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STRIPE TO RESTRICT PASSING ON A 3-LANE ROAD IN MARYLAND

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D. M. BEACH, *Editor*

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The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to described conditions.

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MARKING AND SIGNING NO-PASSING ZONES ON TWO- AND THREE-LANE ROADS

BY THE DIVISION OF DESIGN, PUBLIC ROADS ADMINISTRATION

Reported by JOSEPH BARNETT, Senior Highway Design Engineer

THE delineation of traffic lanes on highways by pavement inserts or painted stripes has long been recognized as an important contribution to safety and driving comfort. The increase in speed of motor-vehicle travel during the past decade has emphasized the importance of the use of centerline or lane-line pavement marking with the result that nearly all States have adopted some system of marking their important highways.

These systems naturally reflected local road conditions, driver habits, and the different opinions of highway officials, so that marking and signing now encountered on the highways frequently differ radically from one State to another and sometimes from section to section in the same State. This confusion is particularly critical in the methods of pavement striping and signing used to indicate zones of short sight distance, unsafe for passing maneuvers.

The obvious solution to the problem created by zones of short-sight distance is their entire elimination, but immediate elimination is not economically feasible in many instances. Most States, therefore, have resorted to some system of pavement striping or signing, or both, to warn traffic against encroachment upon the lane of opposing traffic within the limits of these zones. The marking of "No-Passing Zones" has proved effective in encouraging safe driving, despite the widely varied systems of marking used. Highway engineers are convinced that the Nation-wide adoption of rational standards for marking no-passing zones is highly desirable.

The common desire of the State highway departments, the Public Roads Administration, and other highway organizations to encourage the development of a uniform system for pavement marking led to action through the American Association of State Highway Officials. The problem was approached through action of three existing committees of the Association. The Special Committee on Administrative Design Policies undertook the work of preparing criteria to designate which portions of the highway should be marked as no-passing zones, where the markings should be located, and what the markings should represent. The Committee on Traffic Control and Safety and the Committee on Maintenance jointly undertook the work of determining the details of a normal centerline or lane-line stripe as to color, width, continuity, etc., the changes to be made to the normal stripe to indicate no-passing zones, and the signing of no-passing zones.

SURVEY MADE OF STATE PRACTICES IN MARKING PAVEMENTS

Early in 1939 the Special Committee on Administrative Design Policies requested the Public Roads Administration to make a survey of existing practice in marking and signing pavements on rural highways. In this survey data were obtained from each State regarding the color, width, continuity, mileage, etc., of the normal pavement stripe, or stripes, on rural highways, and the variations in these details, plus information regarding shoulder signs, to indicate no-passing zones on two- and three-lane pavements. Tables 1 to 4 summarize this information. In each table the numbers of States reporting the same systems, values, or items are listed. The large variation in different details and systems now in use by the several States is evident.

TABLE 1.—*Summary of State practices regarding definition of no-passing zones* [1]

Minimum sight distance	2-lane roads	3-lane roads
300 feet	2	2
400 feet	1	1
500 feet	13	3
600 feet	2	1
700 feet	3	1
800 feet	4	3
1,000 feet	4	2
475 to 1,260 feet	1	1
1,000 to 1,200 feet	1	------
1,200 to 2,400 feet	1	------
Minimum sight distance bases not used	5	2
Also use minimum radius control	6	3

[1] 11 States do not mark zones on 2-lane roads, 24 States have no rural 3-lane roads, and 8 States do not mark zones on 3-lane roads.

TABLE 2.—*Summary of State practices regarding color of normal pavement stripe* [1]

Stripe color	Concrete pavement	Bituminous pavement
Black	23	4
White	13	28
Yellow	9	14
Miscellaneous or none	3	2

[1] The same color stripe is used on both concrete and bituminous pavements in 26 States. Different color stripes are used in 22 States.

TABLE 3.—*Summary of State practices regarding type and width of normal pavement stripe*

Type	2-lane roads		3-lane roads [1]	
	Concrete pavement	Bituminous pavement	Concrete pavement	Bituminous pavement
Joint only, or no painted stripe	6	5	2	1
Broken stripe	10	16	4	7
Continuous stripe	29	26	18	16
Miscellaneous	3	1	------	------
Width of stripe:				
3 inches	2		------	
4 inches	26		15	
5 inches	2		------	
6 inches	8		6	
Other	10		3	

[1] 24 States indicated no rural 3-lane roads.

Twenty-two States use broken stripes varying from stripes 10 feet long spaced 10 feet apart to stripes 100 feet long spaced 100 feet apart.

The location of the stripe on widened curves on 2-lane roads also varies considerably among States: In 27 States the stripe is placed on the physical centerline of the road; in 10 States the stripe is placed inside the

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physical centerline of the road; in 4 States the stripe is placed outside the physical centerline of the road; 4 States have no standard; and the remaining 3 States place the stripe either on the physical centerline or outside the centerline.

State practices regarding the marking of no-passing zones on 2-lane roads are summarized in table 4.

TABLE 4.—*Summary of State practices regarding the marking of no-passing zones on 2-lane roads*

Method	States
Signs—normal stripe	5
Special stripe—no signs	11
Special stripe—with signs	21
Not marked—normal stripe	11

Type of special stripe	States
Single continuous line	14
Double or triple continuous line	8
Added line on right of normal stripe	9
Added line on left of normal stripe	1

Signs indicate—	Signs only	Stripe and signs	Total
Beginning only (2 signs per zone)	3	10	13
Beginning and end (4 signs per zone)	1	3	4
Beginning or beginning and end, but not used at all zones	1	8	9

Twenty-two States continue the special stripe (different from the normal stripe) throughout the zone. Ten other States use an added stripe only for the first part of the zone, terminating it at the point where sight distance is no longer restricted. Of these 10, 3 States use a double stripe composed of a broken stripe and continuous stripe of the same color, and 7 States add a continuous stripe of a different color, either white or yellow. One State uses a double or triple stripe throughout but changes the color of the right stripe at the point where sight distance is no longer restricted. One State uses a continuous double stripe throughout but in some cases indicates the end of no-passing length from one direction by a diagonal arrow across the stripe. Thus of 32 States using stripe markings in no-passing zones on 2-lane pavements only 12 incorporate the feature of a unidirectional indication of the point beyond which the sight distance is no longer restricted.

Method (3-lane roads)	States [1]
Special stripe on center line—no signs	3
Special stripe on center line—with signs	6
Special stripes on lane lines—with signs	7
Zones not marked—normal stripe	8

Type of special stripe	States
Single continuous line	8
Double or triple continuous line	4
Added line on right of normal stripe	4

Signs indicate—	States
Beginning only (2 signs per zone)	6
Beginning and end (4 signs per zone)	3
Beginning or beginning and end, but not at all zones	4

[1] 24 States indicate no rural 3-lane roads.

State practices regarding the marking of no-passing zones on 3-lane roads are summarized in the previous tabulation.

Of the 16 States marking no-passing zones on three-lane highways, 9 have systems restricting all passing in the entire length of the zone by means of centerline striping, 6 have a lane-marking system permitting two-lane operation as soon as the road opens up to view and 1 permits two-lane one-way operation on the upgrade only. Thirteen States apparently use one or more signs in conjunction with the pavement stripes in the zones and 3 States use no signs.

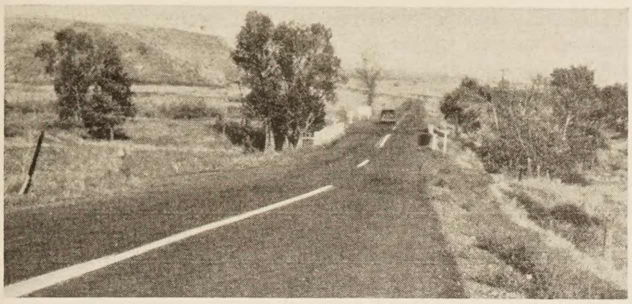
The summary of existing practice was given serious consideration by the three committees of the Association.

MARKING SHOULD INDICATE NO-PASSING ZONES SEPARATELY FOR TRAFFIC IN EACH DIRECTION

In establishing criteria for no-passing zones and the location of stripes the Special Committee on Administrative Design Policies felt that it was of paramount importance that the marking should indicate no-passing zones separately for traffic in each direction. The sight distances ahead and to the rear on a road are generally of unequal lengths. If a stripe indicating a no-passing zone, such as a single stripe on the centerline, does not differentiate between opposing directions of travel, the usefulness of the road is seriously impaired and a disrespect for restrictive stripes may be developed. When, for example, a highway is on tangent and sight distance over the crest of a hill is inadequate for passing, the restrictive stripe should begin where the sight distance for traffic approaching the hill is less than a desirable minimum, but beyond the crest where the road ahead opens up to view the stripe should not restrict a vehicle from making a passing maneuver. A stripe, however, is required to prevent passing by vehicles in the opposite direction approaching the crest. Both objectives may be attained by the use of a system of striping which restricts passing to traffic in one direction only, such as a dashed stripe throughout the length of the road with an additional continuous stripe on the side where sight distance is limited.

A no-passing zone for traffic in one direction may overlap a no-passing zone for traffic in the opposite direction or there may be a gap between the ends of the zones. A system of striping which differentiates between traffic in opposing directions naturally will show these overlaps and gaps. A normal broken stripe with a continuous stripe alongside to indicate a no-passing zone would, for example, have a continuous stripe on both sides where the no-passing zones overlap on a two-lane road.

Passing on three-lane roads is accomplished on the middle lane. If the system of marking at no-passing zones restricts traffic in both directions from passing, the middle lane becomes ineffective. Most of the middle lane, however, can be used effectively; confusion can be avoided, hazard diminished, and utility of the road increased by a system of striping which restricts traffic in one direction to one lane but permits traffic in the opposite direction to use two lanes. There has been some question regarding the most desirable type of operation over the crests of hills on three-lane roads on which widening to four-lanes is not justified. Some engineers contend that the delay caused by slow-mov-

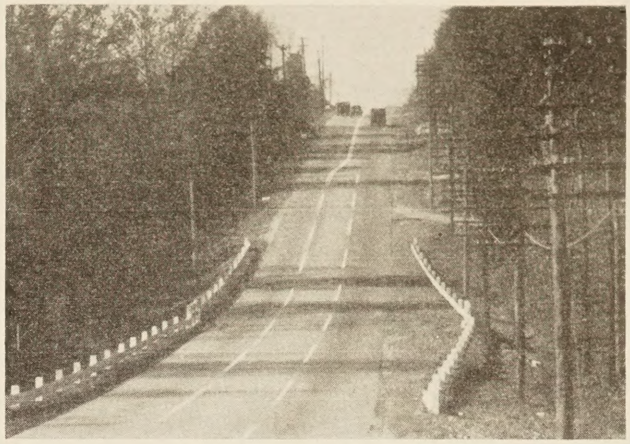


View Taken From Crest of Hill. Non-Directional Marking Restricts Passing Despite Adequate Sight Distance.

ing trucks going uphill should be avoided by reserving two lanes for upgrade traffic. From the standpoint of sight distance this system is hazardous in that it encourages passing when the sight distance is limited. Traffic should be confined to the right lane when sight distance is inadequate for passing just as on two-lane roads. When the road ahead opens up to view, the restriction should be terminated and passing permitted on the middle lane.

