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REMOVING SNOW FROM A BRICK ROAD IN OHIO

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TABLE OF CONTENTS

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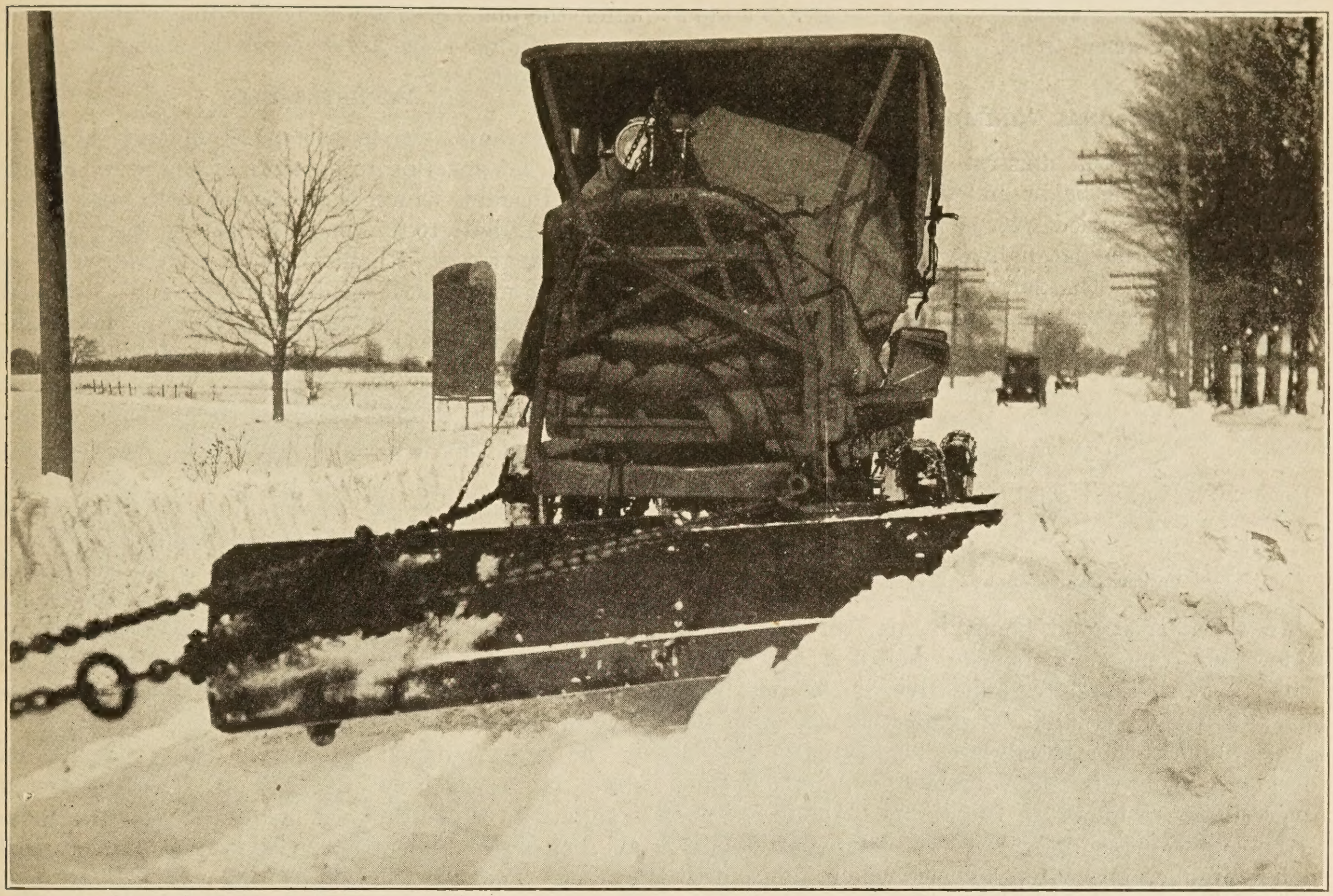
EASTERN STATES PLAN THEIR SNOW REMOVAL WORK FOR COMING WINTER

By J. L. HARRISON, Senior Highway Engineer, Bureau of Public Roads.



A CLOSE-UP OF THE SNOW PLOW IN ACTION.

MODERN production is not, generally speaking, a seasonal matter. Coal is mined, clothing is manufactured, food is made ready for consumption alike in summer and in winter. The coming of winter stops only the supply of raw products of the soil. Many, even of these products, continue to pass through the multitudinous processes which convert raw food into forms fit for consumption all through the winter.

Transportation, the servant of production, must be ready at all times to serve its master. Stoppage of transportation is equivalent to cessation of production. These facts are axiomatic—platitudinous. We all agree as to their verity.

Railroads do not abandon their shippers when snowdrifts cover their tracks. They clear away the snow. No matter what the cost, trains must be moved. Nor is this done because of any immediate profit to the railroads, for, as a matter of fact, it might often be cheaper for the roads to suspend traffic for days or even weeks at a time than to go to the enormous expense of clearing the tracks and moving trains when the snow piles high. Rather is this action based on the fact that business conditions and the number of laborers who can be kept employed are so vitally affected by even minor delays in the distribution of commodities that the railroad administrators realize that the ultimate gain that accrues is worth whatever it costs.

And so it is now coming to be with the traffic on our highways. The commerce of our country as a whole is increasingly dependent on them. Production has increased faster than the capacity of the railroads to supply transportation. True the congestion we have experienced these last few years is abnormal. Nevertheless, the railroads are not anxious to take up again the whole burden of the country's transport. Neither is it wise that they should be permitted to if they would. The motor truck will claim its own. Perhaps that means the short haul, but how short or how long none now can say. At any rate the motor truck has transformed highway freight traffic. Never again will the highway serve only the locality—the truck reaches out. Fifty miles are as 10 in the day of the horse. And such is the nature of the truck that it brooks no delay. Time saving is its raison d'être. Commodities are moved by truck because they must be moved promptly. Hence the old attitude toward highway traffic has changed. It is no longer of a kind that can be carried on at convenience—halted with indifference.

SEASONAL TONNAGE ON HIGHWAYS.

A few figures will illustrate the point. They are given in the table below and they represent the seasonal tonnage carried over a section near Rahway, N. J., of the principal highway between Philadelphia and New York. The daily tonnage carried in motor trucks (60 per cent assumed to be goods in transit) is reported as follows:

DAILY TONNAGE.

Year.	Spring.	Summer.	Autumn.	Winter.
1918	2,019	2,723	2,370	1,992
1919	2,503	2,129	2,840	2,092
1920[1]				

[1] Maximum reported one week, 9,620 tons per day.

In New Jersey and Pennsylvania, through which this route runs, snow removal is not a new thing. This table is, therefore, indicative of the relatively constant freight traffic over roads that are open the year round. Incidentally it illustrates also the decided tendency for the volume of commerce carried over the more important highways to increase.

The movement of rural products, particularly dairy products, is often almost wholly dependent on the highways. In some parts of the East, particularly where manufacturing is the principal business, factory interchange is now largely carried in trucks. Other similar and equally important matters might be mentioned. They would, however, only serve to emphasize the fact that to keep this traffic moving at all seasons of the year is vital. To do so will involve heavy expenditures, which may be open to public attack. On the other hand, to stop this traffic, especially at the present time, when it is admittedly impossible to move it in any other way than over the highways, will involve direct loss to many individuals, who are thereby thrown out of employment, as well as indirect and often unappreciated losses to business of all kinds, which will much more than offset any saving that appears to result from a failure to keep these highways open.

Having these general statements in mind, it may be of interest to note that there is very general recognition of the importance of keeping the heavy traffic routes open. Indeed, the State highway departments in those States where the snow is heavy and the traffic important are all doing whatever they can under the law to meet the situation. The plans of the various highway departments differ somewhat though their actual field methods are very similar. Hence in the subject matter which follows little is said of the field methods used by individual States. On the other hand, the plans of these States for the coming winter may be of interest, as are some of the special features of their work.

PENNSYLVANIA.

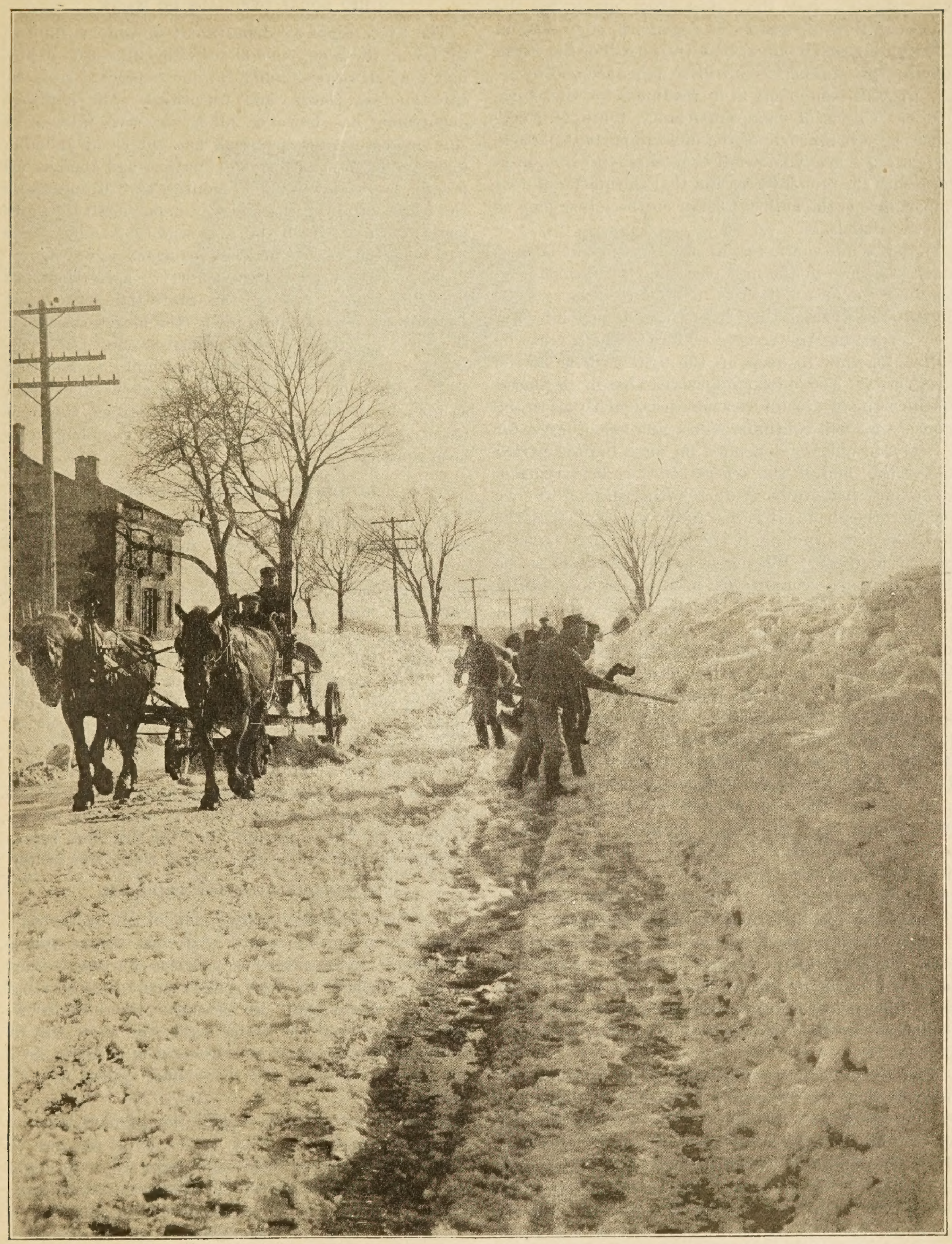
Pennsylvania, the leader in all matters of snow removal, is expecting to do more of this work during the approaching winter than has ever been attempted before. Indeed, to that end the State is equipping 75 additional trucks with snow plows and adding to its correlated mechanical facilities and its snow removal organization in a similar proportion. This additional equipment, it is assumed, will be sufficient to enable the State highway department to keep open through routes connecting all of the principal manufacturing centers and connecting with the neighboring States.

Pennsylvania is a mountainous State. Hence the snow removal problem is a difficult one. Moreover, the snowfall is heavy. However, by the liberal use of snow fences—used more liberally in this State than anywhere else in the country—it has been possible to so control drifting that the heavy trucks can keep the roads clear with a minimum of assistance in the way of handwork.

The snow-removal operations in Pennsylvania differ in no essential points from those considered standard in other States and discussed at length in another part of this article, nor is the equipment used by the Pennsylvania State highway department unusual, though the organization probably has more V-shaped plows than are found in other States. It is, however, worthy of note that by reason of the fact that the right of way is kept scrupulously clear of weeds, brush, etc., that obstructions of all sorts are removed wherever possible, and that snow fences are liberally used, the cost of snow removal is reported to be as low as from $50 to $200 per mile.

One feature of the Pennsylvania snow-removal program, not so well known as the methods of actually handling the snow, but deserving of general adoption, is the cooperative arrangement with the Weather Bureau by which the highway department is informed in advance of the approach of storms. This information is at once sent out to the field engineers, who, by reason of the exact information that is furnished both as to the intensity of the coming storm and its probable duration, are the better able to prepare for the emergency.

The patrol system of men, who are employed regularly on the highways, forms a nucleus about which a larger organization can be created whenever condi-



HAND METHODS SUPPLEMENT THE PLOW WHEN THE PILES GROW HIGH.

tions require, and the information given by the Weather Bureau assists the district engineers in determining well in advance of the arrival of the storm whether any special forces will be necessary and insuring that all equipment is in readiness for the emergency. This is of great importance, for it is everywhere agreed that one of the most important matters in fighting a heavy snowfall is getting onto the job in time with the proper forces and that the matter of next importance is the ability to stay on the job as long as the snowfall lasts.

Advance information as to storms assists in both of these matters—in the first particular by furnishing a basis for a determination as to the forces that will be needed and in the second by giving advance information concerning the reserve of forces which must be gotten together to keep up the fight as long as the storm lasts. Too much emphasis can hardly be placed on the value of this information, particularly as to the storms that will continue over a number of days, for a crew can only be depended on for a limited period every day; and if the temperature is low, replacements may have to be made at rather short intervals. On the other hand, it is absolutely essential that the plows be kept running if the final result is to be a cleared highway. Whenever a bad storm is to be faced, the only assurance of success, therefore, lies in ample reserve forces, and Pennsylvania's success in fighting the snow under very difficult conditions can be largely traced to the clear grasp that the State highway department has had of this phase of the matter.

Pennsylvania keeps the public informed as to the condition of the highways. Each patrolman is assigned to a definite section and every day reports to the district head the condition of his section. The district office telegraphs or telephones these reports both to the Weather Bureau at Pittsburgh and Philadelphia and the State highway department, where the information is tabulated and charted, and from these charts information as to the condition of the highways is given to the public either direct or through the Weather Bureau's daily bulletins.

If any point on the designated routes is blocked for more than 24 hours the headquarters organization takes a hand in the matter and men and equipment from other points are thrown in until the men and the equipment available are able to cope with the situation.

The State highway department of Pennsylvania believes that the important trunk-line highways are as important a factor in the Nation's distribution system in the winter as they are in the summer. They are important enough to build and maintain in the summer. They must, therefore, be important enough to keep open during the winter. This is, beyond a doubt, a reasonable point of view and ample defense of the liberal expenditures made to this end.

OHIO LOCAL OFFICIALS DO WORK.

The State highway department of Ohio is limited by law in its snow-removal activities by reason of the fact that all responsibility for snow removal rests on the counties, towns, and townships. The highway department has, however, taken an active interest in the matter of snow removal, has published valuable instructions in regard to this matter, and renders all possible assistance to such counties as will undertake the work. Indeed, the highway department not only loans machinery freely, but will send its own engineers to advise and assist whenever requested to do so.

There is to be a definite effort to keep open the important routes through this State this winter, but as the work must be paid for by the local authorities, the State's activities being confined to efforts to correlate the work in the different local units, to assisting with equipment, and to furnishing such supervision as may be desired by the local authorities, the final result can not be predicted until all of the plans have been completed.

NO DEFINITE PLANS IN INDIANA.

In the State of Indiana the State highway department is fortunate in having ample funds and full authority to use them in any manner that will be of assistance to the traffic and of benefit to the highway. However, snow removal has never been undertaken on a large scale, and it is thought that, generally speaking, the snowfall in this State is not heavy enough to cause much obstruction of traffic. This, coupled with the fact that the State highway department in its present form is a very young organization, explains the fact that no definite plans have as yet been made for handling this winter's snowfall. The head of the highway commission, however, states that the commission has ample authority and ample money to devote to this work and that the principal routes through Indiana will be kept open to traffic this winter.

EXTENSIVE MICHIGAN PROGRAM.

The State highway commission of Michigan did a good deal of snow-removal work last winter and is planning a more extensive program for the coming winter. Indeed, an effort will be made to keep all of the State routes open. In the north, where the snowfall is heavy and the traffic light, the snow will be rolled as often as may be necessary in order to keep the traffic moving. Farther south plows will be operated.

Michigan has already begun the preparations for winter by making a very active effort to get all obstructions cleared from the right of way, tight fences and hedges removed, and wherever possible, snow fences installed. Machinery is also being prepared.

Michigan, like all large States, faces the fact that on her State highway system some routes are of more

TRUCKS IN TANDEM WITH THE SNOW PLOW BETWEEN.

importance than others. The important routes will, of course, receive first attention, and it is fully expected that, no matter what difficulties are encountered, the through routes connecting Michigan's important centers with each other and with the adjoining States will be kept open throughout the winter.

THE ILLINOIS SITUATION.

The State highway department of Illinois is in the unique position of having under its control for maintenance only those sections of the proposed State highway system on which paving has been completed. This gives the State highway department at the present time only two routes of importance—one from Chicago north to the Wisconsin boundary line and the other from Chicago to the Mississippi River at Clinton. The snowfall in Illinois is not heavy. Indeed, only on an average of one year out of three is the fall heavy enough to obstruct traffic. Even then it is the drifting of the snow that generally causes whatever trouble there is. As there are few cuts on the Mississippi River road and none deserving of mention on the road north of Chicago, the State highway department anticipates no trouble with snow but has plenty of equipment to handle the situation should trouble arise.

The State highway department has under its control a good deal of highway; that is in short stretches which are a part of through routes now under construction. Owing to the fact that detours not under State jurisdiction have to be used in order to make any use of these short sections, detours on which it is probable that no snow-removal work will be undertaken, the State engineers hardly expect to find it necessary to handle the snow on these isolated sections during the coming winter.

NEW JERSEY'S PROGRAM.

The State highway department of New Jersey has been developing and steadily increasing its snow-removal program for some years and has plans for further increases for the coming winter. During the winter of 1919–20, 280 miles of State highway were kept clear at an expense of $77,710.43. This represents an average expenditure of $278 per mile. As might be expected, however, this average cost gives only a vague impression of the work of snow removal for the cost varies from considerably less than the average where the fall is light to much larger sums where the fall is heavy and drifting is serious. Thus, near Cranberry, on the main road between New York and Philadelphia, $4,326.99 was spent in keeping a short stretch of highway open during February alone. In this case ice as well as snow had to be removed, the work having been seriously complicated by the drainage conditions in this region.

For the coming winter plans are being laid to keep all of the State highway routes—about 700 miles—open to traffic, and equipment is being prepared to that end. Some snow fence will also be used.

In handling the snow situation in New Jersey it is customary to start clearing on a width of 30 feet or as near to that as can be obtained. The plows are ordered out as soon as from 2 to 3 inches of snow has fallen and are worked 24 hours a day while the snowfall continues. As the winter advances, particularly if the snowfall is heavy and the weather uniformly cold, the width worked over gradually narrows down until only about 18 feet is kept clear. This permits two-way traffic at all times, which is felt to be of importance not only because it facilitates the movement of the traffic but because it prevents the formation of the snow ruts that are so destructive of certain types of pavement.

