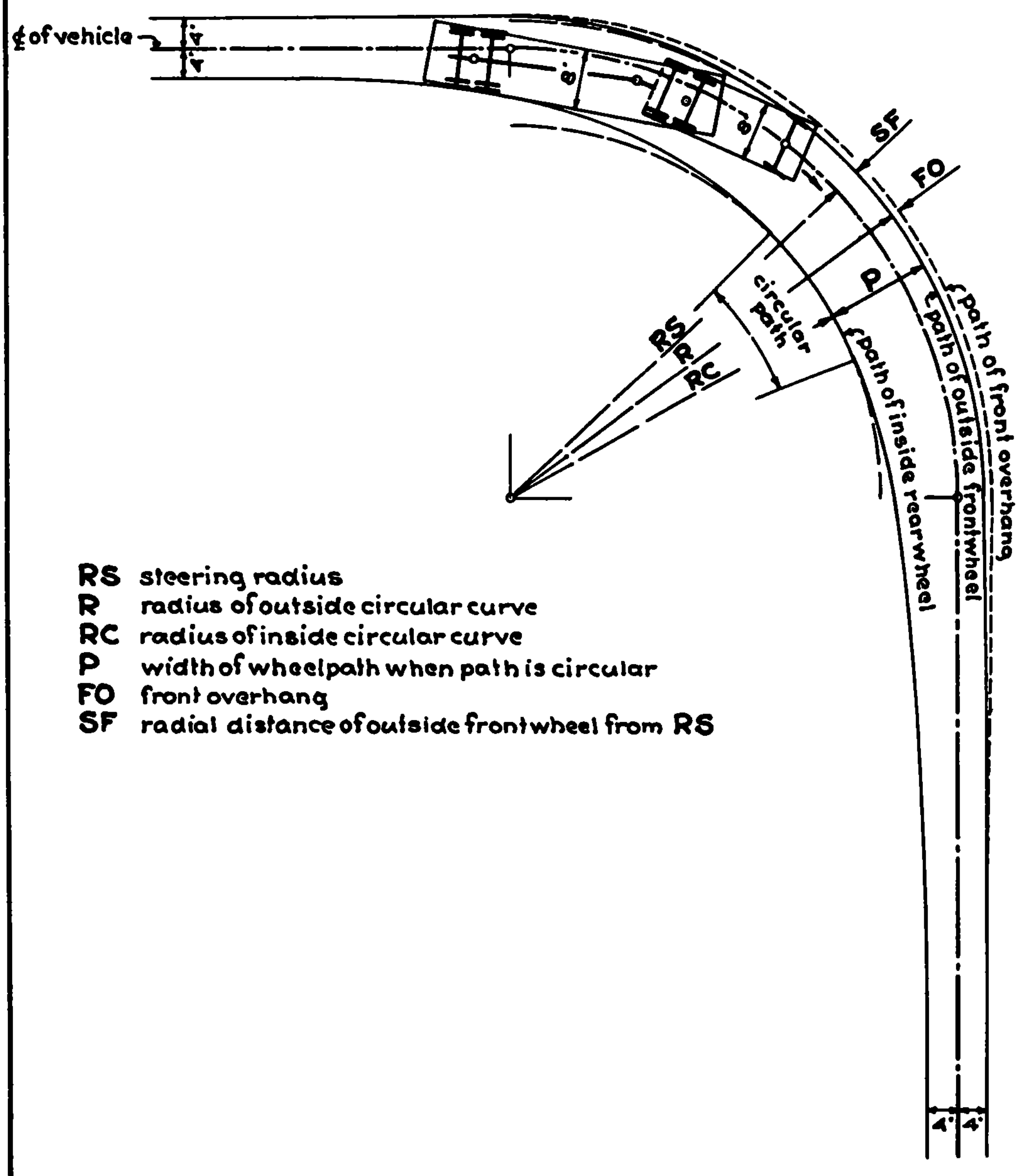
60-ft. TRUCK & TRAILER
Min. R 45 ft.