Diagonal striping should be provided in the middle lane, crossing from the inside of the left lane to the beginning of the restrictive striping on the inside of the right lane. The diagonal striping should meet the longitudinal restrictive striping at the beginning of the no-passing zone. The diagonal striping should inform drivers in one direction of the necessity of moving over to the right lane without crossing the diagonal striping but should not restrict crossing by vehicles traveling in the opposite direction.

In striping a highway to restrict passing of vehicles where sight distance is inadequate the general concept in choosing factors to determine sight distance below which passing should be restricted is totally different from that in choosing factors to determine sight distance to design a highway. If the same factors are chosen and a highway is striped to restrict passing wherever the sight distance is less than the passing minimum, and almost all drivers accept the dictum that they are required to keep to the right of a restrictive stripe throughout its length, the use of the highway is severely impaired.



Three-Lane Highway Marked To Restrict Traffic to Two Lanes Over the Crest of a Hill Where Sight Distance for Up-Hill Traffic Is Restricted. Such Non-Directional Marking Unnecessarily Restricts Down-Hill Traffic Which Has Adequate Sight Distance for Passing, Thus Encouraging Disregard for Restrictive Line and Passing as Shown.

SIGHT DISTANCE FOR STRIPING DEPENDS ON DESIGN SPEED

The desirable minimum sight distance on which to base restrictive striping for a two- or three-lane road lies between the minimum passing sight distance used in design and a sight distance of no appreciable length. The former is on the side of safety if the line is respected but restricts the use of the road. The latter is highly hazardous but permits passing at will so that even if a driver sees only enough of the road ahead to pass a vehicle practically standing still in the face of opposing traffic traveling at a very low speed he is not deterred by a restrictive stripe.

The sight distance for striping as finally recommended in the second column of table 5 is a compromise based on a passing maneuver such that the frequency of maneuvers enabling passing where sight distances are shorter is not great enough to impair seriously the usefulness of the road. Note that the sight distance for striping varies and is dependent on the design speed. The design speed is one which is greater than that used by almost all drivers on any particular road or section of road when traffic is not heavy enough to impede

Table 5.—*Relation of limits of no-passing zones to the point of intersection of vertical curves for purpose of marking pavements*

Design speed (miles per hour)	Minimum passing sight distance for marking pavements (feet)	Value of algebraic difference of grades, percent ÷ 100													
		0.04		0.06		0.08		0.10		0.12		0.14		0.16	
		A [1]	B [2]	A	B	A	B	A	B	A	B	A	B	A	B
30	500	40	330 −170	160	390 −110	200	420 −80	280	440 −60	340	460 −40	390	490 −10	420	510 10
40	600	180	420 −180	310	480 −120	410	520 −80	525	580 −20	630	620 20	740	660 60	930	720 120
50	800	320	620 −180	500	700 −100	680	790 −10	860	860 60	1,030	940 140	1,200	1,020 220	1,360	1,080 280
60	1,000	600	820 −180	930	980 −20	1,250	1,120 120	1,530	1,260 260	1,880	1,400 400	2,160	1,540 540	2,500	1,690 690
70	1,200	980	1,060 −140	1,480	1,320 120	1,970	1,540 340	2,460	1,760 560						

[1] A=Length of vertical curve resulting in minimum sight distance permitted in design.

[2] *B*=Horizontal distance from the point of intersection of vertical curve to limits of no-passing zone. The upper figure in each case is the distance in feet to the beginning of the no-passing zone. The lower figure is the distance to the end of the no-passing zone. When the lower figure is a minus value the end of the zone is on the near side of the point of intersection, the length of the no-passing zone is the difference between the two figures, and there is a gap between the ends of no-passing zones in opposite directions. When the lower figure is a plus value the end of the zone is on the far side of the point of intersection, the length of the no-passing zone is the sum of the two figures, and no-passing zones in opposite directions overlap.

smooth operation. It is governed largely by the physical characteristics of the road such as sharp curvature and by the surroundings, wide-open spaces encouraging higher speeds than built-up areas. Sight distance for marking is based on height of eye and height of object above the road surface both being 4.5 feet.

No-passing zones on an existing road are evaluated by determining the design speed of the road or section of road, after which the beginning and end of each no-passing zone are located. The sight distance at these points corresponds to the minimum passing sight distance for marking. The methods of measurement are relatively simple and are not discussed in this report.

An idea of the location of no-passing zones at hill crests can be obtained from table 5 which shows their location for various changes in grade for which the lengths of vertical curve are those resulting in the minimum sight distance permitted in design.

RESTRICTIVE STRIPE NEEDED AT INTERSECTIONS AT GRADE

It is desirable that vehicles approaching an intersection on two- and three-lane roads keep to the right and that all passing maneuvers should be completed before reaching the intersection. Passing while crossing an intersection is hazardous because: (1) The passed vehicle may obstruct the view of the cross road to the right; (2) the passed vehicle may turn left in front of the passing vehicle; and (3) the driver of a passing vehicle may find it difficult to observe crossing and turning traffic at the same time that he is required to watch traffic ahead. Two- and three-lane roads, therefore, should be striped to restrict passing for some distance each side of an intersection. Once beyond an intersection, there is no further need to restrict passing if sight distance and traffic conditions permit passing. The stripe, therefore, should restrict vehicles approaching the intersection from passing and not restrict passing beyond the intersection.

When one road at an intersection is a preference road and traffic on the nonpreference road is required to stop at the intersection the use of restrictive striping on the preference road is open to serious question. There is some hazard in the possibility of a left-turning vehicle cutting in front of a passing vehicle but the hazard due to possible restriction of sight caused by the passed vehicle is nil. It appears to be inadvisable, therefore, to restrict the free movement of traffic on the preference road by the use of no-passing marking if not required otherwise.

Normally the driver of a passing vehicle should return to the right lane before reaching the beginning of a restrictive stripe. The length of restrictive stripe at the approach to an intersection is, theoretically, zero. The restrictive stripe should, however, be visible for some distance so an arbitrary length is chosen, say 100 to 200 feet. An appreciable length of restrictive stripe will also have the desirable effect of encouraging drivers, who normally return to the right lane some distance past the beginning of the stripe, to return to the right lane before reaching the intersection.

At intersections where vehicles are stopped by a traffic light, stop sign, preference road sign or, in the absence of such controls, by cross traffic, it is desirable that vehicles facing the intersection line up on the right so that traffic is free to move in both directions when permitted. The restrictive stripe encourages vehicles to keep to the right under such circumstances and its length may be determined by the probable number of vehicles which will be thus lined up, allowing about 20 feet for each passenger vehicle.

A restrictive stripe on a three-lane road approaching an intersection normally should be located on the right lane line in the same manner as at a location with short sight distance. This marking serves to line up vehicles approaching the intersection and permits passing by vehicles leaving the intersection. If vehicles are likely to be stopped, however, it may be desirable to locate the restrictive stripe on the center line of the pavement. If stopping is effected by continuous traffic light control it may be desirable to use only normal lane stripes and omit restrictive stripes altogether. Passing may be accomplished when the light is green if sight distance and traffic conditions along the road are favorable and two lanes in each direction may be used for storage when the light is red. If traffic is evenly divided in both directions, opposing traffic in the middle lane will have to free itself on the go signal. When traffic is heavy, however, it generally is unbalanced and the omission of restrictive stripes may have the desirable effect of providing two lanes for storage and movement in one direction. At important intersections three-lane roads may be widened to four lanes and a restrictive stripe placed at the centerline.

At intersections where there is a considerable volume of left-turning traffic it may be desirable to omit the restrictive stripe and mark the middle lane on the approaches to the intersection for the exclusive use of left-turning vehicles.

Traffic should be restricted from passing while crossing a railroad at grade. While there is no left-turning traffic the passed vehicle may obstruct the view of the signal and the track to the right. A restrictive stripe also has the desirable effect of lining up vehicles in the right lane when the crossing is closed so that traffic is free to move in both directions when the crossing is clear.

At places where the number of traffic lanes change, as where a two-lane road changes to a three- or four-lane road, traffic should be informed of the change by appropriate signs and marking in both directions to encourage traffic to keep in its proper lane or lanes.

The Special Committee on Administrative Design Policies has prepared a statement entitled "A Policy on Criteria for Marking and Signing No-Passing Zones on Two- and Three-Lane Roads" from which the preceding discussion is largely taken. The approved conclusions are given at the end of this report.

RESTRICTIVE STRIPES SHOULD VARY IN COLOR, TYPE, AND WIDTH

The committees which jointly undertook to establish a standard system for the details of marking and signing no-passing zones took the following basic principles into consideration:

1. The no-passing marking should be easily understandable.
2. It should be economical to place.
3. It should conflict as little as possible with existing practice in road striping.
4. The stripe itself should be the same for two- and three-lane roads, regardless of its position on the pavement.

There was general agreement that the essential element should be a conspicuous and distinctive "restrictive" or "barrier" line placed along the right side of the centerline. This line could be made distinctive and conspicuous in any one of the three details of color, type, and width, or by combinations of them. It is evident that the starting point for the distinctive line is the normal stripe, the three details of which must be known. By analysis of existing practice a normal stripe, either black or white in color, continuous or broken in type, and about 4 inches in width, appears to be the best compromise.

To be distinctive the barrier stripe should differ from the normal stripe in at least one or two, and preferably all three, of the color, type, and width details. The color difference itself appears to be the least effective distinction, but certainly desirable, and, in some instances, necessary. With regard to type difference the barrier line should invariably be a solid line. Where the normal center line is a broken line, a solid auxiliary line will stand out conspicuously, whereas reversed types would seem definitely weak. If both lines are solid, either color or width variations must be included and preferably both should be used.

It is quite generally agreed that for the normal centerline a broken line, which permits a 50 percent saving in paint, is about as effective as a continuous line. Recent developments indicate that equipment can be perfected to lay down either continuous or broken lines exactly as desired once the general demand for such mechanical performance is created.

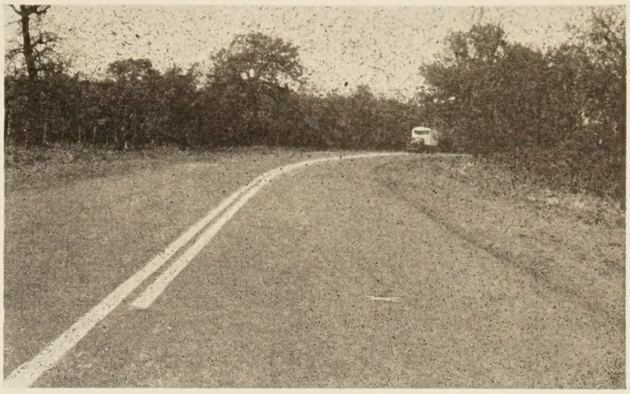
In view of the possible variations in color and type of stripe, considerable attention should be given to the width of the barrier line. It should be at least 4 inches wide, never narrower than the normal stripe and preferably at least 6 inches wide. The barrier line should be separated from the normal stripe rather than immediately adjacent to it.

The use of shoulder signs provides warning when conditions such as snow or dirt on the pavement are such as to make the marking insufficiently visible. Equally important, they help make clear the meaning of the pavement striping. Standard signs ("no-passing" and "end no-passing zone") are preferable to more explanatory signs, but signs at every no-passing zone are an unnecessary and unwarranted expense. Their use is optional.