IN MASSACHUSETTS.

Snow removal in Massachusetts is a new thing, the legislature having only recently appropriated $50,000 to be used in assisting in the removal of the snow on important routes. The Massachusetts law does not contemplate that the State shall bear the whole cost of snow removal, hence, the relatively small appropriation, but appears to contemplate a general supervision of activities, the cost of which will be paid from other than State funds.

Massachusetts, indeed, all of New England, is the seat of numerous large manufacturing enterprises. The freight problem is not, therefore, the long-haul problem, as it is known in most parts of the country, but a problem of plant interchange on a large scale. This arises from the fact that relatively few factories take the raw material delivered from a distance and turn out the completed article of commerce. To illustrate, few shoe factories take the hide, tan it, dye it, etc., and finally convert it into shoes. Rather the hide is tanned at one point, often moved a considerable distance to a dye plant for further treatment, and only sent to the shoe factory for final manipulation. It often happens that the tannery, the dye plant, etc., are owned by the corporation that owns the shoe factory, but the fact that they are separated, often by considerable distances, creates a problem in interplant transportation which resembles the problem of handling partially completed units in a large factory more than it does the problem of the bulk transportation of raw products.

Working on the basis of the facts above outlined as the salient feature in the Massachusetts situation, though by no means overlooking any of the other factors in the traffic situation, the Massachusetts State highway commission has set out to solve the snow-removal problem by cooperative agreement with those interests most directly affected by any closure of these highways—the large factories and the large trucking companies. To these companies, as well as to the larger towns and the cities, the highway commission is pointing out the advantages of a cooperative effort toward keeping the highways clear and securing agreements with such organizations as will cooperate, these agreements covering fixed sections of the routes that are to be kept open. Under these agreements the State will supply the plows and hold them at definite points, where, on notice from the State's engineers, and regardless of the day or the hour, they are to be picked up by the trucks owned by the cooperating agencies and kept on the road as shall be needed in keeping the assigned sections clear. Under this arrangement the cost of the supervision falls to the State, but the cost of operating the trucks is borne by the cooperating agencies. The scheme is unique, but under the peculiar conditions existing in Massachusetts, and with the excellent supervision that the connection of the Massachusetts State highway commission with this enterprise is bound to insure, it ought to prove successful.

CONNECTICUT.

The State Highway Department of Connecticut removes snow from the State highways, paying for the cost from its maintenance funds which are secured from the license fees from automobiles. The State has battled with the snow, with greater or less success, for the past three or four years, and will carry on the work during the coming winter as in the past. Sufficient equipment is available to take care of the ordinary snowfalls, and the labor required will be supplied from the regular forces employed by the maintenance department. Last year snow was removed from about 1,000 miles of road and it is confidently expected that the same program will be carried out this year.

MARYLAND.

Maryland has made no attempt to remove snow in previous years. Except in the mountains of the western section of the State, the snow problem is not a serious one. In that section however the snow fall is heavy and some seasons covers the ground from early fall to late spring. The Roads Commission now recognizes the need for clearing and this year is planning to keep open the roads from Washington, through Baltimore to the Delaware line, the road from Baltimore to Cumberland and Western Maryland, the boulevard from Baltimore to Annapolis, and the roads to Solomons Island and Point Lookout. At least 20 trucks of the four-wheel-drive type will be equipped with plows and held in readiness for the work on these roads.

ON NEW YORK'S ROAD SYSTEM.

The State of New York has the largest State highway system in the United States. Over $200,000,000 have been invested in this system. But, owing to the fact that the State laws place the responsibility for snow removal on the local authorities, it has, so far, been impossible to devise any method by which this $200,000,000 improvement can be kept at the disposal of the public during the winter months. The commissioner does not believe it a good policy to allow $200,000,000 worth of roads to lie idle from two to three months every year and is willing to assume the responsibility for keeping the important routes open whenever funds are made available, but can do very little toward that end under existing laws.

TOP. AFTER SEVERAL SNOWS IT WILL BE DIFFICULT TO CLEAR THE ROAD UNLESS THE EARLY FALLS HAVE BEEN MOVED WELL BACK. BOTTOM. THE CLEARING AFTER THE FIRST SNOWFALL SHOULD BE WIDE ENOUGH TO ALLOW SPACE FOR THE DISPOSAL OF THE LATER FALLS.

SNOW-REMOVAL METHODS.

The actual work of snow removal that will be done this winter is handled in pretty much the same fashion by all of the States. It is the common and the logical practice to turn this work over to the maintenance department. In most States the maintenance departments are now well organized, and the addition of snow-removal work to the previously assigned duties of the maintenance department has the advantage of making what, for the lower grades of employees, has been a seasonal occupation into a full-time position. In the long run this will have a very beneficial effect, for it will make it possible to obtain and to keep a better grade of men.

The methods used in handling this snow problem are also similar in all of the States. Indeed, they resolve themselves into two distinct groups of activities:

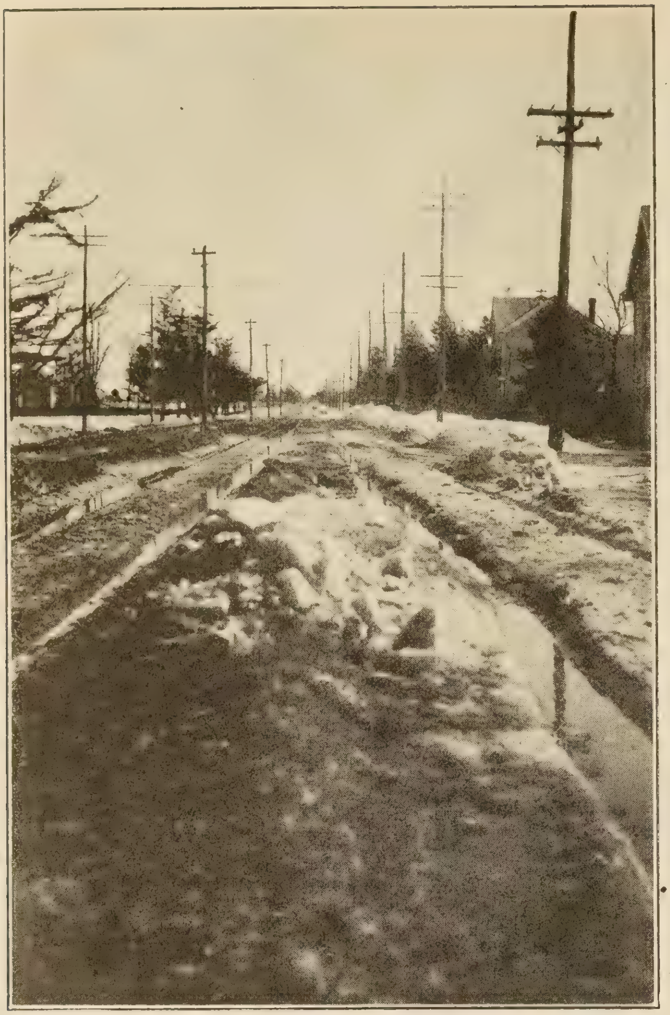
(1) The removal of snow from the highways and
(2) Preventive methods tending to keep it from blowing into the highways in objectionable quantity.

These naturally go hand in hand, but as the expense of removing snow is apt to be greater than the expense of preventing it from accumulating on the roads, the preventive methods will be treated at the greater length.

PREVENTIVE MEASURES.

Snow, of course, falls uniformly and sometimes lies as it falls. More generally, however, there is some wind in connection with a snowfall, and when this is the case there is, depending on the velocity of the wind and the character of the snowflakes, more or less drifting. Snowflakes are carried along by air currents just as sand and silt are carried by water currents. Moreover, the greater the velocity of a wind current the more snow it can carry. And herein lies the cause of drifting, for wherever an air current that is carrying snowflakes is checked some of the snowflakes are, perforce, dropped, and as this continues a drift is formed, the whole process being quite the same as that by which sand bars are formed in water currents.

It should be noted, however, that in general the snow that is moved about by the wind is not raised very far above the surface of the ground. The distance that it is raised depends, of course, on the velocity of the wind, but it is only in exceptional cases that the wind is so high that the snow is carried at an elevation which prevents the control of the area in which it will be deposited.



IF SNOW IS NOT REMOVED RUTS ARE FORMED AND THE DAMAGE TO THE HIGHWAY IS OFTEN MUCH GREATER THAN THE COST OF SNOW REMOVAL.

Snowdrifts are formed on the lee side of obstructions. This naturally follows from the fact that back of such obstructions there is a body of relatively quiet air. Indeed, the velocity of an air current may be affected for as much as 10 times the height of such low obstructions as fences, hedges, etc. From this it naturally follows that where snow is being carried by wind, low obstructions will clear the air current of snow by causing it to be deposited in a relatively quiet space back of these obstructions.

This matter has been treated at some length because of its relation to all of the means that must be adopted for preventing the formation of drifts. These begin with the removal from the right of way of everything that can cause drifting. Weeds are the most common source of trouble These should be carefully cut down and removed, for a growth of weeds or high grass, even if no more than a foot or two high, will cause drifting whenever the wind is right. Moreover, this applies even to such places as the tops of fills that would otherwise blow clear. Too much emphasis can hardly be placed on this matter, for more drifting is caused by weeds and brush allowed to accumulate along the roadway than in any other way. The weeds should, of course, be kept down by constant trimming, but if this has not been done they should at least be cleared away in the autumn and the right of way left unobstructed during the winter months.

HEDGES, FENCES, AND TREES.

Next in order of importance as causes of drifts on the highways are the hedges. These should be removed wherever experience has shown that they cause trouble. A hedge will, of course, cause drifting whenever the wind is right, but there are many regions where the winds that carry snow are so constantly from one direction that only a relatively small fraction of the hedges need to be removed to correct practically all of the trouble originating from this cause.

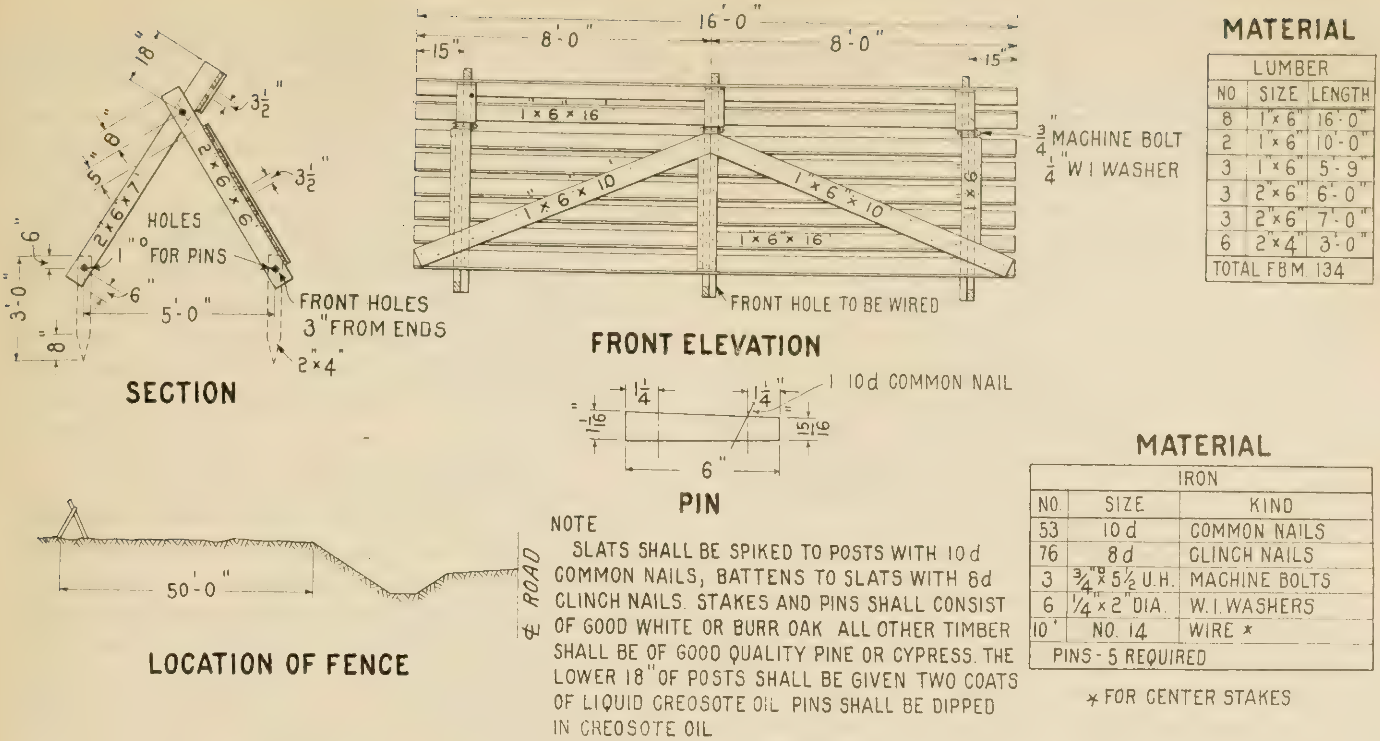
Stone fences, rail fences, picket fences, indeed, all of the tight fences, can and often do cause drifting. To reduce drifting to a minimum, such fences should therefore be taken out and wire fences erected in their places, for wire fences, being open, offer no obstruction to the wind and so do not create a condition under which snow will be deposited.

Rows of trees sometimes cause drifts to form. Where this is the case it will generally suffice to trim the branches well above the ground. Sometimes, however, this is not sufficient, and the trees themselves must be taken out. At this point measures of snow removal come into conflict with roadside beautification and home or town improvement and a problem is created that can not be solved with the snow problem solely in mind. Indeed, this same applies to some extent to the removal of fences and hedges, and, in practice, it will be found that in spite of the obvious advantage of removing such obstructions there may arise even more patent disadvantages which will prevent the complete elimination of all of these sources of trouble.

Besides the above causes of drifting there are conditions lying in the topography of the country and in the manner in which roads have been built that tend to cause drifting. A hill may affect the air currents a good deal. A cut may be so placed that it catches the flying snow. Matters of this kind can not be corrected by eliminating the cause of the drifting, however, a good deal can be done by erecting snow fences.

As has been stated above, the snow that is carried by the wind is usually carried near the ground. Where cuts drift full, or where the general contour of the country causes drifting, snow fences may be so placed that the air currents will be cleared of snow before they pass over the road.

To accomplish this, such fences should be erected on the windward side of the road and from 50 to 60



MATERIAL

LUMBER		
NO	SIZE	LENGTH
8	1" × 6"	16'-0"
2	1" × 6"	10'-0"
3	1" × 6"	5'-9"
3	2" × 6"	6'-0"
3	2" × 6"	7'-0"
6	2" × 4"	3'-0"
TOTAL F.B.M. 134		

MATERIAL

IRON		
NO.	SIZE	KIND
53	10 d	COMMON NAILS
76	8 d	CLINCH NAILS
3	¾" × 5½ U.H.	MACHINE BOLTS
6	¼" × 2" DIA.	W. I. WASHERS
10'	NO. 14	WIRE *
PINS - 5 REQUIRED		

* FOR CENTER STAKES

PORTABLE SNOW FENCE DESIGNED BY THE OHIO STATE HIGHWAY DEPARTMENT.

feet distant. These fences may be either permanent or portable, but as rural highways quite generally run through land that is used for agricultural purposes, the portable fences have the wider adaptability in highway work, for they can be set up after all crops are removed from the land and removed in the spring before the land must be worked for the next year's crop.

Snow fences are generally either of the "board fence" type (see figure) or of the picket type. The permanent fences are generally of the board type. Eight 6-inch boards, separated from 2 to 4 inches on the nailing strips, make a very satisfactory fence for this purpose, the portable fence of this type differing from the permanent installation only in that it is made up in sections of convenient length and held in place by stakes or driven posts rather than by set posts.

Picket fences are often used where a portable fence is required. The best fence of this kind is one made of light pickets held in place by a number of strands of heavy wire. Such fences can be readily erected on driven posts and when out of use rolled up and stacked where they will be out of the way.

WHERE PREVENTIVE MEASURES FAIL.

After all of these preventive measures have been resorted to, there will still remain to be handled all of the snow that lies as it falls and such minor drifting as can not be economically handled by the erection of fences and this may amount to a good deal, for, ranging from little or nothing in the southern part of the country, the normal snowfall increases to the north, until in many parts of the northeastern, northwestern, and northern Lake regions it exceeds 100 inches a year. Indeed, in the regions where there are heavy snowfalls the problem of keeping the highways clear is a serious one even after all preventable drifting has been eliminated, and it is not an easy one to handle though the snowfall is only moderate.

There are really only two methods of keeping roads open to traffic where the snow is heavy—the compaction method and the removal method.

OPENING ROADS BY COMPACTING THE SNOW.

Solving the snow problem by compaction consists of rolling the road after every snowfall with a roller 6 or 8 feet in diameter and from 10 to 12 feet long. To insure that the roller shall work well, the ends must be closed. Two widths should be rolled so that vehicles can pass without either one getting off of the compacted snow.

This method does very well where the traffic is light and is composed principally of horse-drawn vehicles and possibly a few light automobiles. It is not, however, satisfactory for roads where the traffic is heavy, and is wholly unsatisfactory where many automobiles or heavy trucks must use the highway, for such vehicles are apt to lose traction, even in well-compacted snow, and to spin their drive wheels until they are as effectively stalled as on a muddy road.

This system has the added disadvantage of facilitating the formation of ruts. Even compacted snow cuts away rapidly, and as there is a tendency for each vehicle to follow its predecessor bad ruts are soon formed. Indeed, these often cut clear through to the underlying pavement, which, because all of the traffic is concentrated in two narrow wheel tracks, may be very materially damaged thereby.

It should not, however, be assumed that these snow ruts are formed only when the snow is compacted. As a matter of fact they are still more readily formed where nothing at all is done toward dealing with the snow. Indeed, one of the best reasons for removing the snow from the highways lies in the fact that where this is not done, if the traffic is of much volume, snow ruts are formed, and the damage thereby done the highway is often much greater than the cost of removing the snow would been.

REMOVAL NECESSARY ON SOME ROADS.

Where the roads must be kept clear and the traffic is such that compacting the snow is not sufficient, there remains nothing but the removal of the snow. This may be accomplished by the use of plows or by hand. Sometimes rotary plows are used, but as yet they have not been commonly adopted for this work in this country. Ultimately the writer believes that the heavier snowfalls will be handled by some form of apparatus resembling the modern elevator grader. Such a machine might be readily designed to clear the full width of the highway at a single cut and, by using a fast-moving belt, to discharge the snow well away from the line of travel and where it would tend to prevent rather than to stimulate further drifting.

The present practice in snow removal is, however, to push the snow off of the highway by means of blades similar to those used on road graders. Indeed, road graders are frequently used for this work, though the more common practice now is to fasten a heavy blade ahead of a heavy truck (the four-wheel drive type being preferred for this work) and to use the powerful driving force of the truck to push the snow off of the highway. Sometimes, and this applies particularly where the fall of snow is heavy, a second truck is used, this truck being hitched ahead of the truck that carries the plow. In this way a heavier plow can be used and the deeper snow thrown aside.

Operating in this fashion, all equipment must be kept available at all times and must be set in operation whenever the necessity arises, regardless of the day or the hour. The present practice is to start work as soon as from 2 to 3 inches of snow has fallen and to continue operations as long as the fall continues. The snow may be moved from the center to both sides, but in order to prevent drifting it is better to move all of the snow to the leeward side of the road. Even then some drifting may result from piling up the snow, but much less than will result from any piling of the snow on the windward side of the road.