	Path					Pavement		
RS	RC	R	P	FO	SF	1	1E	2
42	26.9	45.6	18.7	1.4	3.6	23	39	42
50	37.1	53.7	16.6	1.2	3.7	21	36	39
60	48.8	63.8	15.0	1.0	3.8	20	33	36
66.5	56.1	70.3	14.2	1.0	3.8	19	32	35
80	70.8	83.9	13.1	0.8	3.9	18	30	33
100	91.9	103.9	12.0	0.6	3.9	17	28	31
120	112.6	123.9	11.3	0.5	3.9	16	26	30
150	143.3	154.0	10.7	0.4	4.0	15	25	29
200	194.0	204.0	10.0	0.3	"	15	24	28
250	244.4	254.0	9.6	0.3	"	15	23	28
300	294.6	304.0	9.4	0.7	"	15	22	28
350	344.8	354.0	9.2	0.2	"	15	22	28
400	395.0	404.0	9.0	0.2	"	14	21	27
450	445.1	454.0	8.9	0.1	"	14	21	27
500	495.2	504.0	8.8	0.1	"	14	21	27

NOTE:
Pavement designed for semitrailer S-50-18 is adequate for the 60-ft truck & trailer

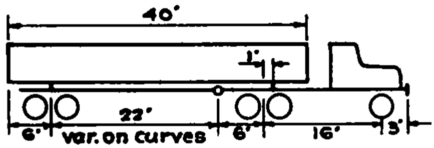
Dimensions in feet

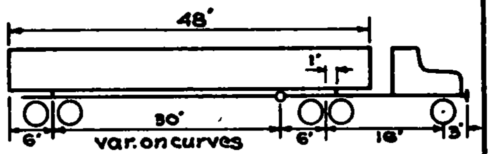
PATH OF LOGGING TRUCK & TRAILER LOADED FOR 6 FT. OVERHANG



No scale

LOGGING TRUCK & TRAILER
LOADED FOR 6 FT. OVERHANG





RS	40 ft. LOGS								48 ft. LOGS							
	Path					Pavement			Path					Pavement		
	RC	R	P	FO	SF	1	1E	2	RC	R	P	FO	SF	1	1E	2
42	27.4	45.7	18.3	1.1	3.7	23	*	*	16.0	45.7	29.7	1.1	3.7	34	*	*
50	37.8	53.8	16.0	1.0	3.8	21			31.4	53.8	22.4	1.0	3.8	27		
60	49.5	63.9	14.4	0.8	3.9	19			45.0	63.9	18.9	0.8	3.9	24		
66.5	56.8	70.4	13.6	0.7	3.9	18			52.9	70.4	17.5	0.7	3.9	22		
80	71.4	83.9	12.5	0.6	3.9	17			68.4	83.9	15.5	0.6	3.9	20		
100	92.4	104.0	11.6	0.5	4.0	16			90.1	104.0	13.9	0.5	4.0	19		
120	113.0	124.0	11.0	0.4	"	16			111.2	124.0	12.8	0.4	"	17		
150	143.6	154.0	10.4	0.3	"	15			142.2	154.0	11.8	0.3	"	16		
200	194.2	204.0	9.8	0.3	"	15			193.2	204.0	10.8	0.3	"	15		
250	244.6	254.0	9.4	0.2	"	15			243.8	254.0	10.2	0.2	"	"		
300	294.8	304.0	9.2	0.2	"	15			294.1	304.0	9.9	0.2	"	"		
350	345.0	354.0	9.0	0.2	"	14			344.4	354.0	9.6	0.2	"	"		
400	395.1	404.0	8.9	0.1	"	"			394.6	404.0	9.4	0.1	"	"		
450	445.2	454.0	8.8	"	"	"			444.8	454.0	9.2	"	"	"		
500	495.3	504.0	8.7	"	"	"			494.9	504.0	9.1	"	"	"		

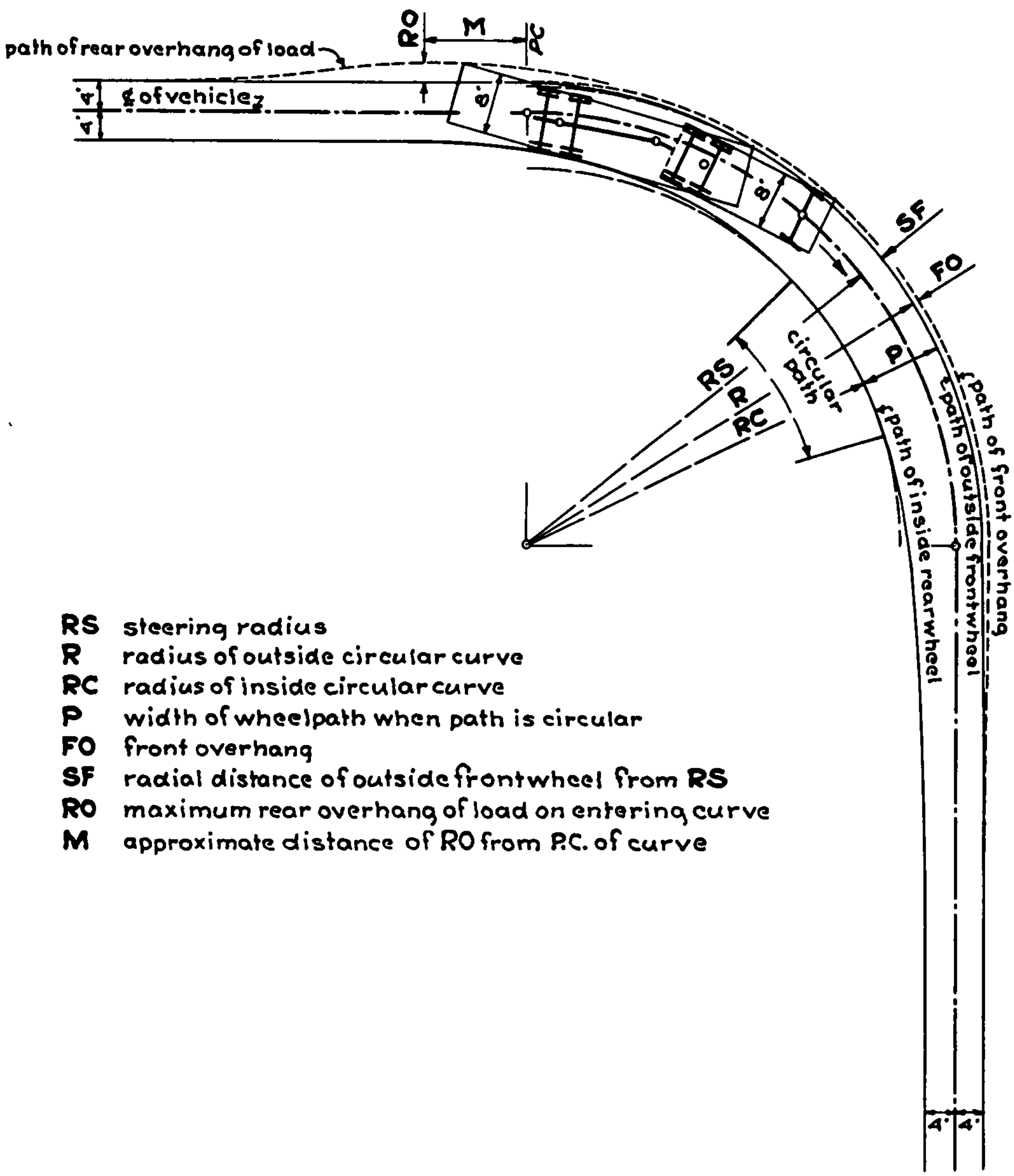
* Width of pavement to be determined from requirements of vehicles using second lane.

NOTE:

1. Pavement designed for semitrailer S-50-18 is adequate for logging trucks loaded with 40 ft. logs - 6 ft overhang.
   Pav't designed for S-50-18 is adequate for logging trucks loaded with 48' logs - 6 ft. overhang when RS is 80 ft. or over. When RS is less than 80 ft. the logging truck requires a greater lane width than S-50-18.

Dimensions in feet

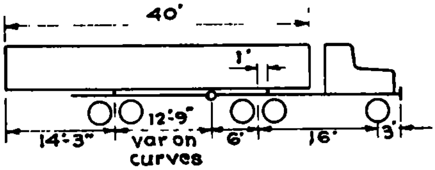
PATH OF LOGGING TRUCK & TRAILER LOADED FOR 1/3 OVERHANG

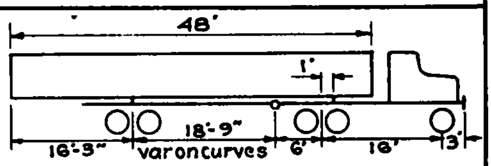


RS steering radius
R radius of outside circular curve
RC radius of inside circular curve
P width of wheelpath when path is circular
FO front overhang
SF radial distance of outside front wheel from **RS**
RO maximum rear overhang of load on entering curve
M approximate distance of RO from P.C. of curve