On two-lane roads the no-passing marking should be placed along the centerline. On three-lane roads exactly the same type of barrier stripe can be used, placed so as to prevent use of the middle lanes by any vehicle having a restricted sight distance. On three-lane roads the no-passing marking should permit two-lane operation of traffic in one direction only (and one-lane operation in the other direction) after it has passed beyond the point of restricted sight distance.

With these considerations a subcommittee representing the Committees on Maintenance and on Traffic Control and Safety prepared a report [1] from which the preceding discussion regarding the details of marking and signing are largely taken and recommended standards for marking and signing no-passing zones as given at the end of this report.

The recommendations submitted by the three committees together comprise complete standards for determining, locating, and marking no-passing zones on two- and three-lane highways. They have been recommended to the American Association of State Highway Officials for adoption, and at present are being considered by the association members. Fortunately pavement markings rarely are permanent in character so that little expense is involved in changing to any standard system, once adopted, in a comparatively short time, possibly in the course of a single year. It will, of course, be necessary to educate drivers as to the meaning of the directional system of marking, but once they understand the principles upon which it is based they may be expected to adapt themselves rather easily to any minor interstate differences that may arise.



Centerline Stripe and Directional Stripe to Restrict Traffic Approaching the Curve. The Marking Would Be More Effective Were the Centerline Stripe Broken Instead of Solid or Different in Width or Color.

Following are the approved conclusions of the committees:

A POLICY ON CRITERIA FOR MARKING AND SIGNING NO-PASSING ZONES ON TWO- AND THREE-LANE ROADS

A no-passing zone for the purpose of marking two- and three-lane pavements shall be one in which the sight distance ahead is less than 500, 600, 800, 1,000, and 1,200 feet for assumed design speeds of 30, 40, 50, 60, and 70 miles per hour, respectively.

No-passing zones shall be determined and indicated separately for traffic in each direction. No-passing zones for traffic in opposite directions may overlap or there may be a gap between their ends.

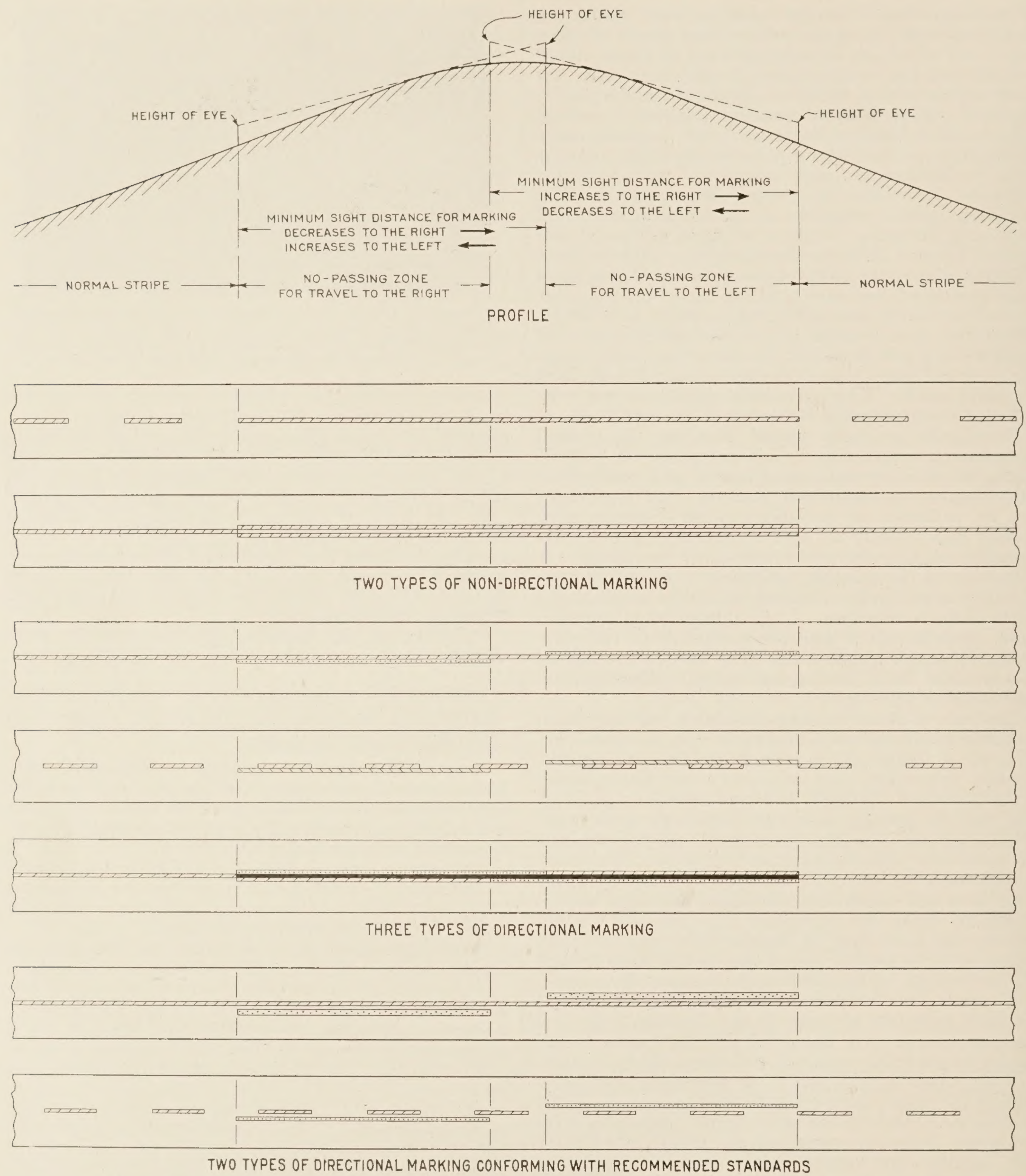
Sight distances shall be measured between eye and top of vehicle, both 4.5 feet above the pavement surface.

The system of marking pavements of two- and three-lane roads shall restrict passing within the limits of no-passing zones and shall differentiate between traffic in opposing directions so that traffic in each direction will not be restricted from passing when the road opens up to view.

The system of marking pavements of three-lane roads shall restrict traffic in each direction to the right lane within the limits of a no-passing zone. Diagonal striping across the middle lane shall be provided approaching the beginning of a no-passing zone. The diagonal striping shall indicate that it must not be crossed by traffic approaching the no-passing zone but may be crossed by traffic in the opposing direction.

Intersecting roads for some distance from the intersection should be considered no-passing zones for traffic approaching the intersection. Where one road is a preference road the nonpreference road only may be considered a no-passing zone.

[1] The Marking of No-Passing Zones on Highways, by E. W. James, Papers and Discussions, Convention Group Meetings, American Association of State Highway Officials, 1938.



Types of Pavement Markings for No-Passing Zones Over Hill Crests on 2-Lane Roads.

No-passing zones at intersections may be marked in the same manner as other no-passing zones except that three-lane roads with stop control should have the restrictive stripe on the centerline instead of on the right lane line and where stop control on three-lane roads is effected by traffic lights restrictive stripes may be omitted.

The system of marking pavements for no-passing zones is primarily intended to be used for restricted vertical sight distance or a combination of restricted vertical and horizontal sight distance. The restriction in horizontal sight distance alone usually is obvious while the impairment of vertical sight distance on tangents generally is not realized by the average motorist.

(*Continued on p. 202*)

A SIMPLE ACCUMULATING-TYPE TRAFFIC COUNTER

BY THE DIVISION OF HIGHWAY TRANSPORT, PUBLIC ROADS ADMINISTRATION

Reported by O. K. NORMANN, Associate Highway Economist

A TRAFFIC COUNTER consisting of a dollar watch, a lever arm, a diaphragm and a rubber tube is the newest and simplest addition to the growing family of traffic counters. Previous articles have described two types of automatic traffic counters, one of the recording type and one of the simple accumulating or nonrecording type.[1] Each type has its own field of use in obtaining data on highway traffic volume needed in planning future highway improvements. In the highway planning surveys now being conducted by 46 States in cooperation with the Public Roads Administration, more than 500 recording-type counters and over 200 nonrecording-type counters are in use.

In general the recording counters are used to obtain long-time records at fixed locations. The most important function of these counters, aside from providing a continuous record of traffic flow past that particular point, is to furnish data to serve as a basis for establishing fundamental traffic trends and determining normal traffic patterns. These data provide a valuable basis for deriving and checking factors for expanding short counts of traffic made at numerous locations.

Simple accumulating-type traffic counters are useful in taking a relatively few counts properly distributed as to time and location. These short counts are then expanded by applying appropriate factors, thus providing a measure of the increases or decreases of the total traffic volume. It is essential that such counters be inexpensive and easily portable. Other requirements are simplicity, ruggedness, ease of installation, and ability to make an accurate count of vehicles traveling at high speeds.

The new counter consists essentially of a watch mounted over a rubber diaphragm which is connected to a rubber tube stretched across the highway. The air impulse generated by the wheels of a vehicle passing over the rubber tube is transmitted to the diaphragm, causing it to rise. This actuates a lever arm which moves the escapement arm of the watch. The front and rear wheels of a passing vehicle each cause a separate air impulse; thus each two-axle vehicle moves the escapement arm twice. In the type of inexpensive watch used, two cycles of the escapement arm are required to move the second hand of the watch forward one second.

OPERATION OF COUNTER DESCRIBED IN DETAIL

Figure 1 shows the various parts of the counter, consisting of: A metal cap, which fits over the watch and screws onto the base; a watch, which is mounted on a heavy metal base containing the rubber diaphragm; a hollow stem, which screws into the base and over which the rubber tube fits; and a section of rubber tubing. Figure 2 shows two views of the assembled counter ready for use. The stem can be screwed into the center of the base, as shown at the right in figure 2, or into the side of the base as shown at the left. A short screw, as shown at the right in figure 2, is used to plug the hole not used for the stem connection.

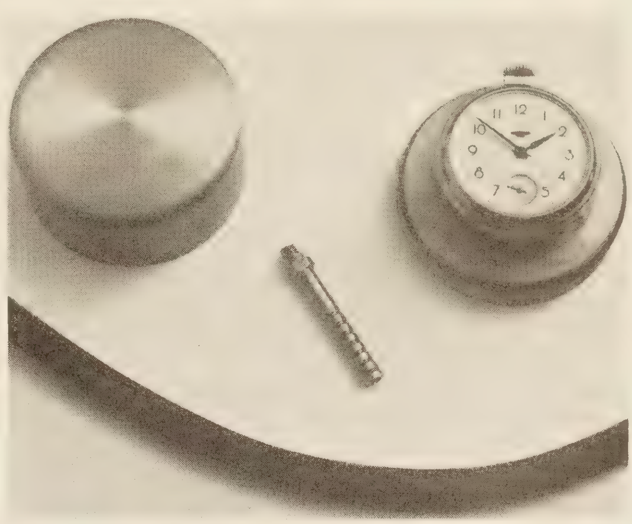


Figure 1.—The Simple Accumulating-Type Traffic Counter. Upper Left, the Cover; Upper Right, the Counting Unit Mounted on Metal Base; Center, the Stem; Lower, Rubber Tubing of the Kind Used.