The first clearings of the season should be wide enough. Indeed, the best practice is to clear at least 10 feet more than the traveled way. If an 18-foot road is being cleared this will mean that one cut should be made beyond each edge of the road surfacing where the snow is thrown to both sides, or that two cuts should be run beyond the edge of the pavement where all the snow is piled on the lee side of the road. As the season advances, this extra space will be used to store the later snowfalls. Therefore, though it appears during the early part of the winter that cutting this extra width is a considerable inconvenience, it will usually prove a time saver as well as a money saver in the end.

GET TRUCK ON JOB EARLY.

The success or failure of this system depends on getting the trucks onto the job early enough and keeping them there regardless of weather conditions. A well-driven truck can handle about 10 miles of highway. It should always be in good condition when sent out on work of this sort and particularly so when sent out on night work. At least one and preferably two assistants should accompany the driver. If a heavy blanket of snow is being moved a half dozen men with shovels should go out with the truck. Under normal operating conditions, a well-handled truck should make one cut an hour, but as it will take four full cuts to clear the necessary width at the beginning of the seasons and generally three during the later months, it will be clear that the truck must be kept in constant operation as long as the storm continues if the final result is to be an open road. However, if the trucks are set to work early and kept at work regardless of the weather, it will not often happen that other methods have to be resorted to.

On the other hand, occasions will arise when, due to high winds and the failure to provide proper snow fences, cuts will drift full in spite of all that the trucks can do; or, possibly, it might be more correct to say that, because cuts are relatively narrow if the snow drifts into them rapidly, the trucks will often be unable to find the space to store the snow that must be handled if such cuts are to be kept clear. When this happens, as it will from time to time, the usual method is to put men in with shovels and clear away the drift by hand. Work of this kind is expensive, so the temptation to clear a minimum width is strong, but the most economical width is not necessarily the minimum that will serve the traffic. If the major portion of snow removal is being handled by the trucks, in which case any further snow falling on the road must be pushed to one side as it falls, the cleared width should be wide enough to give the trucks a chance to handle the later falls when they come. Otherwise the cuts will be blocked almost at once and hand shoveling must be resorted to whenever there is a snowfall.

[Concluded on page 32.]

LAYING OUT CIRCULAR CURVES BY DEFLECTIONS FROM THE P. I.

By T. F. HICKERSON, Professor of Civil Engineering, University of North Carolina.

THE writer hopes that the tables based upon formulae given below will fill the long-felt need of a simple and time-saving method for laying out circular curves by deflections from the point of intersection of the tangents (the P. I.), thus avoiding the trouble of moving the instrument and resetting the vernier.

Referring to figure 1, P is any point on the circular arc CB and A is the point of intersection of the tangents. Also, C is the point of curve (P. C.), and B is the point of tangent (P. T.). Lines from points A and O to point P make angles of Θ and α with the line AO, these angles being plus when measured above AO and minus when below it. PN is drawn perpendicular to AO. The deflection angle is called Δ.

$$Tan\ \Theta = \frac{PN}{AN} = \frac{R sin \alpha}{E + R - R cos \alpha} = \frac{R sin \alpha}{R(sec \frac{1}{2}\Delta - 1) + R - R cos \alpha}$$

Hence,

$$tan\ \Theta = \frac{sin \alpha}{sec \frac{1}{2}\Delta - cos \alpha} \qquad (1)$$

Formula (1) shows that for a given value of Δ, the angle Θ is independent of the radius of the curve or the length of curve.

Imagine the curve divided into *10 equal parts*, then formula (1) gives the deflections to these points of division as follows:

$$\alpha = \tfrac{4}{10}\Delta,\ tan\ \Theta_1 = \frac{sin \frac{4}{10}\Delta}{sec \frac{1}{2}\Delta - cos \frac{4}{10}\Delta},$$

$$\alpha = \tfrac{3}{10}\Delta,\ tan\ \Theta_2 = \frac{sin \frac{3}{10}\Delta}{sec \frac{1}{2}\Delta - cos \frac{3}{10}\Delta},$$

$$\alpha = \tfrac{2}{10}\Delta,\ tan\ \Theta_3 = \frac{sin \frac{2}{10}\Delta}{sec \frac{1}{2}\Delta - cos \frac{2}{10}\Delta},$$

$$\alpha = \tfrac{1}{10}\Delta,\ tan\ \Theta_4 = \frac{sin \frac{1}{10}\Delta}{sec \frac{1}{2}\Delta - cos \frac{1}{10}\Delta},$$

$$\alpha = 0,\ \Theta_5 = 0$$

$$\alpha = -\tfrac{1}{10}\Delta,\ \Theta_6 = -\Theta_4$$

$$\alpha = -\tfrac{2}{10}\Delta,\ \Theta_7 = -\Theta_3$$

$$\alpha = -\tfrac{3}{10}\Delta,\ \Theta_8 = -\Theta_2$$

$$\alpha = -\tfrac{4}{10}\Delta,\ \Theta_9 = -\Theta_1$$

$$\alpha = \tfrac{5}{10}\Delta,\ \Theta_{10} = -\tfrac{1}{2}(180 - \Delta)$$

Values of Θ_1, Θ_2, Θ_3, etc., computed by means of the above formulae for different values of Δ show that they change *uniformly* with Δ; so that interpolation gives results as closely as one minute for ranges of 1° in Δ.

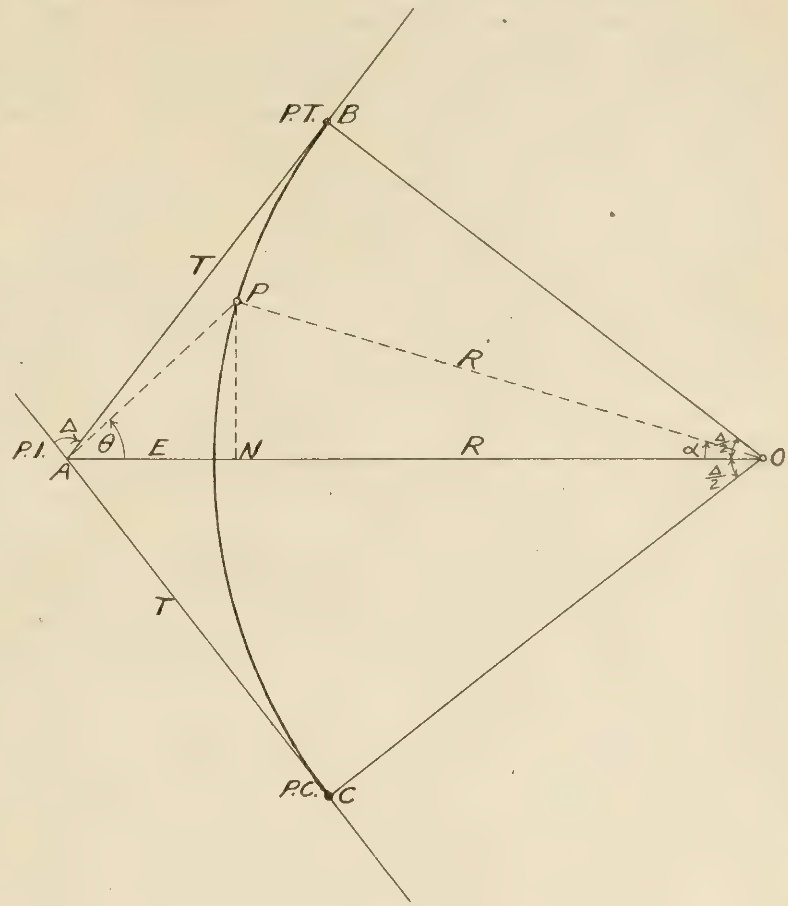


FIG. 1

For convenience in laying out curves without resetting the vernier, these directions to points on the curve are referred to the first tangent, the line CA produced.

Instrument at the P. I., and vernier reading $\Delta°$ on the P. T., we have:

Deflection to point (1) $= \Delta + \frac{1}{2}(180° - \Delta) - \Theta_1$

$= 90° + \frac{1}{2}\Delta - \Theta_1$

(2) $= 90° + \frac{1}{2}\Delta - \Theta_2$

(3) $= 90° + \frac{1}{2}\Delta - \Theta_3$

(4) $= 90° + \frac{1}{2}\Delta - \Theta_4$

(5) $= 90° + \frac{1}{2}\Delta$

(6) $= 90° + \frac{1}{2}\Delta + \Theta_4$

(7) $= 90° + \frac{1}{2}\Delta + \Theta_3$

(8) $= 90° + \frac{1}{2}\Delta + \Theta_2$

(9) $= 90° + \frac{1}{2}\Delta + \Theta_1$

(10) $= 180°$.

It should be noted that the following pairs of deflections add up to $180° + \Delta°$: (1) + (9), (2) + (8), (3) + (7), and (4) + (6).

Using the above formulae, deflection tables have been compiled for all values of the angle Δ varying by 1° from 3° to 128°. This covers all cases that are likely to occur in locating curves for roads and streets.

Figure 2 is a graphical verification of the fact that for a fixed Δ the deflections to points of equal division on a curve remain constant for any length of the curve. This makes the method perfectly general.

The order of procedure in laying out a curve is as follows: (1) Set up the instrument at the P. I., back sight on the first tangent with vernier reading 0°, reverse the telescope, unclamp the vernier, and fix the line of sight on the second tangent, the vernier giving the deflection angle $\Delta°$; (2) decide what length of curve to use (determined usually either by the desired external distance E or the tangent length T); (3) compute T and E, using either the well-known table of tangents and externals for a 1° curve, or, preferably, the tangents and externals for a 100-foot curve (Table II); (4) lay off the tangent length locating the end of the curve (the P. T.); (5) divide the length of curve by 10 and locate each of the 10 points, or every other one, or every third one, etc., depending upon how many are needed to properly define the curve, by starting at the P. T. (or P. C.) and getting the intersection of the end of the chord with the line of sight from the instrument at the P. I., according to deflections read directly from the tables (Table I).

The middle point, or the fifth point of the curve, can not be located precisely by intersections since the end of the chord would be moved in an arc tangent to the line of sight. This point can be located exactly and independently by measuring the external distance E from the P. I., and this serves as a check. If only the second, fourth, sixth, eighth, and tenth points are located, then it is not necessary to know E.

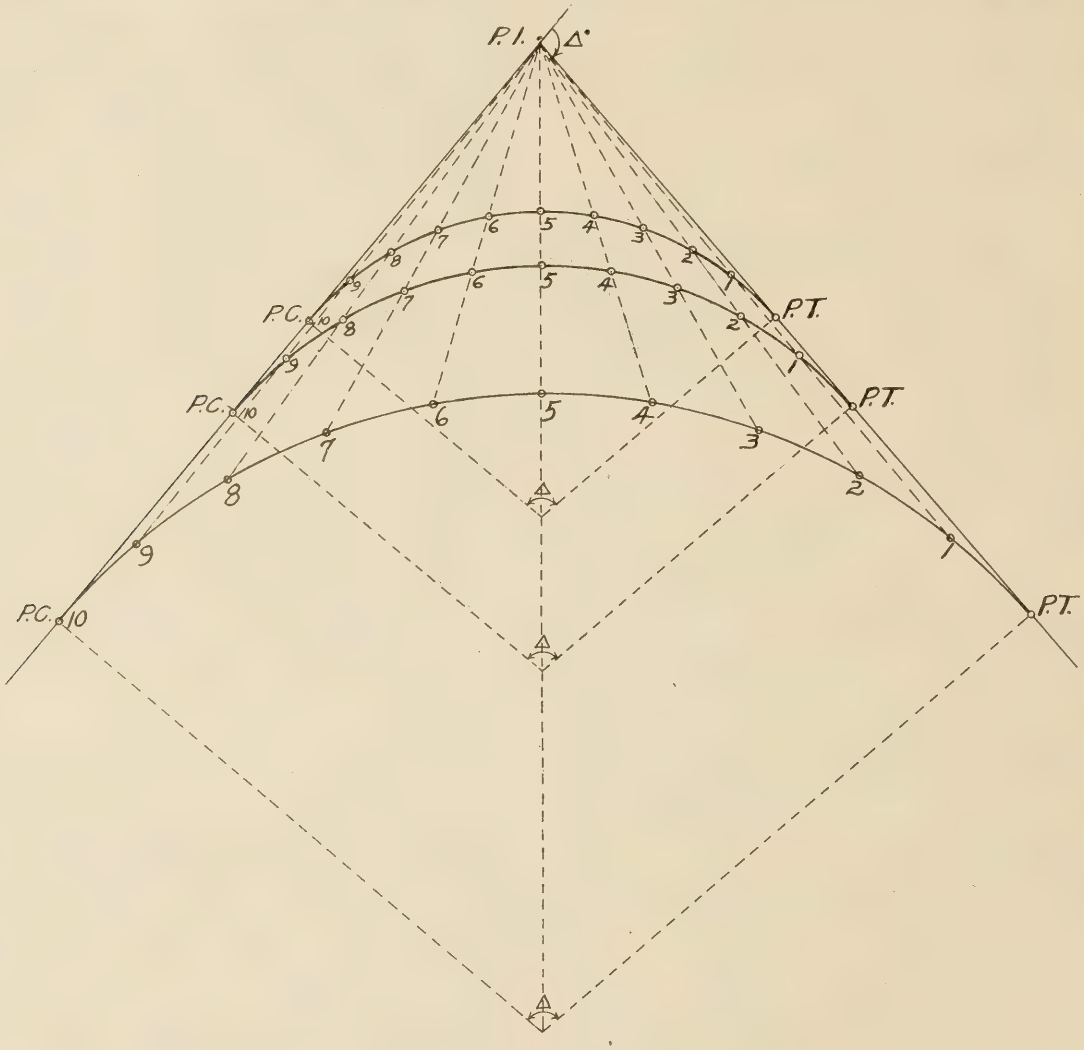


FIG. 2.

The beginning of the curve (the P. C.) is located as the tenth point by a deflection, which is always 180°. The station number of the P. C. is known, hence its location can be checked by measuring the plus distance back to the preceding station. This method avoids measuring the tangent distance from the P. I. in order to locate the P. C.

It should be noted that the curve can be located by starting at the P. C. instead of the P. T., the deflection to the first point being the same as that to the ninth point as given by Table I, etc.

If part of the curve is not visible from the P. I., say, that beyond the sixth point, the instrument may be moved to the sixth point and the remaining points located by deflections from any preceding chord. Thus, suppose the instrument is set up at the sixth point and a back sight is taken to the second point, vernier reading 0°; then, after inverting the telescope, the proper deflection to locate the seventh point is:

$$\frac{4\Delta}{20}+\frac{1\times\Delta}{20}=\frac{5\Delta}{20};$$

the deflection to the eighth point is

$$\frac{4\Delta}{20}+\frac{2\times\Delta}{20}=\frac{6\Delta}{20}, \text{ etc.}$$

In general, if the instrument is set up at the rth point of the curve and a back sight is taken to the kth point, then the deflection to the $(r+1)$th point equals

$$\frac{(r-k)\Delta}{2\times10}+\frac{1\times\Delta}{2\times10};$$

the deflection to the $(r+2)$th point equals the preceding plus $\frac{\Delta}{2\times10}$, etc.

If the P. I. is inaccessible or invisible from the curve, then the instrument is set up again at the P. C. and the points of equal division along the curve are located by deflections from the tangent. Thus if the curve is divided into 10 equal parts the deflections are as follows:

Deflection to first point $=\frac{\Delta}{2\times10}$

Deflection to second point $=\frac{2\Delta}{2\times10}$

Deflection to third point $=\frac{3\Delta}{2\times10}$, etc.

Recently the writer was in charge of a party that surveyed 22 miles of Federal-aid highways in hilly and mountainous country, and the following facts were observed: (1) Not a single case of inaccessible P. I. occurred; (2) along 86 per cent of the curves the P. I. was visible throughout; (3) in only 42 per cent of the curves was the P. T. visible from the P. C. This means that 86 per cent of the curves could have been laid out completely with the instrument set only once (at the P. I.), whereas 58 per cent of them actually required the instrument to be set up three times. The first 11 miles was in fairly open country along the general direction of an old road. Here 96 per cent of the curves were visible throughout from the P. I., but 70 per cent of the P. T. points were not visible from the P. C. The other 11 miles of the survey was partly in a dense forest and not along an old road.

Aside from the time saved in not having to move the instrument, another step in the usual operation of laying out a curve is avoided, and that is the tangent distance is not measured form the P. I. in order to locate the P. C. Curves laid out by the usual method begin and end with subchords of unequal length. This makes the deflections rather tedious to compute. The errors are cumulative, and the writer has seen the best of transit men waste time in trying to find the little error that prevented the final check.

The resident engineer can pick up the P. I. more easily than any other point, and he would find it convenient to realign the curve by deflections from this position while construction is going on, since it is apt to be beyond the grade stakes and not disturbed.

The points on the curve established by deflections according to the proposed new method are at equal and integral distances apart, but they are not full stations. The writer believes the advantages of full-station points are largely imaginary. However, the chainmen can easily locate full station points on their return trip from the P. C. to the P. T. by offsets

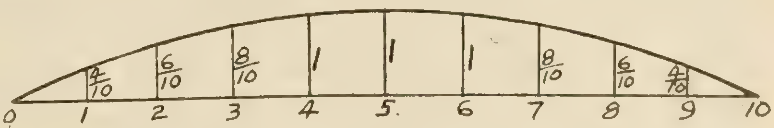


FIG. 3.

from the equal chords. The middle ordinate of the equal chords can be found in Table III, which has been compiled by the writer for the purpose. In this connection it should be remembered that middle ordinates vary practically as the square of the chords; and for any chord, the ordinates vary practically as those of a parabola. (See fig. 3.) Thus, if the middle ordinate is 1 foot the ordinate (or offset) at a point two-tenths of the chord length from the end of the chord is 0.6 foot. The middle ordinate in practice is usually less than 1 foot as will be seen later.