No scale

LOGGING TRUCK & TRAILER
LOADED FOR 1/3 OVERHANG





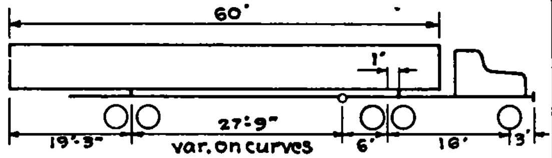
RS	40 ft. LOGS								48 ft. LOGS							
	Path							Pav't	Path							Pav't
	RC	R	P	FO	SF	RO	M	1	RC	R	P	FO	SF	RO	M	1
						approx	approx.	*						approx	approx.	*
42	33.0	45.7	12.7	1.1	3.7	3.0	10	17	29.8	45.7	15.9	1.1	3.7	3.3	15	21
50	41.9	53.8	11.9	1.0	3.8	2.5		17	39.6	53.8	14.2	1.0	3.8	2.8		19
60	52.7	63.9	11.2	0.8	3.9	2.0		16	50.9	63.9	13.0	0.8	3.9	2.3		18
66.5	59.5	70.4	10.9	0.7	3.9	1.8		16	57.9	70.4	12.5	0.7	3.9	2.0		17
80	73.5	83.9	10.4	0.6	3.9	1.4		15	72.3	83.9	11.6	0.6	3.9	1.7		16
100	94.1	104.0	9.9	0.5	4.0	1.0	15	15	93.1	104.0	10.9	0.5	4.0	1.3		16
120	114.4	124.0	9.6	0.4	"	0.8		14	113.6	124.0	10.4	0.4	"	1.0		15
150	144.7	154.0	9.3	0.3	"	0.7		"	144.1	154.0	9.9	0.3	"	0.9		15
200	195.0	204.0	9.0	0.3	"	0.6		"	194.6	204.0	9.4	0.3	"	0.8		14
250	245.2	254.0	8.8	0.2	"	0.6		"	244.9	254.0	9.1	0.2	"	0.7		"
300	295.4	304.0	8.6	0.2	"	0.5		"	295.0	304.0	9.0	0.2	"	0.6		"
350	345.4	354.0	8.6	0.2	"	0.4		"	345.2	354.0	8.8	0.2	"	0.6		"
400	395.5	404.0	8.5	0.1	"	0.3		"	395.3	404.0	8.7	0.1	"	0.5		"
450	445.6	454.0	8.4	"	"	0.3		"	445.4	454.0	8.6	"	"	0.4		"
500	495.6	504.0	8.4	"	"	0.2	15	"	495.4	504.0	8.6	"	"	0.3	15	"

* Width of pavement for 1-lane, 1-way, traffic shown. Width of pavement for emergency passing or 2-lane traffic to be determined from requirements of vehicles using second lane.

NOTE:
Pavement designed for semitrailer S-50-18 is adequate for logging trucks loaded with 40 ft logs - 1/3 overhang or 48 ft logs - 1/3 overhang.
At the beginning of sharp turns it may be necessary to provide clearance for rear overhang.

Dimensions in feet

LOGGING TRUCK & TRAILER
LOADED FOR 1/3 OVERHANG



60 ft. LOGS

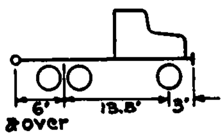
RS	Path							Pav't
	RC	R	P	FO	SF	RO	M	1
						approx.	approx.	*
42	20.5	45.7	25.2	1.1	3.7	3.7	20	30
50	33.6	53.8	20.2	1.0	3.8	3.2		25
60	46.5	63.9	17.4	0.8	3.9	2.6		22
66.5	54.2	70.4	16.2	0.7	3.9	2.3		21
80	69.3	83.9	14.6	0.6	3.9	1.9		19
100	90.8	104.0	13.2	0.5	4.0	1.5		18
120	111.8	124.0	12.2	0.4	"	1.3		17
150	142.7	154.0	11.3	0.3	"	1.1		16
200	193.5	204.0	10.5	0.3	"	1.0		15
250	244.0	254.0	10.0	0.2	"	0.9		15
300	294.4	304.0	9.6	0.2	"	0.8		15
350	344.6	354.0	9.4	0.2	"	0.7		15
400	394.8	404.0	9.2	0.1	"	0.7		15
450	444.9	454.0	9.1	"	"	0.6		15
500	495.0	504.0	9.0	-	"	0.5	20	14

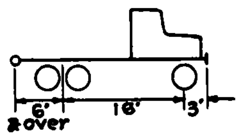
* Width of pavement for 1-lane, 1-way, traffic shown. Width of pavement for emergency passing or 2-lane traffic to be determined from requirements of vehicles using second lane.

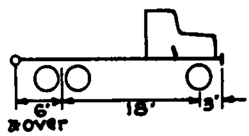
NOTE: Pavement designed for semitrailer S-50-18 is adequate for logging trucks loaded with 60 ft. logs-1/3 overhang when RS is 60 ft. or over. When RS is less than 60 ft. the logging truck requires a greater lane width than S-50-18. At the beginning of sharp turns it may be necessary to provide clearance for rear overhang.

Dimensions in feet.

LOGGING TRUCK TRACTORS



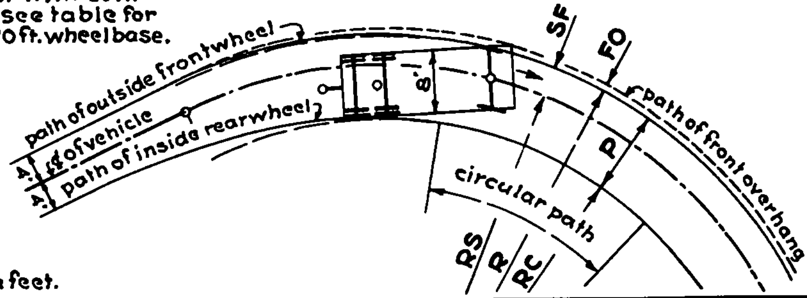




	WHEELBASE 13.5 ft. Min R. 30 ft. ±						WHEELBASE 16 ft. Min. R. 36 ft. ±						WHEELBASE 18 ft. Min. R. 40 ft. ±					
	Path					Pav't	Path					Pav't	Path					Pav't
RS	RC	R	P	FO	SF	1	RC	R	P	FO	SF	1	RC	R	P	FO	SF	1
						*						*						*
42	35.8	45.8	10.0	1.0	3.8	15	34.8	45.7	10.9	1.1	3.7	16	34.0	45.7	11.7	1.3	3.7	16
50	44.1	53.9	9.8	0.8	3.9	15	43.4	53.8	10.4	1.0	3.8	15	42.7	53.8	11.1	1.1	3.8	16
60	54.5	63.9	9.4	0.7	3.9	14	53.8	63.9	10.1	0.8	3.9	15	53.2	63.8	10.6	0.9	3.8	15
66.5	61.1	70.4	9.3	0.6	3.9	"	60.6	70.4	9.8	0.7	3.9	15	60.0	70.4	10.4	0.8	3.9	15
80	74.8	83.9	9.1	0.5	3.9	"	74.4	83.9	9.5	0.6	3.9	14	73.9	83.9	10.0	0.7	3.9	15
100	95.1	104.0	8.9	0.4	4.0	"	94.7	103.9	9.2	0.5	4.0	"	94.4	103.9	9.5	0.6	3.9	14
120	115.2	124.0	8.8	0.4	"	"	114.9	124.0	9.1	0.4	"	"	114.6	123.9	9.3	0.5	3.9	"
150	145.4	154.0	8.6	0.3	"	"	145.1	154.0	8.9	0.4	"	"	144.9	154.0	9.1	0.4	4.0	"
200	195.5	204.0	8.5	0.2	"	"	195.4	204.0	8.6	0.3	"	"	195.2	204.0	8.8	0.3	"	"
250	245.6	254.0	8.4	0.2	"	"	245.5	254.0	8.5	0.2	"	"	245.4	254.0	8.6	0.2	"	"
300	295.7	304.0	8.3	0.2	"	"	295.6	304.0	8.4	0.2	"	"	295.5	304.0	8.5	0.2	"	"
350	345.7	354.0	8.3	0.1	"	"	345.6	354.0	8.4	0.2	"	"	345.5	354.0	8.5	0.2	"	"
400	395.8	404.0	8.2	"	"	"	395.7	404.0	8.3	0.1	"	"	395.6	404.0	8.4	0.2	"	"
450	445.8	454.0	"	"	"	"	445.7	454.0	8.3	"	"	"	445.6	454.0	8.4	0.1	"	"
500	495.8	504.0	"	"	"	"	495.8	504.0	8.2	"	"	"	495.7	504.0	8.3	0.1	"	"

* Width of pavement for 1-lane, 1-way, traffic shown. Width of pavement for emergency passing or 2-lane traffic to be determined from requirements of vehicles using second lane.

NOTE: Tractor with 20 ft. wheelbase, see table for 30 ft. truck 20 ft. wheelbase.



Dimensions in feet.

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