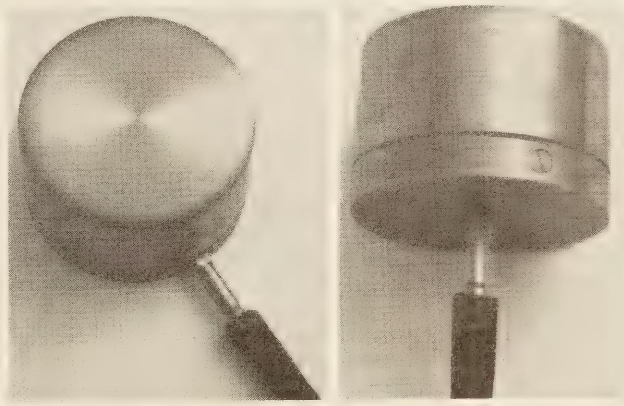


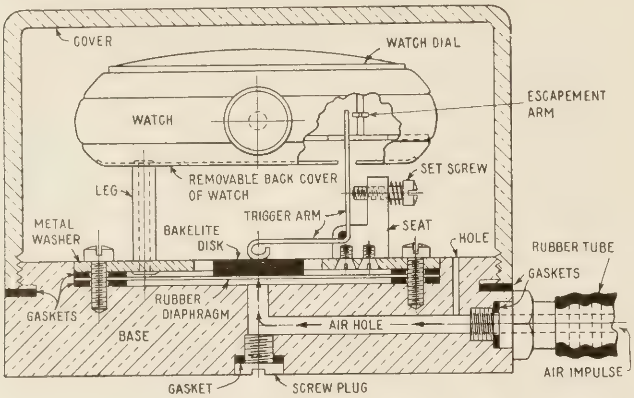
Figure 2.—The Counter Assembled and Ready for Use.

Details of the counter are shown in figure 3. The watch is rigidly mounted over a metal base. The base consists of a metal disk 5/8 inch thick and 2.8 inches in diameter. A thin rubber diaphram is mounted in a circular depression in the top of the base. A metal washer is placed over the rubber diaphram. Screws hold both in place and, with the aid of rubber gaskets above and below the diaphragm, make an airtight connection. A small bakelite disk is cemented on top of the diaphragm at its center.

Two holes have been drilled through the base with a No. 13 drill, one passing vertically and one passing radially and connecting with the first hole at the center. These holes are threaded to fit the stem and the

[1] An Automatic Recorder for Counting Highway Traffic, by R. E. Craig. PUBLIC ROADS, vol. 19, no. 3, May 1938.
A Simple Portable Automatic Traffic Counter, by R. E. Craig and S. E. Reymer. PUBLIC ROADS, vol. 19, no. 11, January 1939.

screw plug. The top edge of the base is threaded to fit threads on the inside of the cap. Rubber gaskets placed at the threaded connections insure airtightness and watertightness. A vertical hole made with a No. 70 drill runs from the top of the base down to the radial hole and serves to equalize the air pressure above and below the rubber diaphragm without affecting its normal operation.



SECTIONAL ELEVATION

Figure 3.—Details of the Counter.

On the metal washer that holds the rubber diaphragm in place is mounted a seat on which the L-shaped trigger arm pivots. This seat also holds an adjusting screw which prevents the trigger arm from moving far enough to injure the escapement arm of the watch. The trigger arm has a small loop on the bottom end, which rests on top of the bakelite disk on the diaphragm. The trigger arm extends vertically through a hole in the removable back cover of the watch and rests against the escapement arm of the watch, which is mounted above the base on three legs. Each of these legs rigidly connects the removable cover of the watch with the metal washer over the diaphragm.

The watch, which serves as the counting unit, is an inexpensive type costing less than a dollar. It has been slightly altered, as shown in figures 4 and 5, to serve as a simple counter instead of a timepiece. This has been done by cutting away a section of the back of the watch containing the rear bearing for the balance wheel and removing the balance wheel and the hairspring. A light wire spring has been inserted to act against the escapement arm of the watch. One end of the spring rests against the case of the watch and the other end is bent in a U-shape and straddles the escapement arm. The spring thus tends to push the escapement arm toward the center of the watch.

The trigger arm is adjacent to the inside edge of the escapement arm, and, when an air impulse causes the diaphragm to rise, the trigger arm pushes the escapement arm away from the center of the watch. After the impulse, the diaphragm descends to its normal position, the trigger arm pivots away from the escapement arm, and the light spring pushes the escapement arm toward the center of the watch, thus completing one cycle and permitting the second hand of the watch to move ahead. The watch must be wound for use but there is no movement of the parts except as permitted by the trigger arm.

In the type of watch used two cycles of the escapement arm are required to move the second hand ahead one second. Each two-axle vehicle is therefore counted

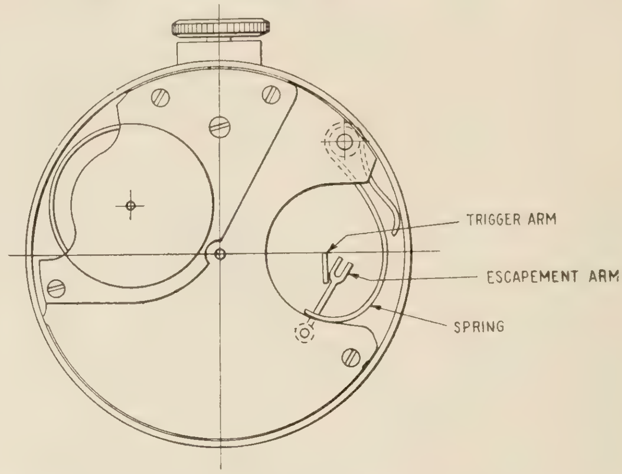


Figure 4.—Alterations on the Back of the Watch That Convert It Into a Simple Counting Mechanism.

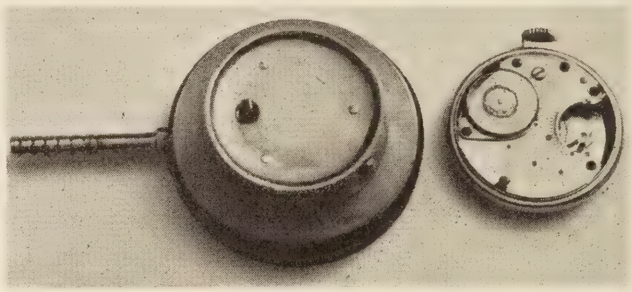


Figure 5.—The Counter, Showing Mounting of the Removable Rear Cover of the Watch and the Altered Watch.

as one vehicle. Were the counter used on roads carrying appreciable numbers of three-axle vehicles, the count registered would be excessive since two three-axle vehicles would be counted as three vehicles. In such instances it would be necessary to estimate the percentage of three-axle (or four-axle) vehicles in the total traffic and adjust the count accordingly.

In making a traffic count with this counter an initial reading of the watch is made at the start of the counting period and a final reading is made at the end of the period, recording the hours, minutes, and seconds at each time. The number of seconds indicated by the difference between the two readings represents the number of two-axle vehicles passing that point during the period. Since each minute indicated on the counter represents 60 vehicles, it is obvious that counts for short periods, even on heavily traveled roads, would not move the hands forward by more than an hour or two. A complete revolution of the hour hand, 12 hours, would indicate passage of 43,200 two-axle vehicles. Since the type of watch used will run more than 24 hours on one winding, more than 86,000 vehicles could be counted before the counter would require attention. If the hour hand has made a complete revolution during a counting period, that fact will be revealed by the amount of winding necessary to rewind the watch.

COUNTER QUICKLY AND EASILY INSTALLED

The new counter has many advantages. Since no type of electrical apparatus is involved in its operation, there is no need for a connection with a power line or

(Continued on p. 203)

ACCELERATED SETTLEMENT OF EMBANKMENTS BY BLASTING

REPORT ON WORK IN WASHINGTON

Reported by A. W. PARSONS, Senior Engineering Aide, District 1, Public Roads Administration

BLASTING has been used as a means of accelerating fill settlement in a number of States during recent years. By both displacing and liquefying unstable materials under and adjacent to fills, blasting enables stable fill materials to be placed upon firm strata underlying peat bogs and muck beds.

Blasting was recently resorted to in effecting fill settlement on sections of Washington Primary State Highway No. 9 between Quilcene and Sequim.

Traffic is fairly heavy on this highway, especially during the summer tourist season. Glacial drift constitutes the surface material of the region traversed by the highway. The terrain is rolling, with many glacial marshes and lakes in the depressions, and the highway crosses several of these marshes in order to preserve minimum curvature in alinement.

The swamps probably originated through sedimentation of lakes and ponds with detritus from surrounding areas. Silts and clays deposited during floods covered the vegetable matter collected in the depressions, with the formation of peat as the result of incomplete oxidation of the organic matter under water. Thus the swamps have been built up gradually with alternate layers of peat and silt or clay.

First construction financed in part with Federal funds on the section of highway (Washington Federal-aid project No. 136–B) consisted of 6.53 miles of grading to a width of 28 feet. The contract for this project was awarded in April 1927, and the work was carried on during the construction seasons of 1927 and 1928. Considerable difficulty was encountered in constructing the embankments across the marshes, and it became immediately apparent that the quantities originally estimated would fall far short of actual needs because of extreme subsidence of the fills.

Conditions at that time were most critical between stations 125 and 140. There the highway crossed what appeared to have been formerly an arm of Lake Leland, now filled to a depth of 35 to 50 feet with soft blue clay and peat. Preliminary soundings had been made at a stream crossing near station 130, but subsurface explorations were not made through the entire section as the surface appeared sufficiently dry and stable to support adequately the proposed low fill.

The available funds were exhausted without completing the embankment between stations 126 and 139 under the original contract. A second contract was therefore awarded in May 1929, for construction of the remaining portion of the fill and for crushed stone surfacing of the entire project. A limited amount of blasting was done to obtain settlement of the fill through the swamp, and at the time of completion (November 1929) it was believed that the embankment had been permanently stabilized.

Further settlement occurred, however, and additional work was done by State maintenance forces from time to time, including some underfill blasting. The roadbed between stations 126 and 139 now appears to be quite stable and further blasting is not considered necessary.

Between stations 227 to 240 and stations 248 to 265, subsidence of the embankment during original construction was so slow that it was believed that the swamp was shallow and that the roadbed would soon become stabilized. During the time since the original construction was completed the fills have continued to settle slowly, resulting in impaired riding qualities of the surface and high maintenance costs. It was on these two sections, therefore, that blasting was done to settle the fills to solid bottom. Figure 1 shows the road before the new work was begun.

A contract was awarded in September 1938 for regrading 5.821 miles of the original project (stations 29 to 337) to a width of 28 feet, for reinforcing the subgrade with selected gravel, and for placing crushed stone surfacing 20 feet wide. No changes in alinement were contemplated, but several revisions in grade were made through low sections where seasonal floods had covered the existing road. Accelerated settlement of the existing fill and new embankment material to be placed between stations 227 to 240 and stations 248 to 265 were provided for in the contract, the estimated cost being $10,000.

UNDERFILL BLASTING SELECTED AS BEST METHOD OF STABILIZING FILL

Assumptions made in designing the reconstruction of the embankments through the swamp areas were based upon preliminary soundings and results of laboratory tests on the various materials encountered. Soundings indicated that the existing fill extended some 8 to 10 feet below the swamp surface, and that the depth from the swamp surface to solid bottom ranged from 15 to 28 feet. The existing fill was therefore floating on a layer of swamp muck and peat averaging about 10 feet thick.

Profiles of the solid swamp bottom, the surface of the old road, and the new road surface, are shown in figure 2. A cross section showing the old and new road surfaces and the holes for mat and underfill blasting are shown in figure 3.

Samples of the swamp material taken from borings were tested in the laboratory. Table 1 shows the results of these tests.

The swamp material was principally peat mixed with brown silty clay near the surface. Solid bottom consisted of firm blue clay. The swamp material was classified as group A–8. As shown in table 1, consolidation of the swamp material could be expected to continue for a long time if left under the fill. The cost of displacing the peat with suitable fill material was therefore considered justified.

TABLE 1.—*Results of consolidation tests on swamp material*

SAMPLE 1 [1]

Laboratory tests			Probable field results	
Time	Consolidation		Time	Consolidation
Minutes	*Inches*	*Percent*	*Years*	*Inches* [2]
0.5	0.0162	24	0.13	2.9
1.0	.0220	33	.25	4.0
1.5	.0265	40	.39	4.8
2.0	.0300	45	.50	5.5
3.0	.0354	53	.76	6.5
5.0	.0420	63	1.26	7.7
7.0	.0463	70	1.76	8.4
10.0	.0503	76	2.52	9.2
15.0	.0544	82	3.78	9.9
20.0	.0572	86	5.04	10.4
30.0	.0604	91	7.56	11.0
45.0	.0634	96	11.34	11.6
60.0	.0663	100	15.12	12.1
SAMPLES 2A AND 2B [3] (AVERAGE)				
0.5	0.0082	14	0.29	2.3
1.0	.0114	19	.58	3.2
1.5	.0138	23	.87	3.8
2.0	.0159	27	1.17	4.4
3.0	.0195	33	1.75	5.4
5.0	.0252	43	2.92	7.0
10.0	.0348	59	5.83	9.6
15.0	.0408	69	8.75	11.3
20.0	.0448	76	11.66	12.4
30.0	.0509	86	17.49	14.0
45.0	.0558	94	26.24	15.4
60.0	.0593	100	34.98	16.4

[1] Taken at station 257+00.
[2] Per total depth of peat stratum.
[3] Taken at station 229+00.

Roadside pits at station 220 and between stations 241 and 248 were selected as sources of borrow material for the fill. Laboratory tests on samples of material from these pits showed the material to be not well suited to the intended use. The top 12 feet of material from each pit consisted of brown cloddy soil. The material below consisted of a gray shale, very hard in its original position but slaking readily in water. These soils were found to have the composition and characteristics given in table 2.

Figure 4 shows materials representative of those obtained from the upper and lower portions of the pit.

TABLE 2.—*Composition and characteristics of materials in borrow pits*

	Material in top 12 feet	Material below top 12 feet
Coarse sand ... percent	5	3
Fine sand ... do	13	11
Silt ... do	53	59
Clay ... do	29	27
Liquid limit	36	36
Plasticity index	12	15
Field moisture equivalent	25	23
Shrinkage limit	18	16
Centrifuge moisture equivalent	15	15
Classification	A–4	A–4

The characteristics of the materials listed in table 2 are indicative of a silty clay soil without coarse material, possessing moderate cohesion and having no appreciable elasticity but important capillary properties with resulting tendency to frost-heave. The pit material is hard in its original position and breaks into fairly large pieces, but its proneness to slake indicates that it would lose stability in embankments under extreme moisture conditions.

This material was not considered particularly suitable for use as fill material to displace the peat; but observations of the same material used in roadway fills indicated that it might give satisfactory results. Since suitable ledge rock or gravel was not available within reasonable hauling distance, it was decided to use this pit material.

In order to cut off capillarity and decrease the possibility of damage to the surface from frost-heave, a gravel ballast course was placed on top of the clay subgrade, the surfacing materials being placed on this base.

Various methods of stabilizing highway embankments were considered by the State before it selected the underfill blasting method as the one best suited to the conditions. The practicability of using vertical sand drains to remove water from the underlying mud was investigated and rejected because the water level of the swamp often rises above the existing road during the winter months.

SWAMP MAT BLASTED TO CREATE RELIEF DITCHES ALONGSIDE THE ROAD

It was believed preferable to include the settlement of the embankments as a force account item in the contract rather than attempt to specify too closely the procedure to be followed. The number of holes to be drilled through the existing embankment and the amount of powder required could not be accurately determined in advance. Also, by using the force account method the procedure could be changed readily as required by any unforeseen conditions encountered during construction.

The fill settlement work was begun at the north end of the swamp (station 226) and was carried forward progressively toward the south end. The first operation consisted of blasting the swamp mat on each side of the existing road from the toe of the slope out approximately 25 feet. The purpose of this blasting was to break up the top mat of clay and fibrous swamp material, and to liquefy the underlying peat and muck, thus decreasing the side support and promoting lateral displacement of the material under the fill.

Experimental blasting was done to determine what method of loading and quantity of explosives would most economically produce the desired results. Shots were placed in three rows spaced 12 feet apart, the rows being parallel to the center line of the road and the inside row being about 4 feet out from the toe of the slope. Charges were spaced 18 inches apart in the rows, and at intervals of 25 feet lateral rows connected the parallel rows. Each charge consisted of five 1¼- by 8-inch sticks of dynamite, placed end to end. The two end sticks and middle stick in each hole were 40-percent gelatin dynamite, the other two sticks being 50-percent straight nitroglycerin dynamite. The charges extended from a foot below the surface down to a depth of from 4 to 6 feet.

The mat was shot in sections from 100 to 200 feet long. Since the charges were detonated by propagation, only one blasting cap was needed in firing each section.

Results obtained by this method of blasting showed that, although the mat was well broken, most of the material was lifted vertically and fell back into its original position without creating the desired relief ditches along the sides of the fill. This was remedied by eliminating the lateral rows between the inside and center rows of holes, thus isolating the inside row and cutting off propagation to it from the outer rows.

An instantaneous electric blasting cap was then used to detonate the center and outside rows of charges, and

Figure 1.—Existing Road Prior to Reconstruction. Picture Taken at Station 235, Showing Cracks Caused by Unstable Subgrade.

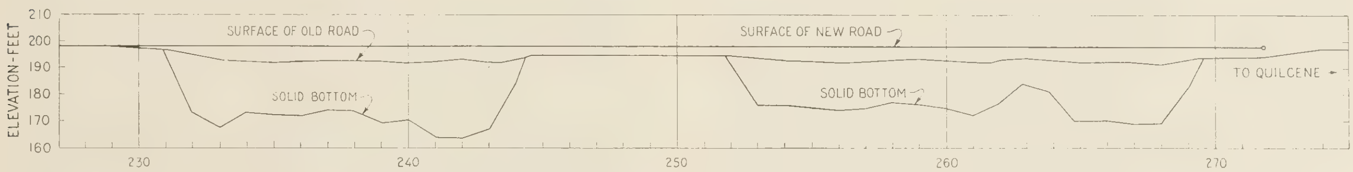


Figure 2.—Profiles of the Old Road, the New Road, and Solid Swamp Bottom.

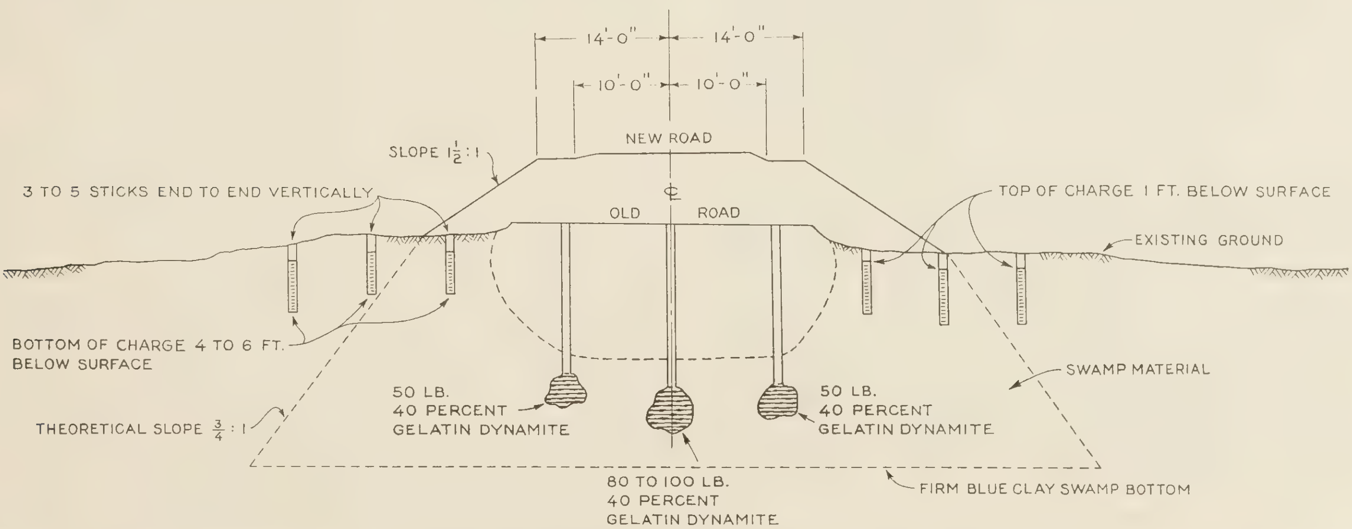


Figure 3.—Cross Sections of the Old Road and of the New Road, Showing the Transverse Position and Depth of Charges for Swamp Mat and Underfill Blasting.

a first delay cap was used for the inside row. The two caps were connected in series and fired simultaneously. The delay of approximately 1½ seconds between blasts had the desired effect of throwing the material out and away from the roadway, leaving a ditch along each side of the embankment averaging 4 to 6 feet deep.

In the softer portions of the swamp it was found that satisfactory results could be obtained by spacing the rows of charges about 7 feet apart, and using 3 sticks of dynamite per hole with holes spaced 2 feet apart. Two sticks of 40-percent gelatin dynamite and one stick of 50-percent straight nitroglycerin dynamite per hole were then used.

Figure 5 shows the punching and loading of holes for blasting the swamp mat. Figure 6A shows a blast in

FIGURE 4.—FILL MATERIAL PILED ON ROAD PRIOR TO UNDERFILL BLASTING. A, MATERIAL FROM UPPER 12 FEET OF BORROW PIT; B, MATERIAL FROM LOWER PART OF BORROW PIT.

FIGURE 5.—PUNCHING AND LOADING HOLES FOR SWAMP MAT BLASTING.

which a delay cap was used to fire the inside row of charges, and figure 6B shows the relief ditch obtained using this method.

After the crew engaged in blasting the swamp mat had advanced several stations, a second crew began the underfill blasting. A trial section was loaded by driving 2-inch iron pipes under the fill from the sides and loading through the pipes. This method was abandoned after the first trial because it was too slow and difficult to place the charges under the fill effectively.

After charges had been placed under a section of road but before they were exploded, the new fill material was piled on the road, as shown in figure 4. This was done to increase the fill mass in order to direct the force of the explosion outward to the sides, as well as to gain more settlement by impact as the fill dropped into place.

FIGURE 6.—A, BLAST IN WHICH A DELAY CAP WAS USED TO FIRE THE INSIDE ROW OF CHARGES. B, RELIEF DITCH OBTAINED BY BLASTING THE SWAMP MAT.

It was found that the time consumed in driving pipes under the toe of the embankment, and in loading the holes and withdrawing the pipes did not allow the blasting crew to keep ahead of the grading operations. A well-drilling outfit was tried and abandoned as too slow. Jackhammers with special 3-inch hardpan bits were finally adopted. Water was poured into the holes during drilling and air jets were used to clean the holes.

After drilling through the compacted fill material, it was frequently possible to air-jet the holes through the underlying peat and muck to the required depth. Loading was done by inserting 2-inch iron pipes in the drill holes and tamping the dynamite into place through the pipes.

Using this equipment and procedure, two drillers in about 8 hours could complete all holes necessary for shooting a section approximately 175 feet long (about 40 holes). The holes averaged about 15 feet in depth, and the cost of drilling was approximately 3½ cents per foot. Five two-man crews could load the holes for a 175-foot section in about 6 hours.

METHODS USED PRODUCED SATISFACTORY RESULTS

Holes were spaced 24 feet apart along the center line of the existing road, and 12 feet apart in rows 11 feet on each side of the center line. Forty-percent gelatin dynamite was used for all underfill shots, 80 to 100

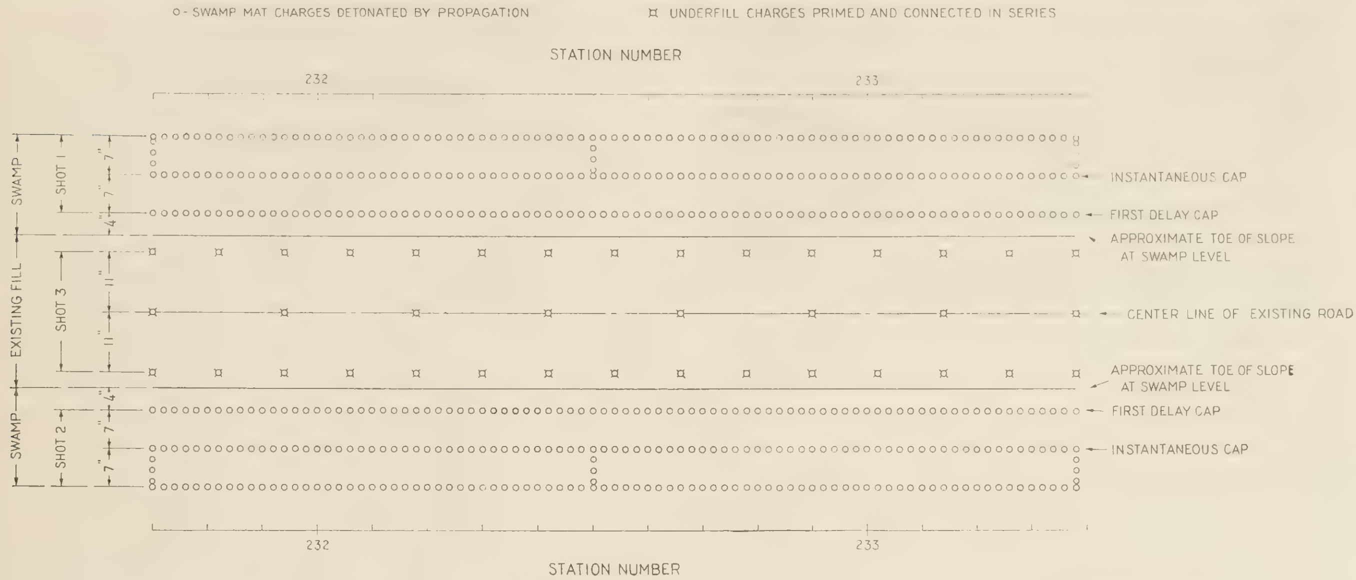


Figure 7.—Locations of Charges for Blasting the Swamp Mat and the Underfill.

pounds per hole being used in the center row and 50 pounds per hole in the outside rows. The depth of the charges varied with the depth of the swamp. The center charges were placed in the lower third of the distance from hard bottom to the bottom of the existing fill, and the side charges were placed at about the midpoint of this distance.

Sections 100 to 200 feet long were blasted at one time, the length being dependent upon the time required to place the borrow material and limited by the capacity of the electric blasting machine. Each charge was primed and caps were connected in series, leaving adequate lengths of wire between caps to prevent breakage by uneven settlement under the weight of the borrow material placed prior to shooting.

A loading diagram for the shooting of a typical section is shown in figure 7. A section of fill ready for blasting is shown in figure 8A, and after blasting in figure 8B.

After completion of the blasting operations described above, additional shooting was done along the edges of the embankment for settlement of the shoulders where such treatment appeared necessary. Holes were drilled through the embankment at the shoulder line, and charges consisting of 15 to 25 pounds of 40-percent gelatin dynamite were placed about 15 feet apart.

The average crew employed on the mat blasting consisted of one powder man and eight unskilled laborers. On the underfill blasting this crew was augmented by two jackhammer operators. The same crew worked on both mat and underfill blasting except for several days at the beginning of the work when it was necessary to use two separate crews to prevent delaying the grading operations.

The following equipment was used on the drilling and blasting work:

One air compressor and accessory equipment.
Two jackhammers and special hardpan bits.
Two iron punch bars, 5 feet long.
Several sections of ½-inch iron pipe from 10 to 20 feet long, used for air-jetting.
Several sections of 2-inch iron pipe from 14 to 20 feet long, used as casings for loading dynamite under the fill.

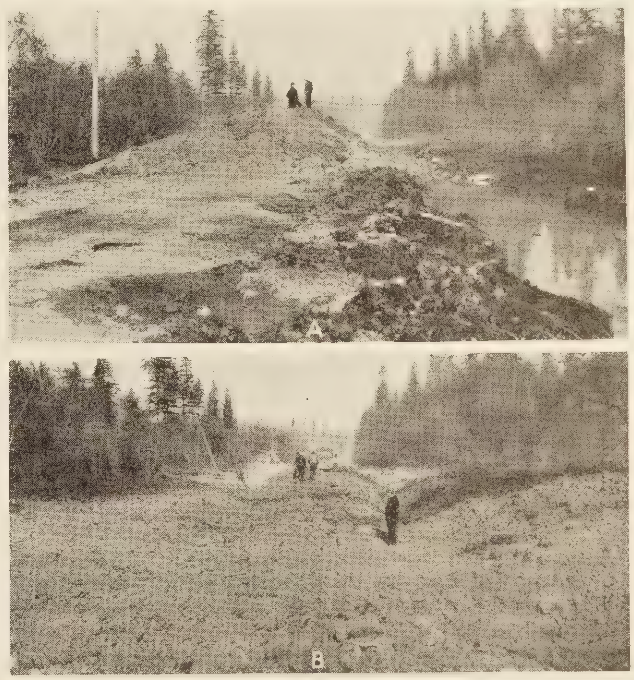


Figure 8.—A, Old Road Loaded With Borrow Material Before Underfill Blasting; B, the Same Section of Road Shown in A After Blasting. The Fill Mass Settled Approximately 15 Feet. Note the Swamp Muck Pushed Out on Each Side.

Miscellaneous small tools such as shovels, picks, axes, pipe wrenches, etc.

Because the matted root growth and clay overlying the swamp peat averaged about 4 feet thick, the cost of breaking up the mat on this project was probably greater than would ordinarily be expected. The total area of swamp mat blasted was approximately 14,000 square yards. The cost of mat blasting was $2,353, or a unit cost of about 16.5 cents per square yard. Approximately one-half pound of dynamite was used per square yard of mat, or a total of 6,700 pounds.

The original volume of swamp material displaced by

Figure 9.—Completed Road. Picture Shows About the Same Section as in Figure 1.

the embankment was estimated to have been 70,000 cubic yards. The cost of underfill blasting was $7,046. About 11 pounds of explosives were required per linear foot of embankment, or a total of approximately 34,000 pounds. The total cost of mat and underfill blasting was thus $9,399, or 13.4 cents per cubic yard of swamp material displaced.

After completion of the blasting operations and before the fill had been completed to final grade, several heavy rainstorms occurred causing considerable rise of the water level. Between stations 232 and 235 the fill material and adjacent swamp muck softened to the extent that a major subsidence of the fill was started. There was a corresponding upheaval of the peat banks along the sides of the embankment and movement of the swamp surface appeared to extend 100 feet or more from the roadway on each side.

When inspected a few months later, settlement of the fill had stopped and it had been brought back up to grade with gravel hauled from a borrow pit at station 342, approximately 2 miles south. Although it appeared reasonable to expect some additional subsidence, because of the extremely fluid condition of the swamp material through this particular section, there has been no extensive settlement. This may be partially explained by the improvement in drainage conditions along the roadway which have allowed the swamp material to dry out and consolidate, thus increasing the support given to the fill. Placing the gravel borrow over the clay borrow slopes seemed to trap the softer material and prevent lateral flow which might have taken place had the same clay type of borrow been used in raising the fill.

No appreciable settlement has been detected on other sections, probably because the adjacent swamp muck was firmer rather than because of any superiority of fill material.

Crushed stone surfacing was placed several months after completion of the embankments. Figure 9 shows the surfaced road through the swamp ready for a bituminous treatment.

The methods used in swamp blasting have produced generally satisfactory results. The use of rock or gravel as fill material would have been desirable from the standpoints of obtaining maximum settlement during blasting operations and of insuring greater stability under the adverse moisture conditions existing on this road. However, it is questionable whether the considerable expense of hauling more suitable materials to this project would have been justified in view of the relatively large quantity of fill material involved.

(Continued from p. 194)

STANDARDS FOR MARKING AND SIGNING NO-PASSING ZONES

No-passing zones for traffic in either direction on a highway, as defined by the Special Committee on Administrative Design Policies, shall be marked by an auxiliary or barrier stripe placed to the right of the normal centerline, i. e., in the lane of traffic that it is to govern.

The barrier stripe shall be a solid yellow line. In order that the barrier line shall be distinctive, the normal centerline shall be either white or black. It may be of solid or broken type.

The barrier line shall not be narrower than the normal centerline, nor in any case less than 4 inches wide. It should preferably be at least 6 inches wide.

The barrier line shall be separated from the normal centerline by a distance equal to half the width of the centerline.

The combination no-passing stripe shall be identical as applied to both two-lane and three-lane roads.

On a two-lane road the no-passing marking shall separate the two lanes throughout the no-passing zone. On a three-lane road the combination no-passing stripe shall start from the left-hand lane-marking line and extend at an angle of not less than 20 to 1 across the center lane to meet the right-hand lane line at the beginning of the no-passing zone, and thence will extend along the lane line to the end of the zone.

The same design of no-passing stripe shall be used for all types of no-passing restrictions.

The use of signs in addition to the above specified markings to designate no-passing zones shall be governed by local legal requirements or otherwise at the option of the State, but when signs are used they shall conform to the specifications set forth in the Manual on Uniform Traffic Control Devices for Streets and Highways.

(*Continued from p. 196*)

batteries. Consequently, there are no troubles from power failures, short circuits, or the other difficulties commonly experienced in the operation of electrical apparatus. Nor is it necessary that the watch used be an accurate timepiece. Almost any type of watch will prove satisfactory. Clocks, pedometers, or specially constructed counting units might also be used instead of a watch. The watch and rubber tube are the only parts of the counter apt to wear. The most delicate parts of the watch have been removed and the rest receive a negligible amount of wear as compared to their use in a timepiece. Should the watch break down and fail to operate, it can be replaced at small cost. The same type and size of rubber tube may be used in connection with this counter as is employed in other electrical counters using a rubber tube as the detector.[1]

The entire unit is enclosed in an airtight, watertight case that is small enough to be placed or buried on the shoulder of a highway without constituting a traffic hazard. The preferable means of installation, requiring only a few minutes, consists of mounting the counter on the back of a guardrail post or special stake beyond the shoulder where it will be inconspicuous. To prevent tampering with the counter when in operation on a highway, it could be placed in a suitable box having a lock, or extensions could be built on the top and base to enable both to be padlocked to a fixed mounting such as a guardrail or pole.

The far end of the rubber tube should be sealed to prevent the entrance of moisture or dust and for the proper operation of the counting unit.

Care must be exercised in selecting the place of installation on the highway for which a traffic count is desired. Places where the traffic is apt to stop, such as near a traffic signal, or where exceptionally high speeds are common, should be avoided. The best results will be obtained if the rubber tube is placed where the surface is hard and has a smooth, uniform cross-section. On gravel or dirt roads, the installation should be made at culverts, bridges, or other places where the drainage is good and the surface smooth. Places close to intersections where vehicles are apt to pass over the tube at an angle should be avoided as each wheel is apt to cause a separate air impulse, resulting in excessive counts.

Several counts have been made to check the accuracy of the unit. As shown in table 1, the traffic count indicated by the counter was only 0.9 of 1 percent less than the traffic as revealed by a manual count taken simultaneously on a two-lane highway. Part of the error for the individual 5-minute periods was undoubtedly caused by the difficulty of reading the second hand accurately at night. For the two lanes in one direction on a four-lane divided highway where speeds were exceptionally high, the error was −3.8 percent as shown by table 2. The major portion of this error was caused by the wheels of two vehicles traveling in the same direction striking the rubber tube simultaneously creating only one air impulse for two axles with the result that only one or one and one-half counts were registered for the two vehicles depending upon whether one or both axles of the two vehicles passed over the tube at the same instant. This, however, is a fault common to the other types of automatic traffic recorders.

[1] See footnote 1, p. 195.

TABLE 1.—*Comparison of mechanical and manual counts of traffic to check accuracy of watch counter on 2-lane highway*

Time (p. m.)	Manual count	Watch counter	Error
	Vehicles	*Vehicles*	*Percent*
8:45–8:50	54	55	+1.9
8:50–8:55	52	51	−1.9
8:55–9:00	56	54	−3.6
9:00–9:05	43	42	−2.3
9:05–9:10	37	38	+2.7
9:10–9:15	49	48	−2.0
9:15–9:20	28	26	−7.1
9:20–9:25	47	49	+4.3
9:25–9:30	40	40	0
9:30–9:35	28	28	0
9:35–9:40	38	38	0
9:40–9:45	45	45	0
9:45–9:50	35	35	0
9:50–9:55	56	55	−1.8
9:55–10:00	63	61	−3.2
8:45–10:00	671	665	−0.9

TABLE 2.—*Comparison of mechanical and manual counts of traffic to check accuracy of watch counter on 4-lane divided highway—1-direction traffic only*

Time (p. m.)	Manual count	Watch counter	Error
	Vehicles	*Vehicles*	*Percent*
5:25–5:30	37	37	0
5:30–5:35	90	85	−5.6
5:35–5:40	18	18	0
5:40–5:45	34	32	−5.9
5:45–5:50	33	31	−6.1
5:50–5:55	33	32	−3.0
5:55–6:00	42	41	−2.4
5:25–6:00	287	276	−3.8

The use of one counting unit on each end of the tube with a dead space of 5 feet at the center formed by plugs in the rubber tube is recommended for obtaining accurate counts on four-lane undivided highways carrying heavy traffic volumes.

As yet only a few counters have been made in the shops of the Administration for testing and development purposes. These models are being thoroughly tested. The counter is not yet available through commercial sources, although it is expected that it will soon be made available at a low price. Application for a patent has been made in the name of the author. The application guarantees free use of the invention by or for the Federal Government.

STATUS OF FEDERAL-AID HIGHWAY PROJECTS

AS OF NOVEMBER 30, 1939

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 3,218,451	$ 1,547,890	171.1	$ 6,853,609	$ 3,406,663	199.6	$ 769,690	$ 381,640	20.9	$ 2,401,970
Arizona	1,452,892	1,031,348	71.6	1,708,823	1,151,634	81.7	385,779	238,721	25.6	516,121
Arkansas	4,879,438	3,861,773	226.0	527,180	407,619	15.3	1,275,964	667,932	53.7	291,074
California	4,409,635	2,408,420	71.2	4,130,491	2,202,913	58.4	1,327,309	695,549	40.1	2,357,057
Colorado	2,182,539	1,206,875	60.2	3,115,307	1,743,743	66.9	166,665	57,849	5.1	1,596,739
Connecticut	357,558	176,334	5.1	1,964,755	977,627	19.9				1,237,956
Delaware	625,675	297,212	23.7	1,169,783	582,478	14.7	181,020	90,510	.1	1,019,316
Florida	595,100	296,978	8.1	3,810,114	1,904,832	66.2	894,037	447,019	24.1	2,306,661
Georgia	3,143,540	1,566,737	171.6	5,919,669	2,959,835	329.4	1,929,157	964,579	60.1	4,814,681
Idaho	1,749,756	1,050,550	101.1	1,113,339	677,696	50.4	337,570	205,639	36.8	980,872
Illinois	5,855,313	2,918,619	135.5	7,173,759	3,585,637	143.1	3,666,958	1,832,085	59.4	1,298,077
Indiana	2,358,830	1,177,351	38.9	6,209,533	3,098,360	140.2	418,794	209,322	8.6	1,814,169
Iowa	3,342,987	1,559,524	166.8	3,868,035	1,677,848	117.3	206,441	96,900	8.3	829,304
Kansas	2,786,800	1,385,688	157.4	2,256,696	1,127,469	104.5	3,162,223	1,578,251	141.4	3,797,902
Kentucky	2,222,696	1,100,489	76.0	2,905,069	1,450,979	67.2	906,765	453,382	22.9	2,696,361
Louisiana	318,148	156,000	10.8	12,078,255	3,088,003	49.7	1,743,135	854,401	50.6	2,276,974
Maine	2,136,361	1,064,144	51.2	768,470	384,235	17.9	13,240	6,620	.5	299,510
Maryland	1,535,408	732,386	23.9	2,536,873	1,250,055	39.5	290,000	139,500	3.9	1,791,766
Massachusetts	3,134,614	1,564,618	25.1	647,015	322,744	4.5	1,243,094	619,260	7.6	2,519,340
Michigan	2,960,062	1,444,239	72.2	3,759,484	1,879,550	125.7	988,800	393,833	15.7	2,517,094
Minnesota	3,914,504	1,940,162	289.7	5,296,979	2,628,778	239.6	1,014,974	506,543	61.9	2,989,091
Mississippi	948,200	314,460	48.4	8,876,358	3,373,795	349.4	599,600	281,500	16.7	2,046,592
Missouri	2,057,951	1,025,912	90.4	4,672,196	2,300,928	154.2	2,901,785	1,178,505	91.9	3,817,983
Montana	2,904,884	1,643,395	183.1	2,201,558	1,247,360	95.5	1,146,906	650,524	95.6	3,116,217
Nebraska	2,026,959	1,008,037	152.0	5,387,012	2,692,858	509.8	2,020,874	865,555	209.1	2,466,508
Nevada	1,072,038	920,633	53.0	794,720	682,311	32.1	354,046	304,152	21.0	603,242
New Hampshire	672,826	330,405	22.3	788,650	387,136	17.1	86,349	42,787	3.4	966,248
New Jersey	400,110	191,531	3.6	4,583,898	2,290,399	34.7	21,340	10,670		1,828,184
New Mexico	1,724,537	1,061,409	127.5	699,730	427,787	24.3	844,449	527,020	80.7	817,582
New York	7,338,759	3,636,849	145.2	12,153,702	5,921,777	185.3	1,727,650	707,345	22.5	486,360
North Carolina	3,249,800	1,622,510	204.6	5,839,388	2,912,602	304.5	916,776	442,320	39.4	1,111,227
North Dakota	209,510	112,244	35.5	1,308,595	701,251	84.2	2,177,590	1,167,133	238.4	3,364,995
Ohio	4,339,108	2,169,554	53.5	7,648,308	3,741,420	79.1	5,556,180	2,641,370	41.7	4,448,560
Oklahoma	1,482,682	787,107	64.9	2,653,866	1,407,649	91.7	2,424,065	1,259,142	84.6	2,888,761
Oregon	1,929,375	1,150,917	100.9	2,693,391	1,548,570	86.7	1,320,017	689,370	39.3	712,328
Pennsylvania	7,120,590	3,525,680	86.3	6,821,050	3,255,169	63.5	2,595,332	1,276,222	29.7	3,068,718
Rhode Island	601,970	300,865	7.8	872,308	435,441	8.3	78,630	39,315	.6	868,267
South Carolina	1,418,740	639,800	64.1	1,646,174	729,986	43.3	642,190	284,300	55.9	2,118,597
South Dakota	3,067,499	1,696,689	287.8	2,948,430	1,650,140	324.1	1,425,600	801,010	167.4	2,622,059
Tennessee	3,017,948	1,437,042	65.8	3,030,140	1,515,070	68.2	1,836,086	918,043	29.2	2,927,279
Texas	9,112,388	4,478,606	518.7	7,094,407	3,527,453	300.7	6,136,489	2,847,438	286.7	3,318,462
Utah	1,887,504	1,353,102	93.0	972,930	679,480	51.1	130,005	93,854	1.6	646,965
Vermont	737,850	361,494	18.4	716,604	358,112	22.7	73,574	36,765	3.0	313,059
Virginia	1,814,930	905,368	59.7	2,470,351	1,186,457	57.7	1,390,074	687,578	37.4	564,334
Washington	1,968,390	1,011,949	33.3	2,726,010	1,301,339	15.6	1,611,317	681,928	24.4	268,439
West Virginia	893,827	483,575	28.5	2,579,755	1,307,114	64.2	733,160	362,275	19.0	1,812,332
Wisconsin	4,769,973	2,344,836	167.4	5,384,113	2,646,310	171.5	154,090	74,165	4.6	1,644,069
Wyoming	1,443,264	895,934	133.0	1,079,572	670,788	112.0	674,561	426,466	45.0	195,323
District of Columbia	137,000	68,500	.8	265,124	132,562	1.9	235,200	117,600	2.3	168,838
Hawaii	141,181	66,938	1.3	1,001,292	488,062	16.4	571,890	282,525	9.8	1,054,625
Puerto Rico	655,310	326,655	13.8	1,357,219	671,980	25.6				376,160
TOTALS	122,325,410	64,359,333	4,821.8	179,080,089	86,700,004	5,347.1	61,307,440	30,136,412	2,348.2	90,994,348

STATUS OF FEDERAL-AID SECONDARY OR FEEDER ROAD PROJECTS

AS OF NOVEMBER 30, 1939

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 215,805	$ 106,600	22.2	$ 961,062	$ 375,050	20.6	$ 67,300	$ 33,650	6.9	$ 709,956
Arizona	198,802	143,374	21.8	99,081	70,942	11.6				325,941
Arkansas	766,428	634,097	70.9	199,605	195,349	24.3	57,560	46,863	5.0	140,811
California	937,631	481,788	40.9	383,054	209,124	9.6	158,068	84,262	3.7	586,359
Colorado	704,902	368,820	25.7	330,983	186,024	10.9				31,948
Connecticut	163,280	67,660	2.9	110,274	54,954	.2				239,855
Delaware	80,840	40,420	17.5	69,537	34,768	7.8				233,447
Florida	286,228	138,856	8.8	710,218	354,651	28.9				371,538
Georgia	229,297	111,062	28.0	269,282	134,641	31.3	355,825	177,913	43.2	964,360
Idaho	310,116	187,461	35.9	226,382	115,065	16.0	88,451	49,635	6.0	84,713
Illinois	1,040,407	517,575	48.5	1,018,000	455,000	73.8	878,550	437,975	38.4	268,727
Indiana	749,553	371,415	61.3	442,370	219,981	34.7	112,122	56,050	9.4	641,861
Iowa	88,190	41,004	44.1	865,421	409,200	113.1	637,523	300,000	104.2	929,603
Kansas	78,622	39,311	43.9	174,250	87,125	4.3	539,934	269,967	20.4	1,185,543
Kentucky	511,845	158,063	52.5	1,135,905	349,982	56.0	377,638	116,918	39.6	223,613
Louisiana	668,295	313,982	57.9	266,920	125,888	20.9	234,263	107,856	18.7	284,846
Maine	432,057	215,560	25.4	68,900	33,244	3.5	8,300	4,150	.5	7,660
Maryland	204,891	98,787	16.0	124,696	50,348	4.8	132,000	48,355	9.3	338,191
Massachusetts	313,052	155,673	7.6	344,720	170,445	7.6	190,910	94,705	4.2	368,845
Michigan	836,852	409,248	64.0	1,078,982	539,491	81.3	38,400	19,200	7.9	769,295
Minnesota	513,256	254,584	35.3	654,706	327,353	95.6	223,841	68,041	21.5	1,008,527
Mississippi	176,500	88,250	6.8	828,662	408,046	68.3	314,260	157,080	17.8	497,490
Missouri	715,897	346,306	101.0	725,253	333,413	70.4	145,614	58,037	26.9	529,972
Montana	746,984	423,684	68.8	102,625	58,143	2.8	177,124	100,464	20.8	749,737
Nebraska	589,903	285,221	119.5	692,092	338,871	114.6	189,161	94,580	29.9	297,651
Nevada	160,893	136,525	25.0	70,067	60,261	18.1	36,557	31,421	2.0	113,649
New Hampshire	61,156	29,708	2.3	83,280	39,815	3.1				150,441
New Jersey	298,990	146,755	10.2	277,250	138,625	14.2	75,270	37,635	.1	471,250
New Mexico	466,270	286,858	42.1	27,020	15,690		361,210	146,391	26.9	80,519
New York	1,448,311	715,796	77.5	2,008,535	957,323	58.5	91,100	45,550	.6	210,481
North Carolina	957,064	478,510	87.5	476,700	238,350	43.9	139,380	57,542	15.5	271,163
North Dakota	115,030	61,606	8.3	37,500	20,100		111,270	59,617	10.9	819,207
Ohio	457,120	227,250	27.2	673,870	343,710	27.9	802,000	401,000	27.8	1,323,392
Oklahoma	99,638	48,414	4.7	333,896	177,663	16.6	657,580	349,882	45.1	751,486
Oregon	589,088	333,232	62.3	234,760	104,050	28.8	45,249	27,160	7.1	274,460
Pennsylvania	1,905,307	940,977	109.3	1,320,516	654,153	46.7	237,638	118,819	8.8	169,157
Rhode Island	93,827	46,890	2.1	81,236	40,618	.2	36,060	18,030	.4	78,277
South Carolina	562,159	228,890	56.9	94,120	33,479	8.3	274,000	88,000	21.2	235,551
South Dakota	16,170	8,890	4.1	11,056	6,088					1,043,072
Tennessee	812,946	353,609	31.7	146,416	73,208	.7				759,721
Texas	1,823,247	893,485	209.7	935,698	450,765	82.6	499,600	237,885	60.2	738,198
Utah	224,185	126,765	38.5	100,365	61,098	6.2	38,880	22,000	2.1	122,199
Vermont	145,522	71,278	5.6	164,292	50,336	6.3				54,849
Virginia	632,234	306,985	65.5	126,550	63,275	6.2	310,590	136,228	17.8	172,363
Washington	585,044	304,627	43.1	277,203	145,318	16.9				218,057
West Virginia	145,150	72,575	8.3	161,665	80,832	8.6	211,788	105,894	11.5	333,195
Wisconsin	803,000	399,787	31.6	408,222	203,760	7.3	391,685	181,540	4.7	465,158
Wyoming	466,828	288,087	26.0	159,738	100,841	10.4	240,660	123,954	28.6	5,103
District of Columbia				117,692	58,346	1.2				14,779
Hawaii	89,392	44,391	3.7	206,686	103,891	4.6	164,258	82,085	6.4	89,633
Puerto Rico				224,464	109,130	12.8	55,188	27,140	2.1	60,233
TOTALS	24,518,204	12,550,691	2,010.4	20,641,777	9,967,823	1,343.0	9,706,807	4,623,474	734.1	20,816,082

STATUS OF FEDERAL-AID GRADE CROSSING PROJECTS

AS OF NOVEMBER 30, 1939

STATE	COMPLETED DURING CURRENT FISCAL YEAR					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	NUMBER			Estimated Total Cost	Federal Aid	NUMBER			Estimated Total Cost	Federal Aid	NUMBER			
			Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise			Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise			Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$538,658	$526,159	5	2		$743,712	$742,184	11			$42,800	$42,800	2		4	$792,946
Arizona						518,061	515,813	4								209,120
Arkansas	189,891	184,017	3			669,853	663,348	3			24,235	24,235	2		8	607,099
California	749,582	749,532	6			1,110,078	1,109,033	7		1	423,597	261,250	1			1,003,772
Colorado	612,531	612,529	5		11	15,924	15,924			3	36,358	32,599			11	791,132
Connecticut						184,564	172,850		1	4	9,492	9,492			3	829,223
Delaware						7,839	7,839	2			2,320	2,320			1	515,203
Florida	219,800	219,800	1			404,947	400,448	3			11,800	11,800			3	1,034,542
Georgia	143,190	143,190	5			396,847	396,847	6	1		437,342	437,342	5	4	21	1,888,641
Idaho	191,612	160,443	3			122,880	122,518	1								466,886
Illinois	2,045,535	2,044,675	13	3	43	1,633,089	1,494,717	8	1	22	1,060,122	897,330	3		32	1,256,783
Indiana	752,205	752,205	3	1	52	536,953	536,953	3		26	291,001	291,001		1	56	722,271
Iowa	365,439	344,400	10		8	503,354	452,506	4		102	597,165	562,050	2		126	743,718
Kansas	934,191	934,191	11		5	429,455	429,455	4			443,949	443,948	7		10	677,069
Kentucky	487,880	483,579	7	4	1	792,807	792,807	7			279,437	279,437	2		15	366,810
Louisiana	122,838	122,830	2			824,494	770,989	7			317,665	317,659	10			584,469
Maine	331,672	329,136	3	2		206,701	206,701	2	1		924	924			1	235,386
Maryland	24,510	15,403				240,795	240,795	2		2	161,200	161,200	1		13	810,099
Massachusetts	265,259	264,538	1	2		257,307	256,764	3			14,320	14,320	1			1,711,447
Michigan	460,359	458,019	4	2	14	1,012,900	1,012,900	5		8	209,865	209,865	2		18	1,344,758
Minnesota	277,522	274,394	1	4	12	1,682,384	1,661,460	13	2	5	8,010	8,010			2	978,333
Mississippi						611,373	611,373	8			246,200	246,200	4	1		680,628
Missouri	138,789	137,484	1	1		1,463,326	1,463,326	8	1		410,364	385,086	2	4		1,324,064
Montana	850,426	850,426	9			213,154	98,073	3			80,000	80,000	1			204,589
Nebraska	472,327	471,727	14		4	717,561	717,561	11	1	7	245,919	245,919		1	38	507,106
Nevada	175,349	175,349		2	4	33,771	33,771		1	6	7,695	7,695			3	104,241
New Hampshire	48,623	48,202	5		1	159,766	159,683	5			91,061	91,061	1			222,539
New Jersey	7,140	7,140			1	730,316	730,316	2	3		150,090	150,090	1			1,289,734
New Mexico	59,805	59,805	2			15,276	15,276				64,518	64,518	1		1	630,719
New York	1,481,630	1,477,930	4	5		2,125,512	2,087,612	9	9		439,300	401,300	2	2		3,037,532
North Carolina	714,864	682,164	4	3	26	908,480	906,080	9	3	10	371,420	371,420	2		30	581,579
North Dakota	105,450	105,450	3	1		818,489	770,087	9								467,161
Ohio	447,210	432,210	7	1		1,502,813	1,431,861	8	2		710,390	710,390	5		5	2,488,560
Oklahoma	266,738	266,738	3		32	187,025	187,025	3		11	419,200	418,300	9	1	8	1,801,271
Oregon	40,500	39,002				266,498	265,203	3								311,060
Pennsylvania						2,344,004	2,132,105	6	4		373,499	373,499	6		2	4,157,624
Rhode Island	431,385	431,385	1	3		7,406	7,406									152,459
South Carolina	246,354	212,972	5	2	7	577,216	554,880	5	4		174,275	174,275		3	26	732,323
South Dakota	207,373	207,373	2	2	16	201,265	201,265	2	1	1	47,550	47,550	1			996,027
Tennessee	79,920	79,920		1	3	786,478	786,478	3	3		6,760	6,760			2	1,339,352
Texas	1,285,296	1,254,240	13	2		2,238,728	2,187,942	17	1		426,767	392,610	4		26	1,560,047
Utah	148,711	148,648	2		48	168,188	168,188	1		58	102,610	102,610			37	177,622
Vermont	34,693	29,881			7	120,402	120,402		1		104,700	81,812		1		119,216
Virginia	587,309	498,309	6	2	17	241,181	237,281	3	1	1	94,395	94,395	2		2	839,081
Washington	201,163	199,751	2		11	136,831	136,831	1	1		196,172	196,172	1	2	1	378,313
West Virginia	64,417	64,417	2			310,434	294,674	5			20,391	20,391	1		3	968,121
Wisconsin	480,877	478,594	6		2	1,065,764	1,021,834	9	1	9	659,196	604,736	3	2	3	662,639
Wyoming	137,852	137,696	1	1	7											518,179
District of Columbia						366,812	333,268	1								47,053
Hawaii	52,950	50,320	1			134,312	134,312	3	1		6,216	6,216			1	351,772
Puerto Rico	49,040	48,840	1			345,312	343,310	8								426,676
TOTALS	17,528,865	17,215,013	177	46	332	31,092,637	30,140,274	237	44	276	9,820,290	9,280,587	84	22	512	44,646,994