Before proceeding with an illustration, Table II will be explained. This table gives the externals, tangents, radii, and degree of curve for circular arcs of 100 feet in length according to values of the deflection angle ranging from 1° to 128°. It is offered as a substitute for the tables giving the functions of a 1° curve. The following formulae were used in computing the values in Table II:

$$D=\frac{100\Delta}{L}=\frac{100\Delta}{100}=\Delta$$

$$R=\frac{5729.578}{D}$$

$$T=R\tan\tfrac{1}{2}\Delta=\frac{5729.578}{\Delta}\tan\tfrac{1}{2}\Delta$$

$$E=R\tan\tfrac{1}{2}\Delta=\frac{5729.578}{\Delta}\text{ex sec }\tfrac{1}{2}\Delta$$

For curves longer than 100 feet the tabular values of the external, tangent, and radius must be multiplied, and the degree of curve divided by the ratio of the given curve length to 100. For example, suppose Δ is 24° and the length of curve to be used is 400 feet, then

$$E=5.334\times4=21.3,\ T=50.744\times4=203.0,\ D=\frac{24}{4}=6°,$$
$$R=238.8\times4=955.2.$$

Table I.—*Deflections from the P. I. to points of equal division along circular curves.*

Points.	Δ= 12°00′	Diff. 1′.	Δ= 12°30′.	Diff. 1′.	Δ= 13°00′.	Diff. 1′.	Δ= 14°.	Diff. 1′.	Δ= 15°.	Diff. 1′.	Δ= 16°.	Diff. 1′.	Δ= 17°.	Diff. 1′.	Δ= 18°.	Diff. 1′.	Δ= 19°.	Diff. 1′.
	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′
1	12 09	+1.00	12 39	+1.00	13 10	+1.01	14 10	+1.01	15 11	+1.01	16 12	+1.01	17 13	+1.01	18 13	+1.01	19 14	+1.01
3	12 48	+1.06	13 20	+1.06	13 51	+1.06	14 55	+1.06	15 59	+1.06	17 03	+1.06	18 07	+1.06	19 11	+1.06	20 15	+1.06
2	14 41	+1.22	14 17	+1.22	15 53	+1.21	17 06	+1.21	18 19	+1.21	19 32	+1.21	20 44	+1.21	21 57	+1.21	23 10	+1.21
4	21 18	+1.73	22 10	+1.71	23 01	+1.71	24 44	+1.69	26 25	+1.69	28 06	+1.67	29 46	+1.65	31 25	+1.64	33 04	+1.62
5	96 00	+ .50	96 15	+ .50	96 30	+ .50	97 00	+ .50	97 30	+ .50	98 00	+ .50	98 30	+ .50	99 00	+ .50	99 30	+ .50
6	170 42	− .73	170 20	− .71	169 59	− .71	169 16	− .69	168 35	− .69	167 54	− .67	167 14	− .65	166 35	− .64	165 56	− .62
7	177 19	− .22	177 13	− .22	177 07	− .21	176 54	− .21	176 41	− .21	176 28	− .21	176 16	− .21	176 03	− .21	175 50	− .21
8	179 12	− .06	179 10	− .06	179 09	− .06	179 05	− .06	179 01	− .06	178 57	− .06	178 53	− .06	178 49	− .06	178 45	− .06
9	179 51	− .00	179 51	− .00	179 50	− .01	179 50	− .01	179 49	− .01	179 48	− .01	179 47	− .01	179 47	− .01	179 46	− .01
10	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00

Points.	Δ= 20°.	Diff. 1′.	Δ= 21°.	Diff. 1′.	Δ= 22°.	Diff. 1′.	Δ= 23°.	Diff. 1′.	Δ= 24°.	Diff. 1′.	Δ= 25°.	Diff. 1′.	Δ= 26°.	Diff. 1′.	Δ= 27°.	Diff. 1′.	Δ= 28°.	Diff. 1′.
	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′
1	20 15	+1.01	21 16	+1.01	22 16	+1.01	23 17	+1.01	24 18	+1.01	25 18	+1.01	26 19	+1.01	27 20	+1.01	28 20	+1.01
2	21 19	+1.06	22 22	+1.06	23 26	+1.06	24 30	+1.06	25 33	+1.06	26 37	+1.06	27 41	+1.06	28 45	+1.06	29 48	+1.06
3	24 22	+1.20	25 34	+1.20	26 46	+1.20	27 58	+1.20	29 10	+1.20	30 22	+1.19	31 33	+1.19	32 44	+1.19	33 56	+1.19
4	34 41	+1.60	36 17	+1.60	37 53	+1.57	39 27	+1.55	41 00	+1.54	42 33	+1.52	44 04	+1.51	45 35	+1.48	47 04	+1.48
5	100 00	+ .50	100 30	+ .50	101 00	+ .50	101 30	+ .50	102 00	+ .50	102 30	+ .50	103 00	+ .50	103 30	+ .50	104 00	+ .50
6	165 19	− .60	164 43	− .60	154 07	− .57	163 33	− .55	163 00	− .54	162 27	− .52	161 56	− .51	161 25	− .48	160 56	− .48
7	175 38	− .20	175 26	− .20	175 14	− .20	175 02	− .20	174 50	− .20	174 38	− .19	174 27	− .19	174 16	− .19	174 04	− .19
8	178 41	− .06	178 38	− .06	178 34	− .06	178 30	− .06	178 26	− .06	178 23	− .06	178 19	− .06	178 15	− .06	178 12	− .06
9	179 45	− .01	179 44	− .01	179 44	− .01	179 43	− .01	179 42	− .01	179 42	− .01	179 41	− .01	179 40	− .01	179 40	− .01
10	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00

Points.	Δ= 29°.	Diff. 1′.	Δ= 30°.	Diff. 1′.	Δ= 31°.	Diff. 1′.	Δ= 32°.	Diff. 1′.	Δ= 33°.	Diff. 1′.	Δ= 34°.	Diff. 1′.	Δ= 35°.	Diff. 1′.	Δ= 36°.	Diff. 1′.	Δ= 37°.	Diff. 1′.
	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′
1	29 21	+1.01	30 22	+1.01	31 23	+1.01	32 23	+1.01	33 24	+1.01	34 24	+1.01	35 25	+1.01	36 26	+1.01	37 26	+1.01
2	30 52	+1.06	31 55	+1.06	32 59	+1.06	34 02	+1.06	35 06	+1.06	36 09	+1.06	37 13	+1.06	38 16	+1.06	39 19	+1.06
3	35 07	+1.19	36 18	+1.18	37 29	+1.18	38 39	+1.17	39 49	+1.17	41 00	+1.17	42 10	+1.17	43 20	+1.17	44 30	+1.16
4	48 33	+1.46	50 00	+1.44	51 26	+1.43	52 52	+1.41	54 17	+1.39	55 40	+1.38	57 03	+1.35	58 24	+1.34	59 44	+1.33
5	104 30	+ .50	105 00	+ .50	105 30	+ .50	106 00	+ .50	106 30	+ .50	107 00	+ .50	107 30	+ .50	108 00	+ .50	108 30	+ .50
6	160 27	− .46	160 00	− .44	159 34	− .43	159 08	− .41	158 43	− .39	158 20	− .38	157 57	− .35	157 36	− .34	157 16	− .33
7	173 53	− .19	173 42	− .18	173 31	− .18	173 21	− .17	173 11	− .17	173 00	− .17	172 50	− .17	172 40	− .17	172 30	− .16
8	178 08	− .06	178 05	− .06	178 01	− .06	177 58	− .06	177 54	− .06	177 51	− .06	177 47	− .06	177 44	− .06	177 41	− .06
9	179 39	− .01	179 38	− .01	179 37	− .01	179 37	− .01	179 36	− .01	179 36	− .01	179 35	− .01	179 34	− .01	179 34	− .01
10	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00

Points.	Δ= 38°.	Diff. 1′	Δ= 39°.	Diff. 1′.	Δ= 40°.	Diff. 1′.	Δ= 41°.	Diff. 1′.	Δ= 42°.	Diff. 1′.	Δ= 43°.	Diff. 1′.	Δ= 44°.	Diff. 1′.	Δ= 45°.	Diff. 1′.	Δ= 46°.	Diff. 1′.
	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′
1	38 27	+1.01	39 28	+1.01	40 29	+1.01	41 29	+1.01	42 30	+1.01	43 30	+1.01	44 31	+1.01	45 32	+1.01	46 32	+1.01
2	40 22	+1.05	41 26	+1.05	42 29	+1.05	43 32	+1.05	44 35	+1.05	45 38	+1.05	46 41	+1.05	47 44	+1.05	48 47	+1.05
3	45 39	+1.16	46 49	+1.15	47 58	+1.15	49 07	+1.15	50 16	+1.15	51 25	+1.14	52 33	+1.14	53 41	+1.14	54 49	+1.13
4	61 04	+1.31	62 23	+1.30	63 41	+1.28	64 58	+1.27	66 14	+1.25	67 29	+1.24	68 43	+1.23	69 57	+1.21	71 10	+1.20
5	109 00	+ .50	109 30	+ .50	110 00	+ .50	110 30	+ .50	111 00	+ .50	111 30	+ .50	112 00	+ .50	112 30	+ .50	113 00	+ .50
6	156 56	− .31	156 37	− .30	156 19	− .28	156 02	− .27	155 46	− .25	155 31	− .24	155 17	− .23	155 03	− .21	154 50	− .20
7	172 21	− .16	172 11	− .15	172 02	− .15	171 53	− .15	171 44	− .15	171 35	− .14	171 27	− .14	171 19	− .14	171 11	− .13
8	177 38	− .05	177 34	− .05	177 31	− .05	177 28	− .05	177 25	− .05	177 22	− .05	177 19	− .05	177 16	− .05	177 13	− .05
9	179 33	− .01	179 32	− .01	179 31	− .01	179 31	− .01	179 30	− .01	179 30	− .01	179 29	− .01	179 28	− .01	179 28	− .01
10	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00

This table gives conveniently a length of curve that will always be a multiple of 10. The chords therefore will always be an integral number of feet in length.

Example 1.

Given $\Delta = 40°\ 00'$; P. I. at Sta. $62+11.8$.
From Table II, $L=100$, $E=9.193$, $T=52.135$, $D=40°$.

Suppose local conditions are such that E should equal 46 feet approximately. Hence, ratio $=\frac{46}{9.2}=5$.
$L=500$, $E=46.0$, $T=260.7$, $D=8°$.

$\frac{500}{10}=50=$ length of each chord to be applied 10 times.

P. I. $= 62+11.8$
T. $= 2+60.7$
P. C. $= 59+51.1$
L. $= 5$
P.T. $= 64+51.1$

For $\Delta = 40°\ 00'$, the deflections are given directly in Table I, as follows:

Point.	Station.	Deflection.
P. T.	64+51.1	Δ
First	64+01.1	40° 29′
Second	63+51.1	42° 29′
Third	63+01.1	47° 58′
Fourth	62+51.1	63° 41′
Fifth	62+01.1 (E=46)	110° 00′
Sixth	61+51.1	156° 19′
Seventh	61+01.1	172° 02′
Eighth	60+51.1	177° 31′
Ninth	60+01.1	179° 31′
Tenth	59+51.1 (P. C.)	180° 00′

As a check in taking deflections from the table, it should be noted that the first + ninth = second + eighth = third + seventh = fourth + sixth $=180+\Delta=220°\ 00'$.

Example 2.

Given $\Delta = 20°20'$; P. I. at Sta. $37+18.2$.
$T=50.532$, $E=4.5$ (Table II).

Suppose $T=100=$ approx. desired length of tangent.

Ratio $=\frac{100}{50.53}=2$, say; hence $L=200$, $T=101.0$, $D=10° 10'$.

P. I. $=37+18.2$
T. $=\ \ 1+01.0$
P. C. $=36+17.2$
L. $=\ \ 2$
P. T. $=38+17.2$

$\frac{200}{10}=20$. Use 40-foot chords applied five times.

Point.	Station.	Deflection.
P. T.	38+17.2	Δ
Second	+77.2	21° 40′
Fourth	37+37.2	35° 13′
Sixth	+97.2	165° 07′
Eighth	+57.2	178° 40′
Tenth (P.C.)	36+17.2	180° 00′

Second + eighth = fourth + sixth $=200° 20'$. Check.

The quantities in Tables II and III are based on the definition that the "degree of curve" is the central angle subtended by an *arc* of 100 feet instead of a *chord* of 100 feet. The radius of a 1° curve is found by means of the following proportion:

$1°:360°=100$ feet: $2\pi R$ feet, hence

$$R=\frac{36,000}{2\pi}=\frac{36,000}{2(3.14159)}=5,729.578.$$

The middle ordinate (M) of an arc whose central angle is $\alpha°$ and whose chord is c feet, is given by the formula:

$$M=R \text{ vers } \tfrac{1}{2}\alpha \qquad (4)$$

$$\text{Also } M=\frac{c^2}{8R} \text{ approx.} \qquad (5)$$

Formula (5) shows that for any radius the middle ordinates vary as the square of the chords. The above formulæ were used in computing Table III.

Assuming the arc to be parabolic, we have a convenient relation between ordinates at any point along the chord and the middle ordinate. (See fig. 3.) For example, an ordinate at eight-tenths of the chord-length from one end of the chord is six-tenths of the middle ordinate.

In practice, the middle ordinate is usually less than 1 foot, because the chords should not exceed the limit where they vary more than 0.05 foot from the arc. Table III shows these limits to be as follows:

100-foot chords up to 6° curves; middle ordinates up to 1.31 feet.
50-foot chords up to 16° curves; middle ordinates up to 0.87 foot.
40-foot chords up to 25° curves; middle ordinates up to 0.87 foot.
30-foot chords up to 37° cnrves; middle ordinates up to 0.72 foot.
25-foot chords up to 47° curves; middle ordinates up to 0.64 foot.
20-foot chords up to 67° curves; middle ordinates up to 0.58 foot.
15-foot chords up to 100° curves; middle ordinates up to 0.49 foot.

Suppose a 30° curve is to be used. Table III shows that 30-foot chords are about the longest advisable. However, if 50-foot points along the arc are desired, then the corresponding chords must be 49.87 feet.

THE "DEGREE OF CURVE"—A PLEA FOR THE ARC DEFINITION.

Books on railroad engineering define the "degree of curve" as the central angle subtended by a *chord* of 100 feet rather than an *arc* of 100 feet. The American Railway Engineering and Maintenance of Way Association indorsed this definition in 1907 by a vote which was not unanimous. The handbooks on highway engineering by Harger and Bonney and Blanchard

TABLE II.—*Externals, tangents, radii, and degrees of curve to a 100-foot circular arc.*

Δ	E.	Diff. 10′.	T.	Diff. 10′.	R.	D.	Deflection per foot.
°						°	
1	0.218	0.036	50.001	0.001	5,730	1	0.3
2	.436	.036	50.005	.001	2,865	2	.6
3	.655	.036	50.012	.001	1,910	3	.9
4	.873	.036	50.020	.002	1,432	4	1.2
5	1.092	.036	50.032	.002	1,146	5	1.5
6	1,310	.036	50.046	.003	955	6	1.8
7	1.530	.036	50.062	.003	818.6	7	2.1
8	1.749	.036	50.081	.004	716.2	8	2.4
9	1.969	.036	50.103	.004	636.6	9	2.7
10	2.189	.036	50.127	.005	573.0	10	3.0
11	2.409	.037	50.155	.005	520.9	11	3.3
12	2.630	.037	50.184	.005	477.5	12	3.6
13	2.851	.037	50.216	.006	440.8	13	3.9
14	3.073	.037	50.251	.006	409.3	14	4.2
15	3.296	.037	50.288	.007	382.0	15	4.5
16	3.519	.037	50.328	.007	358.1	16	4.8
17	3.743	.037	50.370	.008	337.0	17	5.1
18	3.968	.037	50.416	.008	318.3	18	5.4
19	4.193	.038	50.463	.009	301.6	19	5.7
20	4.419	.038	50.514	.009	286.5	20	6.0
21	4.646	.038	50.567	.010	272.9	21	6.3
22	4.875	.038	50.624	.010	260.4	22	6.6
23	5.104	.038	50.683	.010	249.1	23	6.9
24	5.334	.039	50.744	.011	238.8	24	7.2
25	5.565	.039	50.809	.011	239.2	25	7.5
26	5.797	.039	50.876	.012	220.4	26	7.8
27	6.030	.039	50.946	.012	212.2	27	8.1
28	6.264	.039	51.020	.013	204.6	28	8.4
29	6.500	.040	51.096	.013	197.6	29	8.7
30	6.737	.040	51.175	.014	191.0	30	9.0
31	6.976	.040	51.257	.014	184.8	31	9.3
32	7.216	.040	51.342	.015	179.1	32	9.6
33	7.457	.040	51.430	.015	173.6	33	9.9
34	7.700	.041	51.521	.016	168.5	34	10.2
35	7.944	.041	51.615	.016	163.7	35	10.5
36	8.190	.041	51.712	.017	159.2	36	10.8
37	8.438	.042	51.813	.017	154.9	37	11.1
38	8.688	.042	51.917	.018	150.8	38	11.4
39	8.939	.042	52.024	.019	146.9	39	11.7
40	9.193	.043	52.135	.019	143.2	40	12.0
41	9.448	.043	52.249	.020	139.8	41	12.3
42	9.706	.043	52.366	.020	136.4	42	12.6
43	9.965	.044	52.487	.021	133.3	43	12.9
44	10.227	.044	52.611	.021	130.2	44	13.2
45	10.491	.044	52.739	.022	127.3	45	13.5
46	10.757	.045	52.871	.023	124.6	46	13.8
47	11.025	.045	53.006	.023	121.9	47	14.1
48	11.296	.046	53.145	.024	119.4	48	14.4
49	11.570	.046	53.288	.025	117.0	49	14.7
50	11.846	.047	53.435	.025	114.6	50	15.0
51	12.125	.047	53.586	.026	112.3	51	15.3
52	12.407	.047	53.740	.027	110.2	52	15.6
53	12.691	.048	53.899	.027	108.1	53	15.9
54	12.979	.049	54.062	.028	106.1	54	16.2
55	13.270	.050	54.230	.029	104.1	55	16.5
56	13.564	.050	54.402	.029	102.1	56	16.8
57	13.861	.050	54.577	.030	100.5	57	17.1
58	14.161	.051	54.758	.031	98.79	58	17.4
59	14.465	.051	54.943	.032	97.11	59	17.7
60	14.773	.052	55.133	.033	95.49	60	18.0
61	15.084	.053	55.328	.033	93.93	61	18.3
62	15.399	.053	55.527	.034	92.41	62	18.6
63	15.718	.054	55.732	.035	90.95	63	18.9
64	16.041	.055	55.941	.036	89.52	64	19.2

define the "degree of curve" as the central angle of a 100-foot arc. The writer prefers this definition because it is more logical, simpler to use in practically all calculations, and involves no more work in the field.

The real difference between the two definitions is expressed by the formulae for the radii:

$$R_1=\frac{50}{\sin \frac{1}{2}\Delta}, \text{ for "chord" definition.}$$

$$R_2=\frac{5729.58}{D}, \text{ for "arc" definition.}$$

This difference is almost negligible for very flat curves but quite appreciable for sharp curves.

If $D=1°$, $R_1=5{,}729.65$ and $R_2=5{,}729.58$. These values of R_1 and R_2 are so nearly the same that tables giving the functions of a 1° curve apply to either definition, as is indicated by the following formulæ:

Tangent $=T=R\tan\frac{1}{2}\Delta=5{,}729.6\tan\frac{1}{2}\Delta$.
External $=E=R\ \mathrm{exsec}\ \frac{1}{2}\Delta=5{,}729.6\ \mathrm{exsec}\ \frac{1}{2}\Delta$.
Long chord $=2R\sin\frac{1}{2}\Delta\quad 2\times 5{,}729.6\sin\frac{1}{2}\Delta$.

The formula for the actual length of curve: $L=100\times\frac{\Delta}{D}$ is absolutely exact according to the *arc* definition but only approximate for the *chord* definition, and departs too far from the truth for sharp curves.

To further illustrate the confusion caused by the *chord* definition, suppose $\Delta=90°$ and a 40° curve is to be used. Here $R_1=146.19$ and $R_2=143.24$, a difference of practically 3 feet. Tangent length for 1° curve $=5{,}729.6$ (Keith's Tables in back of field book). Tangent for 40° curve $=\frac{5{,}729.6}{40}=143.2$. Nominal length of curve measured along 100-foot chords $=100\times\frac{\Delta}{D}=100\times\frac{90}{40}=225$. The actual length of arc is 229.6 feet. Now, to make the tangents fit this arc, corrections must be added. In this case (for $\Delta=90°$ and $D=40°$), we find 2.94 in Table V of the field books.

Corrected tangent $=143.22+2.94=146.2$. Suppose the station number of the P. C. is $37+00$, then the number of the P. T. is $3{,}700+225=39+25$. The P. T. stake is labeled the same as it would be according to the *arc* definition, but it is 2.94 feet farther along the tangent than it should be. Hence, if this is repeated 10 times, the road is recorded as 29.4 feet shorter than it really is.

If after the P. C. and P. T. are established with the correction added, the curve is laid out by starting the measurements at the P. C., using 25-foot chords (that is, chords which are practically equal to the corresponding arcs); then the distance of 225 feet will fall short of the P. T. by about 4.6 feet. The instrument man, unless he remembers the real meaning of the "correction," will wonder what is wrong and perhaps waste time trying to find the error.

The use of the "correction" implies 100-foot chords, but chords of such great length would not properly define a 40° curve. If shorter chords are used for sharper curves, so that the chords will closely approximate the arcs (see Table III), then "corrections" for the tangents and externals are unnecessary. This suggestion was made by A. M. Wellington years ago.

Many highway engineers still make use of the "chord of 100 feet" definition in dealing with curves, but they admit considerable difficulty in laying out short radius curves. The writer has formulæ and tables for two different special methods of locating sharp curves derived by highway engineers who still use the *chord* idea. These methods are clever but far from simple.

With the "arc of 100 feet" definition and shorter chords, there is absolutely no more difficulty in locating sharp curves than flat ones.

If highway engineers adopt the "arc" definition, then the tables in the back of field books No. 361 should be revised. Table V giving "corrections" for the tangents and externals is unnecessary and very confusing. Table VI giving deflections for subchords for short radius curves is inconsistent with the *arc* definition and hence it should be left out. Table III, giving radii, middle ordinates, etc., should be enlarged to include curves as sharp as 100° and revised to agree with the "arc of 100 feet" formulæ. Table IV, giving the tangents, externals, and long chords to a 1° curve, is the same for either definition.

TABLE III.

Degree curve.	Radius.	Middle ordinates.					Chords.				
		For chords of—					For arcs of—				
		100 feet.	80 feet.	60 feet.	50 feet.	40 feet.	100 feet.	80 feet.	60 feet.	50 feet.	40 feet.
°											
1	5,730	0.2	0.1	0.1	0.0	0.0	100	80	60	50	40
2	2,865	.4	.3	.2	.1	.1	100	80	60	50	40
3	1,910	.6	.4	.2	.2	.1	100	80	60	50	40
4	1,432	.9	.6	.3	.2	.1	100	80	60	50	40
5	1,146	1.1	.7	.4	.3	.2	100	80	60	50	40
6	955	1.3	.8	.5	.3	.2	100	80	60	50	40
7	818.6	1.5	1.0	.6	.4	.3	99.94	80	60	50	40
8	716.2	1.8	1.1	.6	.4	.3	99.92	80	60	50	40
9	636.6	2.0	1.2	.7	.5	.3	99.90	79.95	60	50	40
10	573.0	2.2	1.4	.8	.5	.3	99.88	79.93	60	50	40

Degree curve.	Radius.	Middle ordinates.					Chords.				
		For chords of—					For arcs of—				
		80 feet.	60 feet.	50 feet.	40 feet.	30 feet.	80 feet.	60 feet.	50 feet.	40 feet.	30 feet.
°											
11	520.9	1.5	0.9	0.6	0.4	2	79.92	60	50	40	30
12	477.5	1.7	.9	.7	.4	2	79.91	60	50	40	30
13	440.8	1.8	1.0	.7	.4	2	79.89	60	50	40	30
14	409.3	2.0	1.1	.8	.5	3	79.87	59.95	50	40	30
15	382.0	2.1	1.2	.8	.5	3	79.85	59.94	50	40	30
16	358.1	2.2	1.3	.9	.6	3	79.83	59.93	49.95	40	30
17	337.0	2.4	1.3	.9	.6	3	79.81	59.92	49.95	40	30

Degree curve.	Radius.	Middle ordinates.					Chords.				
		For chords of—					For arcs of—				
		60 feet.	50 feet.	40 feet.	30 feet.	25 feet.	60 feet.	50 feet.	40 feet.	30 feet.	25 feet.
°											
18	318.3	1.4	1.0	0.6	0.3	0.2	59.91	49.94	40	30	25
19	301.6	1.5	1.0	.7	.4	.3	59.90	49.94	40	30	25
20	286.5	1.6	1.1	.7	.4	.3	59.89	49.94	40	30	25
21	272.9	1.7	1.1	.7	.4	.3	59.88	49.93	40	30	25
22	260.4	1.7	1.2	.8	.4	.3	59.87	49.93	40	30	25
23	249.1	1.8	1.3	.8	.5	.3	59.84	49.91	40	30	25
24	238.8	1.9	1.3	.8	.5	.3	59.84	49.91	40	30	25
25	229.2	2.0	1.4	.9	.5	.3	59.82	49.90	39.95	30	25
26	220.4	2.0	1.4	.9	.5	.3	59.81	49.90	39.95	30	25
27	212.2	2.1	1.5	.9	.5	.4	59.79	49.89	39.94	30	25
28	204.6	2.2	1.5	1.0	.5	.4	59.78	49.88	39.94	30	25
29	197.6	2.3	1.6	1.0	.6	.4	59.77	49.87	39.93	30	25
30	191.0	2.3	1.6	1.0	.6	.4	59.76	49.87	39.93	30	25
31	184.8	2.4	1.7	1.1	.6	.4	59.74	49.85	39.92	30	25
32	179.1	2.5	1.7	1.1	.6	.4	59.73	49.84	39.92	30	25

Degree curve.	Radius.	Middle ordinates.					Chords.				
		For chords of—					For arcs of—				
		50 feet.	30 feet.	25 feet.	20 feet.	10 feet.	50 feet.	30 feet.	25 feet.	20 feet.	10 feet.
°											
33	173.6	1.8	0.6	0.4	0.3	0.1	49.83	30	25	20	10
34	168.5	1.8	.7	.5	.3	.1	49.82	30	25	20	10
35	163.7	1.9	.7	.5	.3	.1	49.81	30	25	20	10
36	159.2	2.0	.7	.5	.3	.1	49.80	30	25	20	10
37	154.9	2.0	.7	.5	.3	.1	49.79	29.95	25	20	10
38	150.8	2.1	.7	.5	.3	.1	49.78	29.95	25	20	10
39	146.9	2.1	.8	.5	.3	.1	49.77	29.95	25	20	10
40	143.2	2.2	.8	.5	.3	.1	49.75	29.94	25	20	10
41	139.8	2.2	.8	.6	.4	.1	49.74	29.94	25	20	10
42	136.4	2.3	.8	.6	.4	.1	49.73	29.94	25	20	10
43	133.3	2.3	.8	.6	.4	.1	49.71	29.93	25	20	10
44	130.2	2.4	.9	.6	.4	.1	49.69	29.93	25	20	10
45	127.3	2.4	.9	.6	.4	.1	49.67	29.92	25	20	10
46	124.6	2.5	.9	.6	.4	.1	49.65	29.92	25	20	10
47	121.9	2.6	.9	.6	.4	.1	49.63	29.92	24.95	20	10
48	119.4	2.6	.9	.6	.4	.1	49.62	29.92	24.95	20	10
49	117.0	2.7	1.0	.7	.4	.1	49.60	29.91	24.95	20	10
50	114.6	2.7	1.0	.7	.4	.1	49.59	29.91	24.94	20	10

BELGIAN TRAFFIC CENSUS REPORT ISSUED AFTER LONG DELAY BY WAR

COPIES of a report issued this year by the Belgian Ministry of Public Works, administration of bridges and roads, dealing with a census of traffic on all the roads of the Kingdom in 1908, have recently been received in this country.

The preparation of the report has long been delayed by the war. In fact, some of the most valuable records were destroyed by the Germans during the occupation. The figures representing the extent of the traffic on the various roads are now, of course, of little value; but the description which accompanies the report, of the purpose of the census and the methods adopted in conducting it, will interest engineers in this country who believe that the time is ripe for a similar comprehensive survey of American roads.

PURPOSES OF THE CENSUS.

The census was conducted primarily to supply accurate data upon which to base a classification of the roads of the Kingdom. It was the intention to use the data to classify all roads among the three categories as follows:

1. Roads of the first importance by reason of the intensity of their traffic, their direction, width, and state of improvement.
2. Roads of much less importance in the above respects, ranking comparatively with ordinary country roads.
3. Roads intermediate between the preceding in importance.

It was also a matter of importance to the adminstration of bridges and roads to possess an authentic basis for a correct apportionment of appropriations for construction and maintenance, according to the importance of the several roads.

METHODS ADOPTED FOR THE CENSUS.

The census was taken on 24 days between March 10 and December 18, distributed in such a way as to represent variations in traffic due to the seasons and the days of the week. In some places supplementary counts were made on market days and days of fairs, pilgrimage, noted processions, etc. The counting began on the regular days at 8 a. m. and ended at the same hour the next morning.

The counting was intrusted to the road men (cantonniers) and some of the laborers under the direction of the inspectors (conducteurs) of bridges and roads, the number and location of the stations being previously determined by the division engineers.

The cantonniers kept a record of every vehicle which passed the observation points, on a special tabular form, recording for each vehicle its method of propulsion, the number of wheels, the width of tires, the kind of cargo carried, the number of passengers, and the weight of the load.

The weight of the load was obtained at some of the stations by means of platform scales, the location of these scales influencing the selection of the points. At other points, where there were no scales, the weight of the load was estimated by measuring the cubic contents of the load and later multiplying by the unit weight of each commodity as taken from standard tables of unit weights. Frequently the weight of the load was found written upon the boxes or containers in which it was carried. This particularly was the case with goods being carried to or from railroad freight stations.

The report states that the cantonniers found no difficulty in performing their work, that the public gave them the information desired with very good grace, and that no special police measures were required.

At the end of each day's counting the reports of the cantonniers were transmitted to supervising officials, known as the conducteurs, who condensed the data and recorded in another table the total number of each kind of vehicle and the total weight of the loads passing the several points. The provincial chief engineers verified these tables and transmitted them to the Ministry of Public Works.

At the central administration the results of the counts for the 24 days were summarized and the mean totals for the day and the year were determined.

In estimating the weight of vehicles predetermined average weights for each class of vehicles were used by all officials. Thus for automobiles the weight used was 3,970 pounds, which was supposed to include the weight of three passengers. Motorcycles were assumed to weigh 198 pounds, the cyclist 154 pounds: consequently each motorcycle was counted as 352 pounds. No account was taken of the weight of bicycles, nor of the weight of horses, or cattle as these were assumed to cause no appreciable wear of the road surface.

On the basis of the statistical information acquired, two maps were prepared, the first showing by the width of the lines indicating the roads the total annual tonnage transported over each road, and the other in a similar manner the number of automobiles, motorcycles, and bicycles passing each point on the roads annually. These diagram maps unfortunately disappeared during the occupation.

RESULTS OF THE CENSUS.

Taking into consideration with the traffic figures the costs of maintaining the roads, and comparing these figures with similar data for the year 1897, it is shown that the cost of maintenance has not increased proportionately to the volume and weight of traffic.

The traffic data for the two years indicate an enormous increase in traffic in the intervening period. But for purposes of comparing the importance of the various roads the Ministry believes that the data are not entirely satisfactory. Thus a given road in one section, though very important for the neighborhood through which it passes, may have an average traffic much below that of a road serving neighborhoods of much less account in another section. The same road at various points between its extremities was found to present enormous variations of traffic.

These facts confirm the necessity of considering the general direction and economic surroundings of the roads as well as the actual observed traffic for purposes of classification.

IMPROVEMENTS SUGGESTED BY ENGINEERS.

As a result of the experience gained in taking this census the Ministry believes that future efforts should take into account the character and condition of the roads at the time the counts are made, and also the state of the weather. Roads in bad condition or temporarily blocked by construction work in progress may be shown to have less importance than they actually possess unless these facts are taken into account. Bad weather in one section and good weather in another may also influence the classification unfairly unless the weather conditions are considered.

To reduce the expense of future counts and the time consumed in making them, the Ministry believes that the classification of different kinds of loads may be omitted. After all what it is important to know is the gross weight carried over the roads. Another saving might be made, in the opinion of the Ministry, by leaving out of the counting those roads whose traffic is known beforehand to be very light. Still another way of reducing expense would be to confine the counting on all but two or three of the days to the daylight hours, or possibly from 6 a. m. to 8 p. m. To the daytime results could be added the average results of the two or three night counts, and the accuracy and utility of the combined results would not be materially affected.

A NEW CONCRETE ROAD FILM.

The motion-picture laboratory of the Department of Agriculture has recently completed a new motion-picture film of concrete road construction.

The title of the picture is "Modern Concrete Road Construction." The scenario was written by and the photography was directed by engineers of the Bureau of Public Roads. The photographs were taken in Delaware and New Jersey, with the cooperation of the two State highway departments.

Every process involved in the construction of a concrete road is shown in the film, from the heavy grading to the completed road. The picture opens with a view of an automobile stuck in the mud of an unimproved country road. This scene carries the caption "If your roads are like this," and it is followed immediately by a view of a fine concrete highway with the caption completing the question, "why not work for roads like this?"

The methods of constructing such a road are then shown in regular order on the screen. Methods used in light and heavy grading are depicted by wheel-scraper gangs and steam-shovel outfits served by motor trucks, which dash up to the shovel and are off to the dump in incredibly short time. Under the caption "Monster machines are used by modern contractors to rip up old pavements and make light cuts," one scene shows an old macadam road being torn up, the stone screened and loaded into wagons by one modern machine.

The picture continues with views of fine grading and form setting, pictures showing the quarrying of rock for aggregate and the means of handling material at the freight siding, and the conveyance from storage bins to the roadside by industrial railway.

At the site of the work the bodies of the industrial railway cars are lifted from the trucks and the contents dumped into the mixer, and the picture then shows the details of the various processes of depositing and finishing the road, including hand striking, tamping, rolling, and belting; and by way of contrast, another scene shows a mechanical tamper in operation.

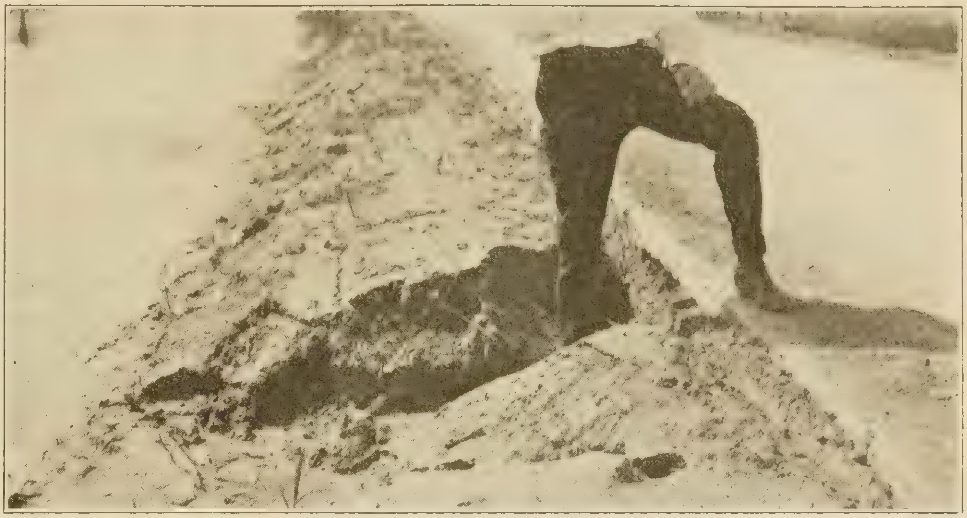
After showing the methods of curing and the trimming of shoulders, several views of completed road are flashed upon the screen, and the picture closes with a thrilling race between a Pennsylvania Railroad train and a motor truck on a concrete highway.

The picture will be loaned to interested persons who make application for use at "good roads meetings," schools, colleges, and meetings of engineers.

The sailors on the 25 vessels of the United States Navy now stationed at the Portsmouth (N. H.) Navy Yard, are the busy little savers. They have discovered that if they put their spare change into war savings stamps and thrift stamps, they can cease to worry about the safety of their coin. If the stamps are registered they are proof against loss, fire, or destruction. If the gob is transferred suddenly, he does not have to worry about transferring his account from one bank to another, for he can either buy or redeem his stamps at any postoffice.

CONCRETE ROAD SLABS UNDAMAGED BY WASHOUT OF SANDY SUBGRADE

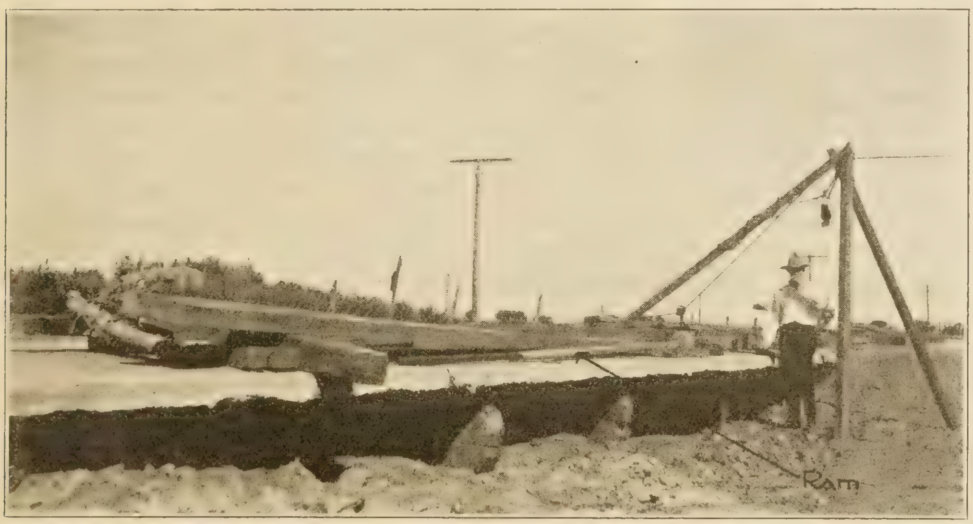
A REPORT received at the Bureau of Public Roads recently contains an interesting description of damage done by high water to the sand shoulders of a section of concrete on the Camino Real near Las Cruces, N. Mex. More interesting than the damage itself is the description of the methods which were adopted by the district engineer for the State highway department, which resulted in saving the road from very serious damage.



ON ACCOUNT OF THE HIGH SHOULDERS, WATER FLOWED ALONG THE CONCRETE UNTIL A SUFFICIENT AMOUNT COLLECTED TO OVERFLOW INTO THE SIDE DITCHES.

The road is a Federal-aid project, known as New Mexico No. 15. The project begins 1 mile south of Mesquite and runs northward 11.68 miles to Las Cruces. The concrete surface is 16 feet wide and has an average depth of 6 inches; the cost of construction is estimated at slightly less than $30,000 a mile.

The soil which forms the subgrade and the shoulders is generally sandy, and in many places the shoulders are of soft blow sand which will not pack. This condition had previously given trouble to automobilists using the road. The loose sand is too soft to hold the weight of an automobile, and if a car, driven at high speed, is turned off the surfaced section there is apt to be trouble. In one stretch a half mile in length seven such accidents are known to have occurred since the opening of the road.



THE SLABS WERE JACKED UP AND CRIBBED IN PLACE AND WET SAND WAS RAMMED INTO THE WASHED-OUT SUBGRADE.

The washouts which occurred in these sandy shoulders as a result of the heavy storm which came during August were not entirely unanticipated. The Bureau of Public Roads had called attention to the probability that such damage would be inflicted by heavy rains nearly a month before. But it is doubtful whether the injury could have been avoided entirely by any amount of foresight.

The most serious damage was done by the unusually large volume of water which reached the sandy side ditches. The water completely demolished the shoulders in many places and undercut the surface to a maximum depth of 11 feet. The origin of the heavy flow of water is not definitely known at this time. An investigation is being made to discover the cause of it, but apparently it did not result from the drainage of the road alone, and it is probable that future damage from the same cause can only be averted by a purchase of rights of way and an alteration of natural water-courses several miles from the project.

In part, however, the damage was due to the fact that the shoulders had not been trimmed, and that the water which drained from the road itself could not reach the ditches directly, but was forced by the high shoulders to run along the edge of the concrete until

[Concluded on page 25.]

9,630 MILES OF MARKED TRAILS TO BE BUILT WITH FEDERAL AID

UP TO September 30, 1920, Federal aid had been approved for the construction of 855 projects, which form links in one or the other of the 24 marked trails which have been laid out by private associations to cross the country from East to West and North to South.

The mileage which will be constructed with Federal aid on each of the several trails is shown in the following table:

MILEAGE OF APPROVED FEDERAL AID PROJECTS ON VARIOUS NATIONAL TRAILS AS OF SEPT. 30, 1920.

	Length Federal aid approved projects miles.
Dixie Highway	895
Ozark Trails	294
Yellowstone Trail	455
Meridian Highway	677
Bankhead Highway	963
National Old Trails	826
King of Trails	474
National Parks Highway	647
Theo. Roosevelt International Highway	425
Jefferson Highway	604
Lincoln Highway	766
Old Spanish Trail	516
Mississippi Valley Highway	237
Dixie Overland Highway	259
Jackson Highway	161
Pacific Highway	183
Roosevelt National Highway	314
Colorado to Gulf	22
Pikes Peak Ocean to Ocean	319
Atlantic Highway	140
Miscellaneous	452
Total	9,630

The extent to which Federal aid has been applied to the trails varies in the different States. Quite naturally the Western States are using much more of their Federal apportionments in developing roads of this character than the Eastern States. This is due to the fact that the routes in the Eastern States had already been improved to a large extent before the roads were selected by the pathfinders. This was not true in the West, where long stretches of the selected roads were still in an unimproved condition when they were designated.

Nevada leads in its use of Federal funds on roads of this character. Eighty-three per cent of its entire mileage of approved Federal-aid roads lies on one or the other of the trails which cross the States. On these roads Nevada will spend 90 per cent of the Federal money which has been granted to her.

Indiana is a close second, with 80 per cent of its entire Federal-aid mileage and 83 per cent of its money aid applied to the construction of the trails; and Oklahoma, with 76 per cent of its mileage and 81 per cent of its Federal funds, is not far behind.

Florida takes the lead in the percentage of its funds which will be used for trail building, with 94 per cent of its Federal allotments so applied; but this amount will be spent for only 56 per cent of the mileage which has been approved in the State.

In addition to the above, the States of Illinois, Kansas, Montana, New Mexico, Utah, and Washington are each using 50 per cent or more of their Federal money for the upbuilding of the trails.

The average expenditure on these roads of 35 per cent of the Federal money allotted to all the States would be greatly increased by the exclusion of such States as Connecticut, Delaware, Maine, Massachusetts, New Hampshire, Vermont, and West Virginia, which are either not traversed by any of the trails or have a very limited mileage within their borders. It would be further increased by eliminating such States as New Jersey, New York, and Pennsylvania, in which the selected routes have been improved in large measure by the States.

In presenting this analysis it is recognized that the system of trails does not constitute an entirely satisfactory system of transcontinental roads. Their selection in many cases has been influenced by such factors as preexisting improvement, promises of improvement by local communities in return for the designation of the route through the community, and pressure of selfish influences leading to the diversion of the route from the ideal location. In general, also, too much weight has been given to the desirability of touching points of historic and scenic interest. The Bureau of Public Roads believes that there are many sections of Federal-aid roads which do not fall on any of the designated trails which will serve to better advantage as sections of a truly national system of roads than the parallel sections of the trails.

In cooperation with the advisory committee of State highway officials the bureau is perfecting plans for a classification of the highways of the country through the coordinate efforts of the several States and the Federal Government. This classification, when it is completed, will rate the millions of miles of roads in the country, for the first time, in the order of their importance, from the national, State, and local standpoints. It is the intention of the departments that it will serve as the basis of all future construction; and it will greatly simplify operations under the Federal-aid act in that, for the first time, it will present a reliable measure of the relative importance of the roads of the country.

THE EFFECT OF ALKALI UPON CONCRETE

By S. H. McCRORY, Chief of Drainage Investigations, Bureau of Public Roads.

THE attention of engineers has been drawn recently to a number of cases in which concrete structures have partially or totally failed, due to the action of alkali upon the concrete. The extent and severity of this action has caused considerable concern among engineers intrusted with the design or construction of concrete structures in regions where the soils and ground waters are alkaline. Such conditions generally are found in the arid and semiarid regions of the United States. Recently, however, a number of failures of concrete drain tile exposed to the action of alkaline soils and ground waters have occurred in the southwestern part of Minnesota. The mean annual rainfall in this region varies from 25 to 30 inches per annum and yet strong concentrations of alkalies are found.

The alkalis present in the soils are the salts of various metals. The more common are sodium chloride ($NaCl$), sodium sulphate (Na_2SO_4), magnesium sulphate ($MgSO_4$), calcium sulphate ($CaSO_4$), calcium carbonate ($CaCO_3$), and calcium bicarbonate ($CaHCO_3$) Other salts are also frequently present. Typical analyses of alkalis from the surface of the ground in various locations are shown in Table No. 1, which is taken from Technological Paper No. 95, Bureau of Standards.

TABLE No. 1.—*Typical analyses of alkalis from various localities.*

Location.	Composition of soluble solids in per cent.					
	Na.	K.	Ca.	Mg.	Cl.	SO_4.
Garland, Wyo	30.8	0.5	0.6	0.1	Trace.	68.0
Fort Shaw, Mont	26.2	.2	2.3	1.1	1.1	69.1
Sunnyside, Wash	23.9	.2	.6	.6	10.0	64.7
Yuma, Ariz	24.7	.5	7.1	....	52.6	15.1
Roswell, N. Mex	10.8	2.3	16.8	4.9	22.0	43.2
Montrose, Colo	9.4	....	2.1	26.7	Trace.	61.8
Grand Junction, Colo	28.1	....	.7	6.6	17.1	47.5
Huntington, Utah	27.6	.6	2.4	2.5	.1	66.8

In Table No. 2 are presented a number of analyses of drain and soil water from various locations:

TABLE No. 2.—*Analyses of drain and soil water from various localities*

Location.	Per cent soluble solids in water.	Percentage reacting values.							
		Na.	Ca.	Mg.	Cl.	SO_4.	CO_3.	NO_3.	HCO_3.
Garland, Wyo	0.33	32.0	10.3	7.7	3.2	40.6	6.2	....	....
Fort Shaw, Mont	.20	30.6	6.6	12.8	1.6	34.2	14.2	....	....
Sunnyside, Wash	.40	24.7	14.0	11.3	6.1	38.1	5.8	....	....
Yuma, Ariz	.11	23.5	16.3	10.2	15.4	12.9	21.7	....	....
Roswell, N. Mex	.46	23.9	19.4	6.7	27.1	20.0	2.9	....	....
Montrose, Colo	.50	9.2	15.8	25.0	.5	46.0	3.5	....	....
Grand Junction, Colo	.85	25.9	10.1	14.0	17.7	28.7	1.9	1.7	....
Huntington, Utah	.30	18.3	20.1	11.6	1.8	40.8	7.4	....	....
Lyon County, Minn.	.28	3.5	22.2	24.3	.3	47.5	.2	....	1.9
Lyon County, Minn.[1]	3.06	25.9	8.6	15.5	T.	49.5	.1	T.	.4

[1] Soil water.

FIG. 1.—TWENTY-FOUR INCH CONCRETE TILE WHICH HAS ALMOST COMPLETELY DISINTEGRATED. THIS TILE WAS PLACED AT SUCH A DEPTH THAT IT WAS NEVER SUBJECTED TO FREEZING AND THAWING.

In both tables the SO_4 content is high for all localities except Yuma and Roswell. The alkali at Roswell, though low in SO_4, nevertheless causes serious injury to concrete that is exposed to it. It will be noted in these tables that usually some one of the constituents will predominate in a given section. Along the seacoast the predominating salt is usually sodium Chloride ($NaCl$) or common salt, while in the Great Plains regions the sulphate type predominates.

THE ACTION OF THE ALKALI.

When concrete is exposed to the action of solutions of these salts the lime of the cement combines with the salts to form other compounds. The chemical action is accompanied by a change in the physical condition of the concrete. The first indication of the action of the alkali that can be noted is the presence of minute crystals of various salts in the concrete. These can be detected if fresh fractures are examined. As the action progresses a chalky band forms in the concrete near the surface which is in contact with the soil. In drain tile this band usually forms at first about three-eighths of an inch beneath the outer surface. As the action progresses the band widens and assumes a white chalky appearance, much like lime

FIG. 2.—CONCRETE BLOCK 1–2½–5 CONCRETE THAT HAS BEEN EXPOSED TO THE ACTION OF STRONG ALKALINE WATERS FOR ABOUT 4 YEARS.

mortar. As this chalky band widens, swelling and cracking of the concrete becomes apparent. One of the illustrations shows a 24-inch concrete tile which had been placed in an 11-foot cut and exposed for about four years to the action of soil water containing 2.22 per cent of alkali, of which 49 per cent was SO_4. The swelling and cracking is very noticeable in this instance. The other picture illustrates the typical action of alkali upon mass concrete, in this instance a concrete block which had been exposed to the action of the weather and alkalis for about four years.

Most concrete structures are alternately dry and wet. The alternate drying and wetting has a tendency to impair the concrete. When salts are present this deterioration is intensified, due to their crystallizing in the concrete when it dries. In most localities there is added to this action the disrupting effect caused by alternate freezing and thawing of the moisture in the concrete. While the effect of each of these factors on the concrete may be relatively very small, they combine to make the concrete more porous and thus to admit more readily the salt-bearing solutions to intimate contact with the cementing material. Some experimentors have thought that the disintegration of concrete was caused by the formation of substances having a large molecular volume and that this occurs when the sulphate salts of magnesium and sodium are present. The chemical reactions which take place are not fully understood, but it seems that failure is due to chemical rather than physical action.

A number of samples of concrete that have been subjected to the action of strong solutions of sulphates have been examined, and in each case it is found that a considerable amount of the cement has been removed. Microscopic examinations indicate that the cementing material has been replaced by other compounds of little cementing value, such as gypsum and the carbonates of lime and magnesia.

NO PROOF AGAINST ALKALI FOUND.

Many investigators have tried to find a method of making concrete that would be proof against the action of salts, but so far none has been successful. It has been shown, however, that the more impermeable the concrete, the more strongly resistant it is to the action of the salts. The strength of concrete does not seem to have a definite relation to the action of salts upon it as frequently, in testing concrete tile, specimens are found in which the concrete is seriously disintegrated but which shows little loss of strength when tested. In general, it may be said that all available data indicate that in sulphate waters the extent and rapidity of failure depend upon the concentration of the salts in the soil and soil water to which the concrete is exposed. Concentrations may occur which will cause the disintegration of the most impermeable concrete that can be made by methods now employed. Various experiments and investigations indicate however, that when exposed to solutions of equal strength the richest mix will prove most resistant. Concretes with high absorbtion are especially susceptible to attack.

TO SECURE MOST IMPERMEABLE CONCRETE.

If it is known that concrete is to be exposed to the action of alkalis, great care should be used in grading the materials so as to secure the densest and most impermeable concrete possible. If a choice is possible, the sand and coarse aggregate should be of such a character that they will not be affected by the action of the salts. Limestones, dolomites, and sandstones should be avoided. In placing the concrete great care should be exercised to secure the best possible workmanship. The concrete, after being placed in the forms, should be well spaded and tamped, and extra precautions should be taken to prevent the formation of a porous layer at the close of each day's work. The foundation should, if possible, be thoroughly drained either by open ditches or underdrains. If this can not be done, it might be helpful to make the back fill next to the concrete of coarse gravel so that when the water table drops, capillary action will not bring moisture to the concrete through the soil. When it is necessary to use sand, gravel, or other aggregates that are known to cantain alkali salts in considerable amounts, they should be thoroughly washed before they are placed in the concrete, even if alkaline water has to be used.

Various preparations have been used in an attempt to make concrete impervious to moisture. Cement grout, tar coating, ferrous sulphate, and various waterproofing paints have been tried, but so far none of these seems to have been successful. Any value they have is of a temporary character. The use of intregal waterproofing compounds or hydrated lime might be of value in securing a more impermeable concrete.

Where high concentrations of salts are known to exist, the importance of careful grading and rich mixture, so as to secure the densest and most impermeable concrete possible, can not be overestimated. Under such conditions cement, sand, aggregate, and mixing water should be the best obtainable. The fabrication of the concrete should be done by experienced workmen, and when it is placed in the forms it should be done in such manner that the structure will be truly monolithic. The foundation should be provided with the best drainage obtainable. If these precautions are followed structures can be built which will be strongly resistant to the action of alkali. There is no assurance, however, that concrete of even the highest impermeability that can be obtained under present methods of manufacture will withstand the stronger concentrations of alkali of the sulphate type.

AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS TO MEET AT WASHINGTON

The annual meeting of the American Association of State Highway officials will be held this year at Washington, D. C., from the 13th to the 16th of December, inclusive. The headquarters will be at the Washington Hotel, at which the general meetings will be held. As the hotel is only one block from the Bureau of Public Roads, the bureau's building will be conveniently situated for committee meetings.

At the time this goes to press the program has not been definitely arranged. One of the subjects which is certain to be included, and which is expected to develop a lively discussion, is the problem of rail transportation. This question will be discussed from both viewpoints, those of the States and the railroads, with Mr. Daniel Willard, president of the Baltimore & Ohio Railroad, speaking for the railroads.

Among the other important topics which will probably be discussed are:

Load limitations for primary and secondary highways.

Failures of highways and the reasons therefor.

The treatment of subgrades and foundations.

The relative service value of different types of pavements.

State operation of cement plants.

One afternoon will be devoted to a visit to the experimental laboratory of the Bureau of Public Roads, at Arlington, Va., where the visitors will be given an opportunity to inspect the important impact, wear, and subgrade tests which are being conducted by the bureau.

As an additional attraction the bureau will provide transportation to enable the visitors to inspect the experimental roads which have been constructed in the vicinity of the city.

CONCRETE ROAD SLABS UNDAMAGED BY WASHOUT OF SANDY SUBGRADE

[Concluded from page 21.]

a sufficient amount had collected to overflow into the ditches. Deep cuts, in the fills particularly, were due to this cause.

Before the traffic could be stopped some of the slabs had settled, and the loss of large sections of the surface was narrowly averted. The prompt and intelligent action of the State's district engineer prevented the collapse of large sections of the pavement; but the fact that not a single crack or flaw developed in any slab is a tribute to the excellent workmanship and material employed in the construction of the road.

Until the damage could be repaired the washed shoulders were covered with brush to prevent further erosion in the event of another storm, and as rapidly as possible the undercut gaps in the subgrade were refilled and consolidated. Where it was found that the slabs had sagged out of line wooden stringers were placed under them near the outer edge, and the concrete was raised to the proper grade by means of hand jacks bearing on the stringers.

Once the slabs were raised into true position cribbing was placed under the stringers and the jacks were removed. The sand was then replaced under the slabs, previously wetting it to make it possible to consolidate it. The consolidation was effected by means of a heavy ram, shown in one of the illustrations, which was suspended from a tripod and operated by three or four men.

The shoulders when repaired were not solid enough to support traffic, and posts were set, therefore, along the edge of the concrete to prevent their use, but the concrete surface was opened to traffic at once and is carrying the weight of vehicles without sign of failure. The results of the treatment appear to be excellent in every respect, and no settling is anticipated.

OUTLINE OF THE FIELD TO BE COVERED BY HIGHWAY RESEARCH

By A. N. JOHNSON, Dean of College of Engineering, University of Maryland.

THE need for highway research is becoming more and more apparent as our highway program develops. At the recent convention of land-grant colleges held at Springfield, Mass., the subject of highway research was discussed by Mr. Thomas H. MacDonald, Chief of the United States Bureau of Public Roads, who pointed out that one of the largest fields in engineering endeavor during the next 25 years will be the development of our highways and highway transportation. We can not too soon begin these investigations, the results of which should be at hand if economical and scientific progress is to be insured and the largest return made to the public, which has provided so abundantly the funds for this great undertaking. In the discussions before various engineering and technical bodies the lack of needful data by which intelligently to plan and build our highways has repeatedly been remarked.

It is unnecessary to develop further the argument for the need of highway research. Time and space will be more profitably employed in the discussion of highway research itself. It seems proper, therefore, at first to present a general outline of the field to be covered, as a survey of this field should prove helpful. An attempt has therefore been made to present such an outline, which was prepared in September, at the suggestion of Mr. MacDonald, by Charles J. Tilden, professor of engineering mechanics at Yale University, A. T. Goldbeck, testing engineer of the United States Bureau of Roads, and the writer.

The arrangement, as well as the subjects themselves, as here presented for investigation, should be considered more as a general view of the field, rather than a work program. Three general divisions have been named: (1) Investigations affecting road construction and maintenance or road design; (2) investigations affecting the economics of road operation or the use of the road; (3) investigations affecting the economic value of highways to a community.

Under each of these headings are listed the principal factors involved. In turn, a number of subjects have been named as suggestive of those to be included under the various factor headings.

As various work programs are developed and data accumulated a comprehensive outline becomes useful as a guide to disclose whether the work programs are balanced, and if not, to point to those subjects about which more information should be gathered.

The data that may be developed by a given work program, it is evident, may be useful from a number of viewpoints. Thus a traffic study may furnish not only information as to the weights or loads for which to design our highways, it may serve also as an index of the economic value of the roads, and it may also be taken as a basis from which to determine operation costs. In fact, it may be remarked that traffic data underlie much of the information needed to plan and expend wisely for highway improvements.

Little further explanation of the analysis of the highway research field here presented is thought necessary other than to point out that it is to be regarded as tentative. As more study is given to the subject it doubtless will be possible in the near future to present a considerably more detailed outline which will be of greater assistance in outlining work programs.

A TENTATIVE OUTLINE FOR A COMPREHENSIVE PROGRAM OF INVESTIGATION OF PROBLEMS RELATING TO THE DESIGN, OPERATION, AND ECONOMIC VALUE OF HIGHWAYS.

Investigations of the effect on road construction and maintenance of:

1. Physical geographic conditions—
    - Climate.
    - Topography.
    - Geology.
2. Subgrade—
    - Character of soil.
    - Moisture.
    - Preparation.
3. Shoulders—
    - Width.
    - Character.
    - Roadside vegetation, trees, etc
4. Drainage—
    - Bridges, culverts, etc.
5. Type of pavement—
    - Materials.
    - Construction methods.
6. Loads imposed by traffic—
    - Total weight of vehicle.
    - Distribution of weight—
        - On wheels.
        - Sprung and unsprung.
    - Tires.
    - Speed.
    - Wear.
7. Density of traffic—
    - Width of pavement.

Investigations of the effect on the economics of road operation of:

1. Road planning—
    - Financing.
    - Environment—
        - Farms.
        - Mines.
        - Timber lands.
        - Manufacturing centers.
    - Other transportation systems—
        - Railways.
        - Ocean, rivers, canals.
        - Airplane terminals.
    - Roadside treatment.
2. Grade.
3. Surface.
4. Alignment.
5. Traffic movement—
    - Regulations.
    - Grade separations.
6. Highway transport—
    - Vehicles—
        - Weights.
        - Number of units.
    - Routing.
    - Terminals.
    - Financing.
7. Franchises—
    - Street railways—
        - Motor, freight and bus lines.
    - Pipe lines.
    - Conduits.
    - Telegraph and telephone.

Investigations of the effect on the economic value of highways to a community of:

1. Highway traffic—
    - Distribution of traffic—
        - Geographical—
            - Relation to environment.
        - Seasonal—
            - Time of year.
        - Daily—
            - Day of week and month.
        - Hourly—
            - Hourly variation.
    - Character of traffic— (Weights per vehicle; per wheel; per inch of tread.)
        - Passenger { Horse drawn. / Motor.
        - Freight { Horse drawn. / Motor.
    - Relation to other transportation systems—
        - Rail.
        - Water.
        - Air.
2. Highway costs—
    - Construction costs.
    - Maintenance costs.
    - Operation costs.
3. Financing highway improvements—
    - Methods—
        - Direct taxation.
        - Bond issues.
        - Vehicle taxes and licenses.
        - Tolls.
    - Distribution of cost—
        - To Federal Government—
            - State.
            - County.
            - Local subdivisions.
            - Property owner.

MODIFIED TNT AS A BLASTING EXPLOSIVE

By CHARLES E. MUNROE, Chief Explosives Chemist, and SPENCER P. HOWELL, Explosives Engineer, U. S. Bureau of Mines.

AMONG the surplus explosives left on hand with the War Department was a quantity of that styled Trojan grenade powder, which was especially designed during the war for use as a bursting charge in grenades and for which naturally there would be very little military use in time of peace. With a view to its disposal through use in civil projects a quantity was sent to the Bureau of Mines explosives experiment station, where analysis showed that its characteristic explosive ingredient was nitrostarch and that the powder had the following composition:

TROJAN GRENADE POWDER.

	Per cent.
Moisture	0.71
Nitrostarch	24.37
Oils	1.13
Sodium nitrate	37.62
Ammonium nitrate	33.34
Ammonium chloride	.39
Carbon and ash	2.44
	100.00

Trojan grenade powder appears as a dark-gray granular substance, part of which is slightly pulverulent. The granules are fairly hard. The explosive is not at all dusty, and has the consistency of granulated sugar.

NITROSTARCH.

Nitrostarch is a substance produced by treating starch with nitric and sulphuric acids and in appearance it looks very little different from powdered starch. It resembles nitrocellulose and nitroglycerin in its constitution and explosive properties and has been known longer than either, inasmuch as it was prepared by Braconnet in 1833. Nitrostarch explosives have in recent years been developed for industrial use in this country; they were used to a certain extent in blasting in the Canal Zone, yet as this grenade powder was a special composition it seemed desirable that a complete series of tests should be run upon it. This was done, and the results are reported in the following table in comparison with those previously obtained in testing ammonia dynamite.

Mr. J. E. Crawshaw (explosives testing engineer, United States Bureau of Mines) in reporting these results says:

"It will be noted that the physical characteristics of these two explosives are almost the same. Accordingly, Trojan grenade powder would be specially suited for the type of work for which 40 per cent ammonia dynamite is now used, i. e., quarrying and tunneling in moderately hard rock, road building, excavations, and stump blasting.

"Particular attention is called to the hygroscopic properties of this explosive. As Trojan grenade powder shows a very marked tendency to absorb moisture, it can only be used in dry work, stored in dry places, and used in dry weather. All boxes of this explosive received at the Pittsburg Experiment Station of the Bureau of Mines showed evidence of moisture absorption, and two of the boxes to such an extent that the contents had to be destroyed shortly after their receipt. It is very probable that on examination of this material in storage, many other boxes wll be found in very poor condition.

Results of tests of Trojan grenade powder and ammonia dynamite.

Explosive.	Rate of detonation (motors per second).	Trauzl lead block (cubic centimeters)	Small lead block (millimeters).	Pressure (kilograms per square centimeter).	Unit deflective charge (grams).	Calorimeter (calories per kilogram).	Volume of gas (liters).
40 per cent ammonia dynamite	3,157	202	12.8	8,921	243	1,122	140
Trojan grenade powder.	3,741	216	15.9	8 836	256	1,037.1	131.7

"The products of combustion of this explosive are such that it can be used in places with poor ventilation without danger, as there is only a trace of poisonous gases (CO) present."

Mr. John S. Swenehart, who has been conducting field tests on behalf of the college of agriculture of the University of Wisconsin, reports:

"While we have not completed all our tests on Trojan grenade powder for land clearing, we have gone far enough so that we know it is entirely usable for this work. While it seems somewhat quicker than we think should be used for stumping purposes, yet it can be salvaged to good advantage. The moisture which is encountered in our operations does not offer any difficulty after the material is properly cartridged. A No. 8 cap seems to be necessary for complete detonation, and this cap successfully and effectively detonated grenade powder where we added 2 per cent water to the material. The fumes from the powder are not very heavy. They disappear quickly and, so far as we can determine, have no effect on the user under any conditions. In strength, the material is at least equivalent to ordinary dynamites."

On the receipt of Mr. Crawshaw's report, Trojan grenade powder was allotted, under the law for public use, 600,000 pounds, stored at the general ordnance depot, United States Army, Charleston, S. C., being allotted to the Bureau of Public Roads, but as the transfer was being effected it was reported that this powder had so deteriorated in storage as to be unserviceable. Mr. J. E. Tiffany (assistant explosives engineer, United States Bureau of Mines) was at once dispatched to inspect, and from his report it is learned the explosive was packed as follows.

PACKING.

Fifteen pounds of the explosive were inclosed in a manila paper bag, which was then inclosed in a second paper bag, and tied with a string. Four such packages were placed in a box, 18 by 10 by 9 inches, made of ½-inch white pine, and of lock-cornered construction, the box being lined with paraffined paper so folded that it covered the bottom, sides, and top.

DELIQUESCENCE.

Inspection revealed that owing to the fact that this Trojan grenade powder contains about 71 per cent of easily soluble salts, it had absorbed sufficient moisture to deliquesce, and that the liquid formed had run to the bottom of the boxes, in many cases leaking out so as to saturate the exterior of the boxes and the wooden floor where they were stacked.

SENSITIVENESS.

Samples of Trojan grenade powder taken from several different boxes were made into cartridges and tested by the "Explosion by influence" test, using No, 8 detonators, and found to be too insensitive for use.

ADMIXTURE WITH TNT.

As a packing plant for cartridging surplus TNT for the Bureau of Public Roads was operating near by, it was suggested to try mixing this deteriorated Trojan grenade powder with the dry TNT, which was done, and on testing the product it was found that cartridges of the mixture containing up to 50 per cent of Trojan grenade powder were sufficiently sensitive and gave craters which were, if anything, larger in extent than those produced by TNT alone. It was also noted that the smoke from the mixture was nearly white and the report quite sharp. Furthermore, the mixture was more easily and readily packed in the cartridge cases than the TNT alone, because the latter is rather dusty. The moist Trojan grenade powder holds down this dust, and the mixture is a freer running powder than the TNT itself. Not only is the packing facilitated but the menace to the health of the packers from the existence of the dust is reduced

MODIFIED TNT.

The product formed by mixing TNT with Trojan grenade powder is styled modified TNT. As a result of such admixture there can be used to advantage in civil and industrial operations an explosive which otherwise would be more than a total loss, for it would have to be destroyed at considerable expense and always with the danger attendant on the destruction of explosives. Modified TNT, when composed of approximately equal proportions of TNT, grade III and Trojan grenade powder, appears as a gray granular substance, with occasional yellow specks. Some portions are pulverulent with fairly hard granules. The explosive is not at all dusty. When packed in paraffined paper shells, the cartridges are firm and the explosive as a whole is moderately cohesive. A cartridge 1¼ by 8 inches has an apparent specific gravity of 1.15. While for large projects the powder may be used in loose form in its containers, it is advised that the powder as a rule be packed in paper cartridge cases which are subsequently well paraffined. Modified TNT should be fired as TNT is, and with the same grade detonator.

KEEPING QUALITIES OF MODIFIED TNT.

As modified TNT contains notable amounts of the hygroscopic salts, sodium nitrate and ammonium nitrate, it will always show a tendency to absorb water from the atmosphere When these salts are present in explosive mixtures, such mixtures as a rule show a tendency to "cake" and the cartridges becomes hard or rigid. Because of this loss of plasticity by the cartridge, it becomes more difficult to puncture the cartridge in order to provide a hole for the insertion of the detonator in it; it requires more force to so tamp the cartridge as to drive it past irregularities in a bore hole and make it fit the cavity; and as a rule, as the cartridge becomes rigid, it becomes less sensitive to detonation.

On May 8 and 9, 1920, Mr. Tiffany supervised the packing at Charleston of 20 cartridges containing a mixture of approximately 50 per cent of fairly wet Trojan grenade powder and 50 per cent of grade III TNT of Hercules manufacture. These cartridges were sent to the Pittsburgh testing station where on June 7, 1920, Mr. J. A. Farr observed, in taking off the wrapper, that it required considerable force to break a cartridge in two with his hands.

Mr. Tiffany, in following up this observation on July 12, found that while, in the tests at Charleston, cartridges of modified TNT were as easily punctured for the reception of the detonator as those of 40 per cent straight nitroglycerin dynamite were, on July 12 it was more difficult to effect this puncture, although then it could be done without undue effort. A repetition of the "Explosion by influence" test showed that the sensitiveness of these cartridges to detonation had not materially decreased.

USE OF MODIFIED TNT.

Since, as was to be expected, modified TNT cartridges possess a tendency to absorb moisture from humid atmosphere and as they have shown a tendency to harden, it is advised that they be used as promptly as feasible after receipt.

FEDERAL-AID ALLOWANCES

PROJECT STATEMENTS APPROVED IN SEPTEMBER, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Alabama	80	Lauderdale	12.050	Chert and gravel	Sept. 9	$188,440.31	$94,220.15
	82	Cullman	8.020	Bituminous	Sept. 28	219,273.17	109,636.58
	85	Montgomery and Elmore		Bridge	do	197,007.14	98,503.57
	86	do	6.950	Gravel	do	202,851.00	101,425.50
Arizona	36	Yavapai	3.701	do	Sept. 22	82,748.00	41,374.00
Arkansas	41	Clark	47.260	do	do	197,598.89	76,438.00
	66	Little River	30.200	do	Sept. 4	170,726.05	65,000.00
	113	Lawrence	2.170	do	do	21,780.87	5,400.00
	114	Lonoke	2.840	do	Sept. 3	22,249.37	7,800.00
	115	Madison	19.270	do	Sept. 21	146,027.97	60,000.00
Colorado	39	Morgan	5.902	Sand-clay	Sept. 17	47,978.59	23,989.29
	51	Cheyenne	4.886	Gravel	Sept. 18	24,857.51	12,428.75
	100	Rio Grande	3.125	do	Sept. 28	31,980.74	15,990.37
	101	La Plata	4.100	do	Sept. 2	46,678.50	23,339.25
	107	Moffat	4.235	do	Sept. 4	58,766.88	29,383.44
	119	Saguache	9.890	do	Sept. 28	53,550.20	26,775.10
	127	Lincoln	3.380	Sand-clay	Sept. 4	51,676.35	25,838.17
Florida	30	Hamilton and Columbia		Bridge	Sept. 28	89,863.40	44,931.70
Georgia	162	Gwinnett	4.900	Macadam	do	57,117.50	20,000.00
	170	McDuffie	4.500	Sand-clay	do	22,671.20	11,335.60
	183	Spalding	4.900	Macadam	Sept. 4	120,449.94	50,000.00
Idaho	27	Payette	17.000	Gravel	Sept. 7	204,672.05	102,336.02
	33	Nez Perce	4.000	Earth	Sept. 3	97,005.15	48,502.57
	37	Jerome	4.260	Gravel	Sept. 2	94,904.70	47,452.35
	44	Twin Falls	12.100	do	Sept. 20	136,279.54	68,139.77
Illinois	15	Jackson and Williamson	9.540	Earth	Sept. 18	195,580.33	48,895.08
	16	Jefferson and Wayne	14.690	do	do	487,791.61	121,947.90
Kansas	67	Cloud	6.330	Concrete	Sept. 28	268,499.00	94,950.00
	68	do	2.250	Concrete or brick	Sept. 22	112,508.00	33,750.00
	69	Saline and Ottawa	2.000	Earth	Sept. 28	22,660.00	6,000.00
	70	Franklin	0.265	Brick	do	13,337.50	3,975.00
Kentucky	30	Breathitt	2.500	Earth	do	63,775.08	31,887.54
	37	Breckinridge	32.630	Bituminous	Sept. 11	938,912.29	469,456.14
	39	Knox	11.352	do	Sept. 2	320,646.70	160,323.35
	41	Hopkins	18.800	Gravel	Sept. 28	340,301.50	170,150.75
	42	Henderson	4.620	Earth	do	43,329.00	21,664.50
Louisiana	60	Terrebonne	3.450	Gravel	Sept. 13	88,330.20	44,165.10
Massachusetts	47	Worcester	1.738	Macadam	Sept. 21	83,267.80	34,760.00
Michigan	47	Cass and Van Buren	15.036	Concrete or bituminous	Sept. 28	653,262.50	300,720.00
Minnesota	57	Beltrami		Gravel	Sept. 22		[1] 51,790.03
	74	Sibley		do	do		[1] 54,996.00
	83	Pennington		do	do		[1] 2,577.07
	90	Rock		Concrete	do		[1] 96,535.82
	96	Winona		do	do		[1] 41,498.86
	100	Steele		Concrete, brick, or asphaltic	do		[1] 27,604.78
	105	Yellow Medicine		Gravel	do		[1] 13,219.60
	115	McLeod		do	do		[1] 11,419.25
	117	Mahnomen		do	do		[1] 39,776.50
	129	Clay		Earth	do		[1] 14,714.00
	131	Douglas		Gravel	do		[1] 18,962.31
	132	Becker		do	do		[1] 19,002.29
	133	Wauseca		do	do		[1] 5,587.40
	134	Jackson		Concrete, brick, or asphaltic	do		[1] 38,798.40
	140	Cass		Gravel	do		[1] 21,657.00
	142	do		do	do		[1] 20,900.70
	144	Red Lake		do	do		[1] 12,840.00
	145	Pope		do	do		[1] 19,134.66
	156	Beltrami		do	do		[1] 8,980.00
	158	Itaska		do	do		[1] 45,329.40
	165	Wright		do	do		[1] 45,010.00
	166	do		do	do		[1] 14,497.00
	65	Benton	5.000	do	Sept. 13	[3] 28,215.00	[3] 14,107.50
	76	Morrison	12.030	do	do	[3] 46,349.09	[3] 23,174.54
	104	Renville	3.600	Concrete, brick, or asphaltic	do	[3] 137,772.80	[3] 41,331.84
	106	Benton	14.980	do	do	[3] 580,773.16	[3] 290,386.58
	151	Kittson	15.750	Gravel	do	[3] 89,848.00	[3] 44,924.00
	152	Wadena	7.000	do	do	[3] 45,155.00	[3] 22,577.50
	173	Dodge	3.980	do	do	[3] 44,326.70	[3] 22,163.35
Mississippi	102	Leak	12.850	Earth	Sept. 28	71,156.25	35,578.12
Missouri	106	Dade	5.000	Macadam	Sept. 1	26,000.00	13,000.00
	138	Howell	16.760	Gravel	Sept. 2	72,068.00	36,034.00
	142	Monroe	5.000	do	Sept. 4	26,309.99	13,154.99
	155	Newton	17.400	Chat or gravel	Sept. 18	91,988.99	45,994.49
	157	St. Clair	4.718	Gravel	Sept. 2	47,539.14	23,769.57
	162	Greene	4.250	Clay bound, gravel, or macadam	Sept. 17	21,249.99	10,624.99
	163	Taney		Bridge	do	72,600.00	36,300.00
Montana	130	Dawson	17.000	Gravel	Sept. 8	102,193.80	51,096.90
	135	Rosebud	10.500	do	Sept. 30	47,717.08	23,858.54
	138	Musselshell	6.000	Topsoil	Sept. 3	33,739.20	16,869.60
	4	Carbon	2.550	Gravel	Sept. 8	[2] 81,822.02	[2] 40,911.01
Nevada	32	Humboldt	7.500	do	Sept. 4	68,530.00	34,265.00
	18	Elko	4.000	do	Sept. 17	[2] 105,391.55	[2] 52,695.78
	31	Eureka	12.200	Gravel or crushed rock	Sept. 18	87,824.00	43,912.00
	33	Lyon	6.900	Gravel	Sept. 21	99,506.00	49,753.00
	34	Churchill	8.270	do	Sept. 17	107,101.80	53,550.90
	35	Clark		Bridge	Sept. 22	17,990.50	8,995.25
	36	Washoe	15.000	Gravel	Sept. 18	199,650.00	99,825.00
New Hampshire	126	Rockingham	0.660	do	Sept. 2	9,999.99	4,999.99
	129	do	1.630	Asphalt	do	34,147.30	17,073.65
	131	Carroll	0.700	Macadam	Sept. 8	18,000.00	9,000.00
New Mexico	50	Luna	15.030	Gravel	Sept. 2	72,338.55	36,169.27
	54	Hidalgo	35.000	do	Sept. 6	99,601.92	48,800.96
	55	Grant	4.250	do	Sept. 22	38,501.10	19,250.55
	56	do	9.500	do	do	116,011.50	58,005.75
New York	74	Greene	4.100	Concrete	Sept. 4	164,000.00	82,000.00
	76	do	4.200	do	Sept. 3	168,000.00	84,000.00
	77	Putnam	1.800	do	do	102,600.00	35,910.00
	78	Orange and Sullivan	7.000	do	Sept. 23	399,000.00	139,650.00
	79	Orange	7.500	do	do	427,500.00	149,625.00
	81	Franklin	4.800	Bituminous macadam	Sept. 24	240,000.00	84,000.00

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[2] Revised statements Amounts given are increases over those in the original statements.
[3] Canceled.

PROJECT STATEMENTS APPROVED IN SEPTEMBER, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
North Carolina	121	Stokes	12.100	Topsoil or gravel	Sept. 8	$104,549.50	$52,274.75
North Dakota	112	Dickey	20.000	Earth	Sept. 2	87,450.00	43,725.00
Ohio	156	Licking	5.030	Concrete	Sept. 3	250,000.00	27,000.00
	157	Hancock	2.866	....do	Sept. 4	134,000.00	20,000.00
	161	Seneca	2.546	Macadam	Sept. 30	68,500 00	30,000.00
	171	Hocking	6.549	Gravel	Sept. 9	160,000.00	80,000.00
	175	....do	5.351	Macadam	Sept. 4	220,000.00	82,000.00
	176	Guernsey	5.172	Concrete	Sept. 9	250,000.00	38,400.00
Oklahoma	50	Pontotoc	4.000	Gravel	Sept. 1	61,050.00	30,525.00
	44	Jackson	1.000	Concrete	Sept. 21	50,886.00	20,000.00
Pennsylvania	85	Dauphin and Perry	7.908	....do	...do....	471,695.05	158,160.00
	86	Potter	0.953	....do	Sept. 2	57,098.06	19,060.00
	87	....do	1.495	....do	...do....	109,914.53	29,900.00
	89	....do	4.103	....do	...do....	267,473.74	82,060.00
	90	Greene	2.611	....do	...do....	151,372.18	52,220.00
	91	Lancaster	5.412	....do	Sept. 3	320,312.16	108,240.00
	92	Delaware	2.838	....do	...do....	156,969.34	56,760.00
	93	Butler	4.939	Asphalt	Sept. 4	312,304.49	98,780.00
	94	Northumberland	3.053	Concrete	...do....	164,533.38	61,060.00
	95	Lycoming	5.570	....do	Sept. 3	412,930.98	111,400.00
	96	Cambria	4.627	....do	...do....	359,901.90	92,540.00
Rhode Island	11	Providence	5.000	Bituminous concrete	Sept. 8	247,728.36	100,000.00
South Carolina	62	Marlboro	....	2 bridges	Sept. 4	53,460.00	26,730.00
	64	Lexington	4.948	Topsail	Sept. 22	37,590.16	15,000.00
	83	Union	5.639	....do	....	[1] 39,082.80	[1] 100.00
Tennessee	38	White	13.560	Water-bound macadam	Sept. 1	341,718.38	170,859.19
Texas	88	Cass	24.220	Gravel	Sept. 17	211,978.03	58,375.00
	186	Cottle	18.460	Sand-clay	Sept. 1	83,092.40	41,546.20
	193	Bexar	6.170	Bituminous	Sept. 4	128,715.51	58,168.43
	203	Rusk	24.000	Gravel	Sept. 8	402,628.05	150,000.00
	204	San Patricio	1.700	Bridge and approaches	Sept. 22	412,500.00	200,000.00
	205	Wood	16.000	Gravel	Sept. 17	110,105.60	45,000.00
	206	Fort Bend and Wharton	....	Bridge	...do....	70,062.30	34,000.00
	208	Morris	10.684	Gravel	Sept. 29	111,148.16	48,838.95
Utah	12	Iron and Washington	....	....do	Sept. 23	[1] 145,173.60	[1] 72,586.80
Vermont	18	Rutland	....	Bridge	Sept. 8	12,397.16	6,198.58
	19	Orleans	2.030	Gravel	Sept. 17	52,316.00	26,158.00
	20	Washington	0.220	Bridges and gravel	Sept. 29	33,855.80	16,927.90
Virginia	61	Augusta	4.430	Bituminous macadam	Sept. 17	111,448.70	55,724.35
	72	King William, Queen, and Essex	15.850	Sand-clay and gravel	Sept. 21	145,785.75	72,892,87
	88	Stafford	6.000	Gravel	...do....	99,756.80	49,878.40
	91	King George	7.500	Topsoil	Sept. 17	43,954.35	21,977.17
	103	Arlington	1.710	Concrete	Sept. 29	72,721.00	34,200.00
	106	Southampton	0.979	....do	Sept. 17	57,933.70	19,580.00
Washington	78	Skamania	1.220	Gravel	Sept. 1	50,714.40	24,400.00
	79	Lincoln	2.010	Earth	Sept. 29	44,462.11	22,000.00
	80	Benton	1.613	Gravel	...do....	32,708.17	16,000.00
West Virginia	77	Greenbrier	9.420	Earth	Sept. 8	[2] 68,042.80	[2] 38,080.00
	99	Webster	3.300	....do	Sept. 1	96,940.00	48,470.00
	104	Mineral	4.250	....do	Sept. 29	55,246.40	27,623.20
Wisconsin	151	Door	7.060	Gravel	Sept. 30	79,432.70	27,000.00
	15	St. Croix	7.720	....do	...do....	79,661.89	27,000.00
Wyoming	74	Converse	10.303	Concrete	Sept. 3	[3] 427,460.00	[3] 213,730.00
	89	Natrona	6.974	....do	...do....	[3] 269,940.00	[3] 134,970.00
	93	Washakie	....	Bridge	Sept. 29	6,556.00	3,278.00
	98	Carbon	4.186	Earth	Sept. 4	32,120.00	16,060.00
	99	Goshen	3.398	Selected material	...do....	104,060.00	52,030.00
	101	Big Horn	1.273	Concrete	Sept. 11	49,940.00	24,970.00

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[3] Canceled.

PROJECT AGREEMENTS EXECUTED IN SEPTEMBER, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
California	44	Yolo	10.710	Reinforced concrete	Sept. 8	$278,320.60	$139,160.30
	48	Santa Clara	8.090	Concrete	...do.....	190,439.45	95,219.72
	51	San Diego	6.675	Reinforced concrete	...do.....	161,110.26	80,555.13
	49	Santa Cruz	5.530	Concrete	...do.....	139,146.15	69,573.07
	52	Mendocino	17.800	Reinforced concrete	...do.....	441,263.84	220,631.92
	55	San Diego	4.590	....do	...do.....	119,412.48	59,706.24
Georgia	48	Clark	....	Bituminous macadam	Sept. 23	[1] 83,211.16	[1] 31,368.52
	124	Washington	5.930	Sand-clay	Sept. 21	40,000.00	20,000.00
Idaho	8	Twin Falls and Gooding	....	Bridge	Sept. 28	100,000.00	50,000.00
	14	Bonneville	5.750	Bituminous concrete	...do.....	236,263.50	95,801.64
	16	Jefferson	6.270	Earth	...do.....	53,047.33	26,523.66
	17	Bannock	8.940	Gravel	...do.....	90,000.00	39,925.01
	18	Nez Perce and Latah	22.100	Crushed rock	...do.....	306,815.41	147,815.41
	25	Bingham	1.500	Bituminous concrete	...do.....	58,459.55	29,229.77
	32	Clarke	9.329	Gravel	...do.....	63,079.78	29,999.42
Illinois	6-x	Tazewell	....	Bridge	Sept. 9	74,901.49	37,450.74
	8-xz	Madison	6.720	Concrete and brick	Sept. 14	288,578.88	132,689.93
	1-13	Lee	3.347	Bituminous macadam	...do.....	118,430.63	59,215.31
	1-19	....do	1.394	....do	...do.....	83,429.65	34,940.53
Indiana	1	Elkhart	....	Concrete	Sept. 7	[1] 5,065.15	[1] 2,532.57
	3A	Marion and Johnson	....	Bituminous concrete	...do.....	[1] 15,502.13	[1] 7,711.06
	4	Putnam and Hendrick	....	Concrete and bridges	...do.....	[2] 12,513.49	[2] 10,698.02
	6A	Clay and Vigo	....	Concrete	...do.....	[1] 16,743.99	[1] 8,372.00
	9A	Madison	....	Concrete or brick	...do.....	[1] 2,315.43	[1] 1,157.72
	10A	Marshall	....	Concrete	...do.....	[1] 8,543.03	[1] 4,271.52
	11	St. Joseph and Elkhart	....	....do	...do.....	[1] 16,434.29	[1] 8,217.15
	12A	Jackson	....	....do	...do.....	[1] 4,944.61	[1] 2,472.30
	13A	Hancock	....	....do	...do.....	[1] 18,100.46	[1] 9,050.73
	16B	Warrick	....	....do	...do.....	[2] 740.99	[1] 21,254.37
	17A	Porter and La Porte	....	Concrete or brick or bituminous	...do.....	[1] 18,930.11	[1] 9,465.06
	18A	Howard and Tipton	....	Concrete	...do.....	[1] 10,924.21	[1] 5,462.11
	25	Miami	....	Bridge	...do.....	10,776.64	5,388.32

[1] Modified agreements. Amounts given are increases over those in the original agreements.
[2] Modified agreements. Amounts given are decreases from those in the original agreements.

PROJECT AGREEMENTS EXECUTED IN SEPTEMBER, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Iowa	17A	Dubuque	21.195	Earth	Sept. 8	$131,782.14	$50,000.00
	18	Clinton	17.579	Brick or concrete	Sept. 9	911,044.03	351,500.00
	19	Grundy	14.110	Earth	...do	60,004.67	26,500.00
	26	Adams	9.960	...do	...do	167,593.80	16,507.60
	32	Des Moines	4.890	Concrete	...do	260,678.39	16,584.93
	37	Buena Vista	12.845	Gravel	...do	50,843.98	22,600.00
	40	Muscatine	19.360	Earth	...do	105,207.41	23,300.00
	49	Emmet	3.942	Concrete or brick	...do	200,461.80	78,800.00
	50	Davis	10.321	Earth	...do	106,333.26	31,150.00
	56	Henry	20.620	...do	...do	91,796.04	45,500.00
	68	Dickinson	4.803	Concrete or brick	...do	236,571.39	96,000.00
	77	Fremont	18.070	Earth	...do	147,034.66	73,500.00
	78	Woodbury	2.730	Brick or concrete	...do	160,785.62	54,785.62
	85A, B, C.	Butler	12.850	Gravel	...do	100,746.96	50,000.00
	96	Linn	12.400	Earth	...do	52,358.35	22,800.00
	128	Johnson	2.544	Concrete or brick	...do	128,397.83	50,000.00
Kansas	2C, D, E.	Labette	23.420	Gravel on macadam	Sept. 2	478,461.95	239,230.97
	6	Bourbon	6.533	Bituminous macadam	...do	221,974.61	97,995.00
Louisiana	40	Tensas	3.380	Gravel	Sept. 28	44,848.24	22,424.12
	26	Ouachita		...do	Sept. 10	[1] 6,015.99	[1] 1,053.01
Minnesota	8	Wabasha and Winona	8.960	Earth	Aug. 20	138,589.17	69,000.00
	95	Chisago	19.020	Concrete and gravel	Sept. 17	488,962.87	213,994.66
	127	Stevens	17.462	Gravel	Aug. 31	137,311.54	51,007.26
	130	Big Stone	7.688	...do	Sept. 1	90,810.55	17,103.44
	143	Beltrami	6.210	...do	Sept. 2	52,948.99	20,000.00
	148	Hennepin and Dakota	11.670	...do	Sept. 1	367,946.46	100,000.00
Mississippi	84	Jefferson	35,270	Clay and gravel	June 30	365,304.51	182,652.25
New Hampshire	50	Cheshire		Gravel	Sept. 3	[1] 1,139.60	[1] 569.80
	52	Sullivan and Merrimack		...do	...do	[2] 2,620.85	[2] 1,310.42
	66	Carroll		...do	...do	[1] 1,493.42	[1] 746.71
	83	Strafford	1.020	...do	Sept. 8	21,875.26	10,937.63
	89	Merrimack	0.578	...do	Sept. 3	17,874.59	8,937.29
	99	Coos	1.100	...do	Sept. 1	17,314.22	8,657.11
	108	Grafton	1.930	Bituminous macadam	Sept. 8	64,813.92	32,406.96
	109	Strafford	0.797	Gravel with tar surface	Sept. 3	15,013.51	7,506.75
	110	Merrimack	1.246	Modified asphalt	Sept. 1	24,993.04	12,496.52
	113	Hillsborough	0.410	Bituminous macadam with surface of tar treatment.	Sept. 3	5,951.74	2,975.87
	117	Grafton	0.940	Bituminous macadam	...do	25,087.42	12,543.71
Ohio	31D, E	Union	8.238	Reinforced concrete or bituminous macadam.	Sept. 10	282,000.00	83,800.00
	34	Erie		Reinforced concrete	Sept. 23	[1] 17,000.00	[1] 17,000.00
	46	Ashland		Concrete or monolithic brick	Sept. 24	[1] 50,040.00	[1] 4,000.00
	61	Wayne	4.082	Concrete or brick or bituminous macadam.	Sept. 10	158,000.00	69,000.00
	93	Gallia	6.248	Bituminous macadam	Sept. 29	186,000.00	92,500.00
	112	Jackson	2.332	Concrete or bituminous macadam	Sept. 22	120,000.00	42,500.00
	137	Sandusky	6.542	Brick or bituminous concrete	...do	435,500.00	106,000.00
	151	Clermont	5.489	Bituminous macadam	...do	189,700.00	88,000.00
Oregon	11	Baker		Earth	Sept. 15	[2] 41,814.85	[2] 23,907.42
	32	Lake	11.090	Gravel	...do	140,560.42	70,280.21
	36	Wasco		Earth	Sept. 9	[1] 21,442.74	[1] 10,721.37
	35	...do	8.970	...do	Sept. 15	285,963.97	142,981.98
	37	...do	12.500	...do	...do	299,204.40	149,602.20
	39	Jefferson	17.440	Broken stone	...do	174,002.40	87,001.20
	40	Wallowa	8.390	Earth	...do	123,569.71	61,784.85
	41	Gilliam	6.900	Broken stone	...do	180,158.00	90,079.00
	42	Umatilla	21.880	Broken stone or gravel	...do	129,800.00	64,900.00
	43	Crook	15.150	...do	...do	178,237.51	89,118.75
	46	Malheur	0.891	Concrete	...do	30,744.67	15,372.33
	30	Klamath	13.900	Broken stone or gravel	...do	160,608.97	80,304.48
Pennsylvania	15B	Beaver	5.334	Reinforced concrete	Sept. 3	467,322.46	106,680.00
	20D	Adams	9.732	...do	...do	562,766.95	194,640.00
	33C	Luzerne	3.196	...do	Aug. 8	239,021.53	63,920.00
	71	Lawrence	5.423	...do	Sept. 1	352,364.49	108,460.00
	72	Adams	8.740	...do	Sept. 3	533,961.82	174,800.00
	73	Franklin and Adams	8.364	Concrete	Aug. 30	459,540.86	167,280.00
	76	Mercer	9.179	Reinforced concrete	Sept. 1	643,753.02	183,580.00
	77	Monroe	7.280	...do	Sept. 2	567,596.92	145,600.00
	79	Montgomery	5.655	...do	Sept. 1	349,454.27	113,100.00
	80	Crawford	3.432	...do	Aug. 30	230,420.96	68,640.00
	83	Montgomery	4.915	...do	Sept. 3	309,546.60	98,300.00
	78	Monroe	7.094	...do	Sept. 1	554,859.09	141,880.00
	82	Erie	8.466	...do	...do	572,831.16	169,320.00
South Carolina	17	Calhoun		Bridges	Sept. 28	[2] 4,944.19	[2] 2,472.10
Texas	107	Runnels		...do	Sept. 23	72,963.58	36,481.79
	119	Wichita	10.000	Concrete	...do	568,702.68	100,000.00
	133	Kimble	30.470	Gravel	...do	201,492.45	100,000.00
	134	Polk	22.070	Stone macadam, bituminous top	...do	508,638.61	127,159.65
	145	Tom Green	10.000	Water-bound macadam, surface treatment.	...do	266,674.59	100,000.00
	160	Upshur	9.015	Gravel	...do	78,335.95	39,167.97
	167	Delta	11.700	Concrete or gravel	...do	279,022.45	110,000.00
Virginia	15	Washington		Earth	...do	[1] 98,464.30	[1] 49,232.15
	16	Botetourt and Rockbridge		Macadam	...do	[1] 7,045.78	[1] 3,522.88
	20	Southampton		Gravel	...do	[2] 68,357.47	[2] 34,178.73
	27	Smythe	5.700	Water-bound macadam	Sept. 25	95,608.35	47,804.17
	52	Lee	5.280	...do	Sept. 23	100,381.27	50,190.63
	59A	Nansemond	4.460	Concrete	...do	169,470.07	84,735.03
	46A	Rappahannock	3.086	Macadam	...do	82,914.11	41,457.05
	66	Chesterfield	8.939	Concrete	Sept. 25	346,563.69	173,281.84
	67	Dickenson	5.920	Bituminous macadam	Sept. 23	138,008.39	69,004.19
	70A	Campbell	3.110	...do	...do	102,019.00	51,009.50
	79	Prince William and Stafford	0.549	Concrete	Sept. 25	48,447.48	17,607.98
	81A	Henrico	2.480	Bituminous macadam	Sept. 23	69,666.80	34,833.40

[1] Modified agreements. Amounts given are increases over those in the original agreements.
[2] Modified agreements. Second revision. Increase.

PROJECT AGREEMENTS EXECUTED IN SEPTEMBER, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Washington	30	Skagit		Concrete	Sept. 8	[1]$21,000.09	[1]$10,500.00
	52	Stevens	7.720	Gravel	...do	104,986.17	52,000.00
	53	...do	5.990	...do	...do	89,502.09	44,000.00
	54	Grays Harbor	3.640	Earth	...do	55,429.99	26,500.00
	55	Thurston	6.200	Concrete	...do	258,598.06	125,000.00
	57	...do	1.990	...do	...do	72,114.02	36,000.00
	58	Mason	1.970	Gravel	...do	27,156.36	13,500.00
	59	Snohomish		Bridge	...do	20,577.81	10,000.00
	60	...do	3.090	Concrete	...do	107,342.18	53,000.00
	61	Lewis	1.240	Gravel or crushed rock	...do	37,146.56	18,573.28
	62	Yakima	5.760	Concrete	...do	245,598.40	82,700.00
	64	Snohomish	0.990	...do	...do	39,750.26	19,800.00
	66	Garfield	7.420	Crushed rock	...do	185,357.37	90,000.00
	67	Mason	5.490	Gravel and earth	...do	112,621.34	56,000.00
	68	Grant	3.340	Gravel	...do	51,475.16	25,000.00
	69	Chelan	1.670	Concrete	...do	66,688.71	33,000.00
	70	Lewis	3.960	Earth	...do	68,416.92	34,000.00
	73	Pacific	7.650	...do	...do	279,138.64	138,000.00
	74	Skagit		Bridge	...do	11,817.85	5,400.00
	75	Okanogan	4.140	Gravel	...do	27,794.80	13,500.00
	76	Pierce	0.500	...do	...do	34,733.60	12,736.25
Wyoming	26	Lincoln	9.174	Earth	Sept. 18	43,998.70	21,999.35
	65	Big Horn	3.172	Selected material	Sept. 20	33,371.80	16,685.90
	70	Washakie	2.902	...do	...do	30,643.21	15,321.60
	75	Uinta	2.489	...do	...do	22,622.00	11,311.00
	84	Park	6.954	...do	...do	88,044.77	44,022.38
	85	Natrona	10.000	...do	...do	111,211.40	55,605.70
	86	Johnson	6.477	...do	...do	83,376.26	41,688.13
	90	Hot Springs	3.228	...do	...do	45,973.99	22,986.99

[1] Modified agreements. Amounts given are increases over those in the original agreement.

EASTERN STATES PLAN THEIR SNOW REMOVAL WORK FOR COMING WINTER

[Concluded from page 12.]

WHERE REMOVAL IS BY HAND.

When snow must be removed by hand, it is important that the laborers be furnished with large scoops and that even at some additional first cost the snow be so piled that it will hinder rather than assist the refilling of the locations that have been cleared. It is not generally advisable to load the snow in trucks and remove it entirely, but this is sometimes done, and, indeed, when the cuts that have to be made are both wide and deep this may be cheaper than casting to one side. Snow so removed can generally be disposed of by the simple process of dumping it over the edge of the nearest high fill.

As noted before, the most expensive item in snow removal is the excavation by hand of the drifts that have gotten beyond the capacity of the snowplows. For such work as this there are now manufactured rotary plows that will cut out these drifts and cast the snow considerable distances to the side of the cut which they make. As yet these rotary plows have not come into very general use, largely, it is thought, because the removal of snow from the highways is a comparatively new thing. Their use is, however, bound to increase, for it is not at all likely even after all of the preventative measures noted above have been taken that drifting will be so thoroughly eliminated that the snowplows operated by the modern trucks can fully cope with the situation. Rather, it seems to the writer, that it will prove advisable to supplement the present equipment in most States by the addition of enough heavy plows so that a working space can be kept clear even through the cuts that are known to drift full during severe storms, thereby insuring that full efficiency can be had from the other equipment.

Just how rapidly this change in snow-removal equipment will be made will depend on the development of satisfactory rotary plows, but it can hardly be put off much longer, for the cost of shoveling out deep drifts is very expensive.

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ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS

Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul.*105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913. 5c.
*136. Highway Bonds. 25c.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
*249. Portland Cement Concrete Pavements for Country Roads. 15c.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
370. The Results of Physical Tests of Road-Building Rock. 15c.
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388. Public Road Mileage and Revenues in the New England States, 1914.
*389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914. 15c.
390. Public Road Mileage in the United States, 1914. A Summary.
*393. Economic Surveys of County Highway Improvement. 15c.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
532. The Expansion and Contraction of Concrete and Concrete Roads.
*537. The Results of Physical Tests of Road-Building Rock in 1916, including all Compression Tests. 5c.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691. Typical Specifications for Bituminous Road Materials. 15c.
704. Typical Specifications for Nonbituminous Road Materials.
724. Drainage Methods and Foundations for County Roads.

*Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918. 15c.
*Public Roads, Vol. II, No. 23. Tests of Road-Building Rock in 1919. 15c.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *37. Examination and classification of Rocks for Road Building, including Physical Properties of Rocks with Reference to Their Mineral Composition and Structure. (1911.) 15c.
*43. Highway Bridges and Culverts. (1912.) 15c.
*45. Data for Use in Designing Culverts and Short-span Bridges. (1913.) 15c.

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OFFICE OF PUBLIC ROADS CIRCULARS.

Cir.*89. Progress Report of Experiments with Dust Preventatives, 1907. 5c.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
*98. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1911. 5c.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
*52. State Highway Mileage and Expenditures to January 1, 1915. 5c.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
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Public Roads Vol. III, No. 25. Automobile Registrations, Licenses, and Revenues in the U. S. 1919.
Public Roads Vol. III, No. 29. State Highway mileage 1919.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. 338. Macadam Roads
505. Benefits of Improved Roads.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

B. Y. Sept. 727. Design of Public Roads.
B. Y. Sept. 739. Federal Aid to Highways, 1917.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D-2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D-3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D-4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D-6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D-8. Tests of Three Large-Sized Reinforced-Concrete Slabs under Concentrated Loading.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted.