# PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS

VOL. 9, NO. 2 ▽ APRIL, 1928

Roadside Treatment on a Massachusetts State Highway

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U. S. DEPARTMENT OF AGRICULTURE

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# HOW MASSACHUSETTS IS IMPROVING HER ROADSIDES

Reported by R. E. TRIBOU, Assistant Highway Engineer, District 9, United States Bureau of Public Roads

THE WORK of roadside treatment which Massachusetts started in 1921 has within a relatively few years produced a marked effect on the beauty of its highways, which will be even more striking in future years. Massachusetts is one of the few States where organized attention is given to roadside beautification and because of the general interest in the subject it appears to be worth while to present a short description of the general plan of beautification and methods of handling the work which have produced good results on a considerable mileage of road at a very reasonable cost.

A Border Planting

The Massachusetts Department of Public Works is empowered by law to make roadside improvements, the work including such plantings, replacements, and care as may be necessary. When a road is laid out as a State highway, it is generally made sufficiently wide to provide an area on each side of the traveled portion for roadside improvement. No tree, shrub, or plant within such a highway can be cut, removed, or new ones added without a permit from the highway department.

The work of roadside improvement is done by the maintenance division of the department of public works which is in charge of G. H. Delano, highway engineer. The cost is included as a part of the regular maintenance expenditure of the State. The State has a nursery at Palmer, Mass., where trees and shrubs are propagated and where J. H. Taylor, highway landscape supervisor, trains men in the care of trees and roadside beautification. This nursery is a part of the maintenance division. The following outline shows the scope of the work being done.

#### ATTENTION TO NATIVE MATERIAL

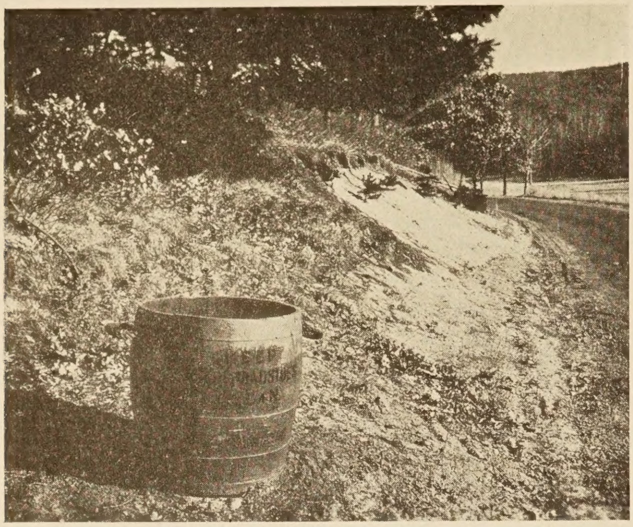
*Removal of dead material.*—Dead and dangerous branches are systematically removed. Trees entirely dead are removed and stumps cut 6 inches below the ground surface.

*First aid to injured trees.*—Mechanical wounds to trunk or branches are trimmed and sealed with tar. Trees split or in danger of splitting are fastened with bolts or cables. Open cavities are suitably repaired.

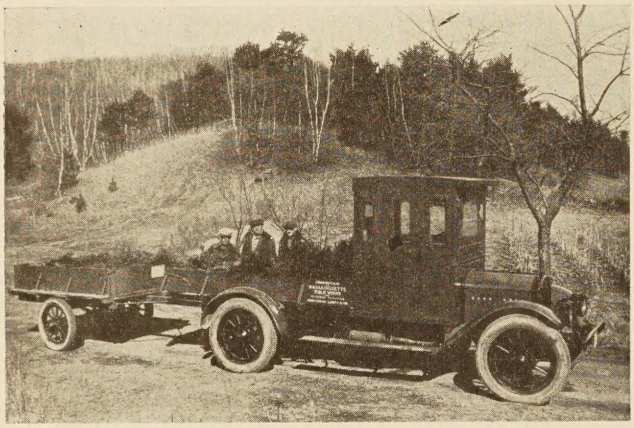
*Care of trees.*—Unsightly, abnormal, or rubbing branches are removed. Pruning and shaping is done by trained men. Spraying is done when necessary. Preservation and culture of natural growth is important work. Intelligent care of this sort will add much to the future beauty of roadsides.

*Safety work.*—Standard traffic clearance is maintained.

*Landscape cutting.*—Vistas of mountains, lakes, and streams are developed by removal of foliage screens.



An Invitation to Be Neat



Ready for a Pine Planting Trip

*Wire clearance work.*—The State supervises all tree trimming for passage of public service wires and prohibits careless and unnecessary cutting.

*Public enjoyment and education.*—Roadside springs are made available to travelers. Benches are provided in suitable places. Public cleanliness is invited by placing rubbish barrels.

#### INTRODUCTION OF NEW MATERIAL

*Healing construction scars.*—Gravel and sand slopes are planted with small pines or other adaptable ground cover. Grass or shrubs are planted where the soil will support growth.

*Tree and shrub planting.*—Trees, shrubs, and vines adapted to soil conditions are planted on roadsides, traffic islands, behind guard rails or stones, etc.

*Replacements.*—Historical and normal growth is perpetuated by annual replacement of the dead with the living.

*Maintenance.*—The success of all planting depends solely upon maintenance. Young trees and shrubs must have care. The future beauty of trees depends largely upon their training in youth, which means that trees should be staked and pruned annually and intelligently. Shrubs must be cut back properly to insure a graceful maturity and soil about the base of all planted stock kept open for proper moisture and air. Such work is imperative and must be done regularly.

A Bare Sand Bank Relieved by Planting Sweet Fern

The men engaged in this work are advised to study how nature plants and imitate it as far as possible. The object is to keep the roadsides as natural as possible by the use of native material. A Colorado blue spruce on a Massachusetts roadside is distinctly out of place and artificial since it is not characteristic of Massachusetts. Importations may be attractive but they do not reflect the personality of the State.

Plantings on roadsides are mainly confined to new construction for several reasons. The wider locations (60 feet or more) give more opportunity for scenic development, and these relocated and widened roads promise a fairly undisturbed future. Shade trees are planted as near as possible to the side line, but for the most part the monotony of straight lines and even spacing is avoided. Grouping of trees and shrubs is at all times preferable.

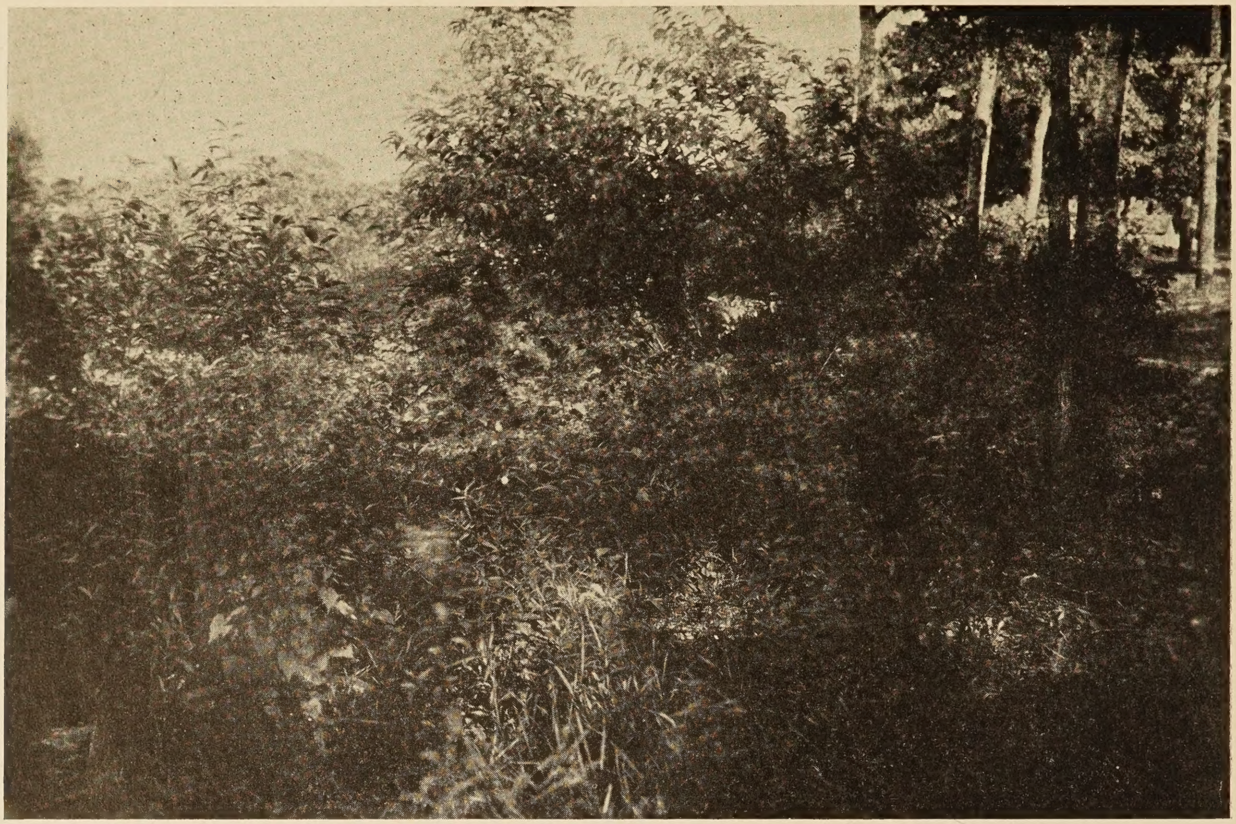
*Planting procedure.*—After a construction job is completed the plan of treatment is determined by an employee trained in the work, who locates the various plantings on a blue print of the layout, using colored pencils. Next the ground is staked for digging. Digging costs are decreased 50 per cent and an extended area is stirred up when holes are blown by dynamite. Pits are filled with the best soil obtainable.

An order for the necessary planting material is forwarded to the nursery and the material is delivered by trucks and trailers. Plantings are carefully made, giving the trees or shrubs every opportunity to get a good start and each planting is staked. After the planting has become well established a final grubbing is given.

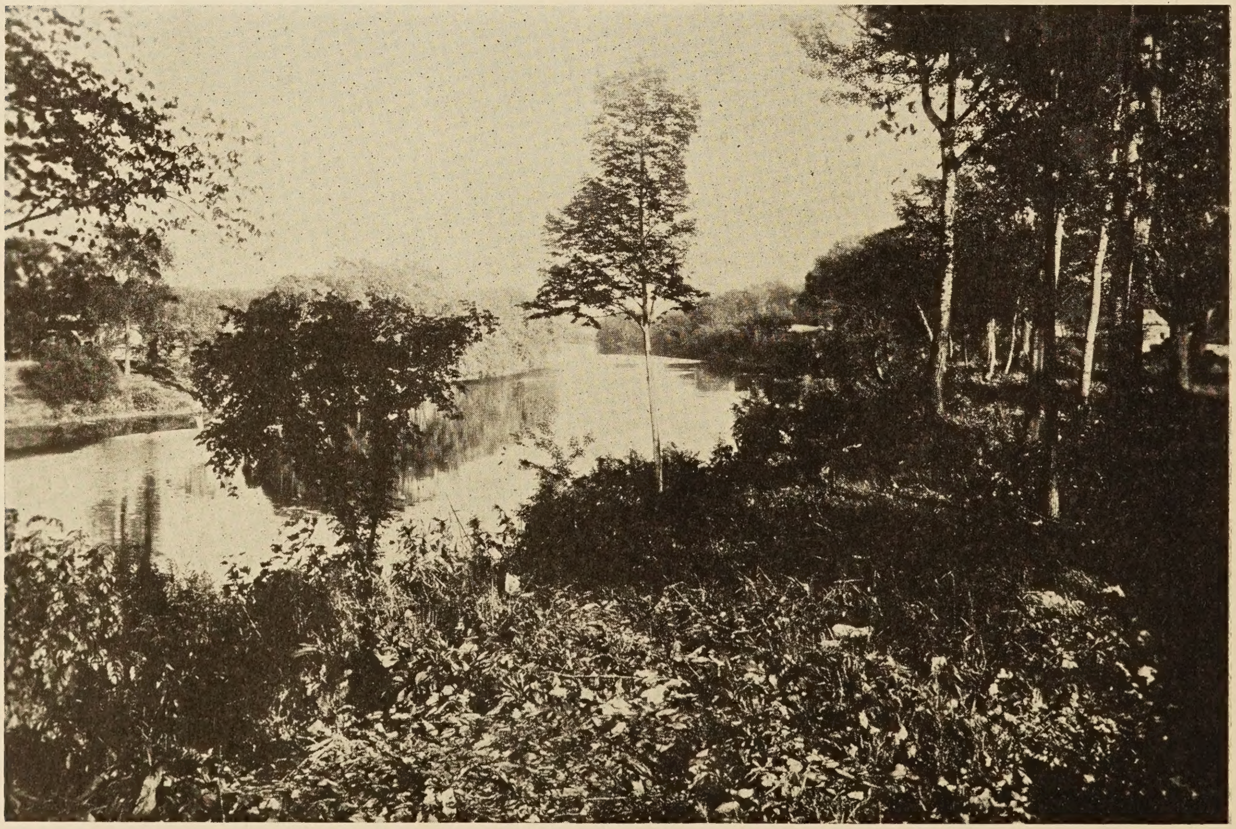
The results which are being secured are best described by the accompanying illustrations which were taken by Mr. J. H. Taylor, Highway Landscape Supervisor.

An Old, Rotten, and Unsightly Growth of Stumps

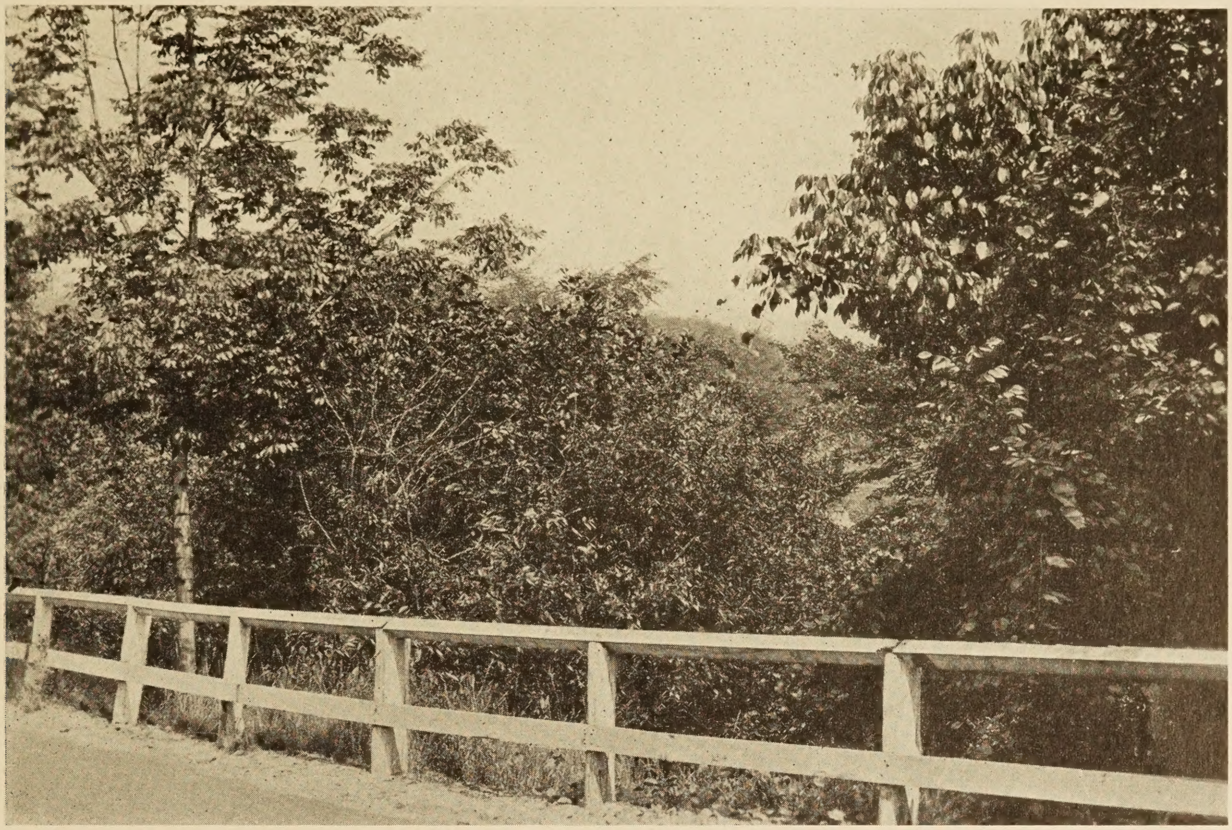
Stumps Removed, Allowing Rapid Development of the Secondary Growth



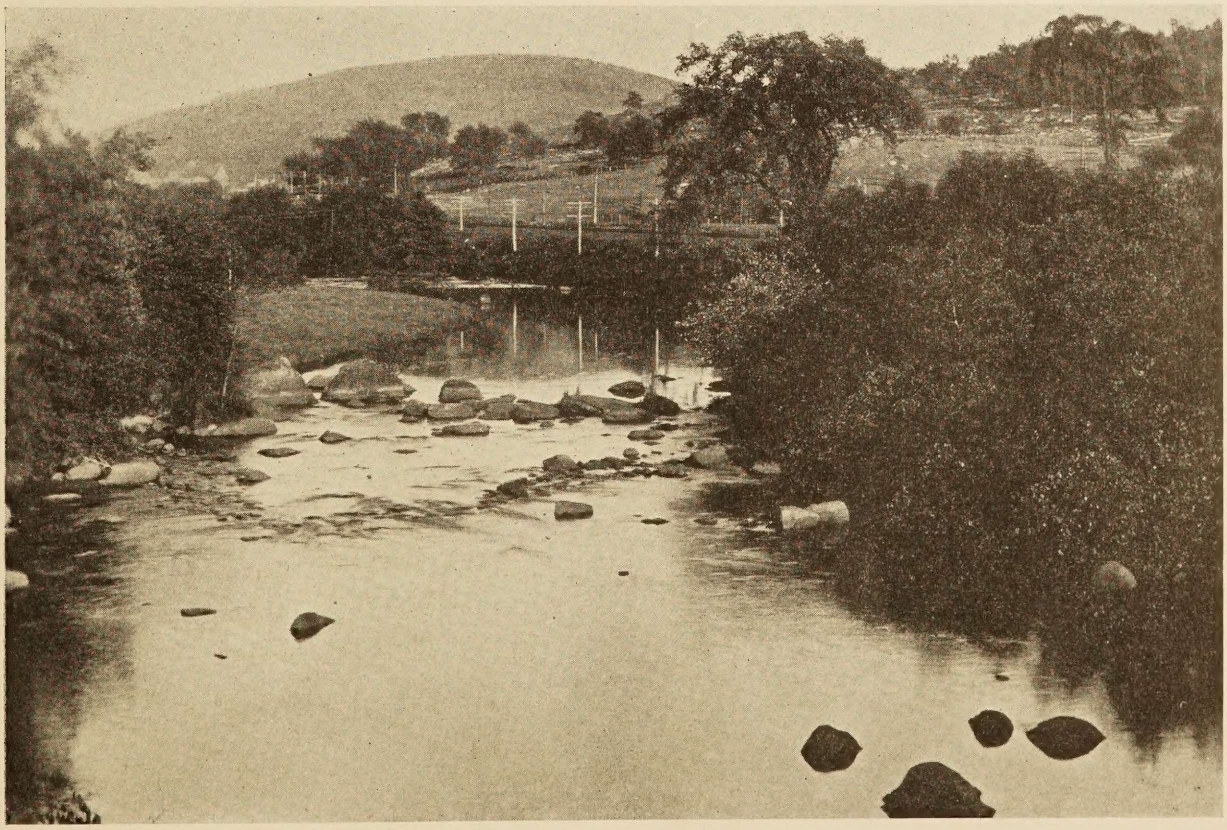
Before Landscape Cutting



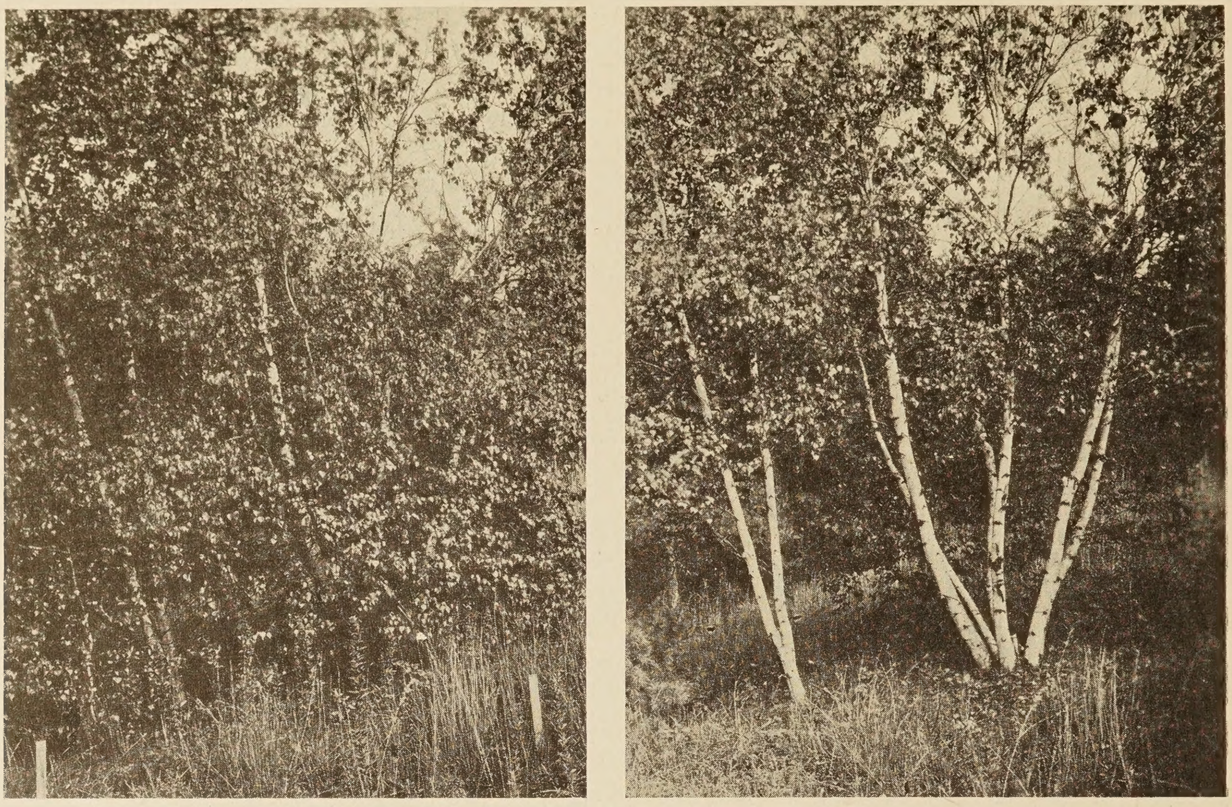
The Result of Landscape Cutting at the Location Shown Above



A Dense Undergrowth Which Cuts Off a Beautiful Vista



After Landscape Cutting at the Location Shown Above

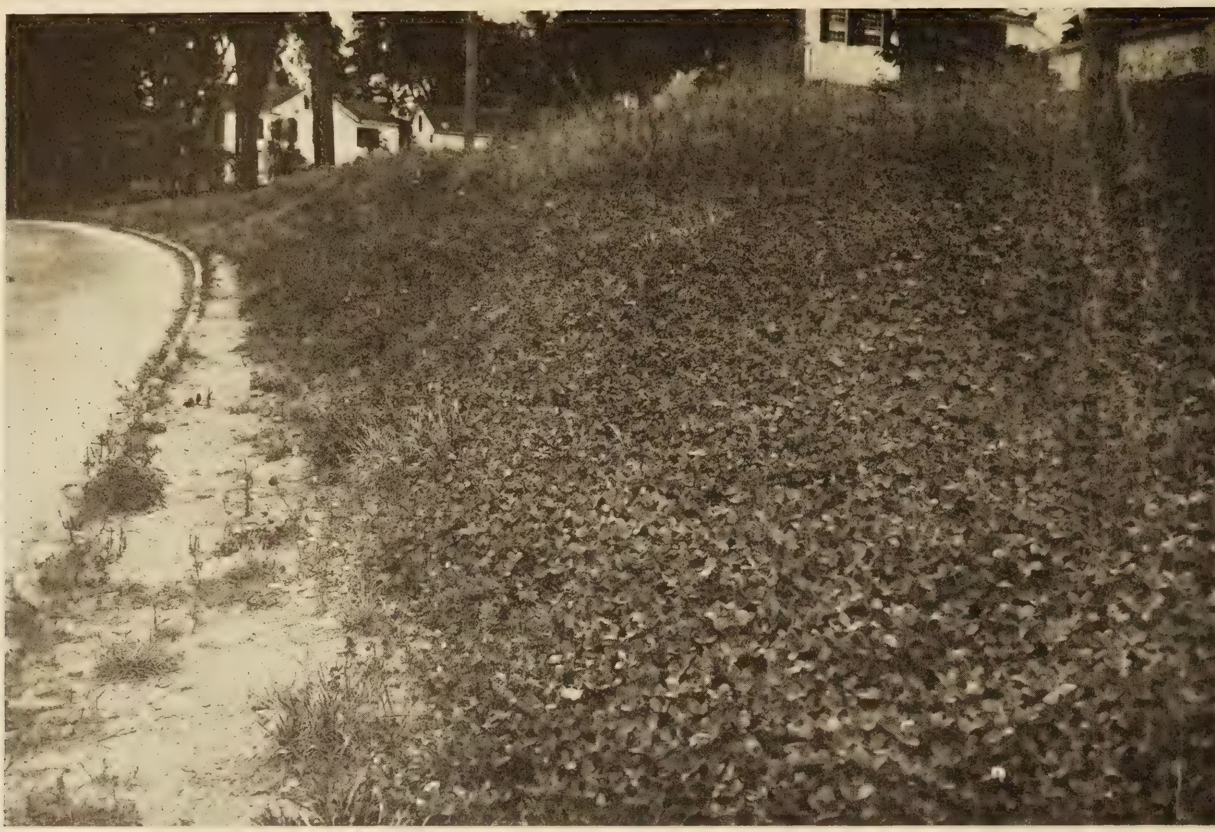


Developing a Group of Birches

Grey Birch, with Brush and Lower Limbs Removed for Trunk Emphasis

A Wayside Spring Developed

Tree Surgery Can Greatly Improve Trees of Undesirable Shape. As a Result of 20 Minutes' Work on the Tree Shown at the Left It Has Been Converted into a Tree of Much Better Proportions



Clover on Chipped Stone and Gravel Bank 41 Days After Sowing Seed

Pine Planting in Untreated Bank

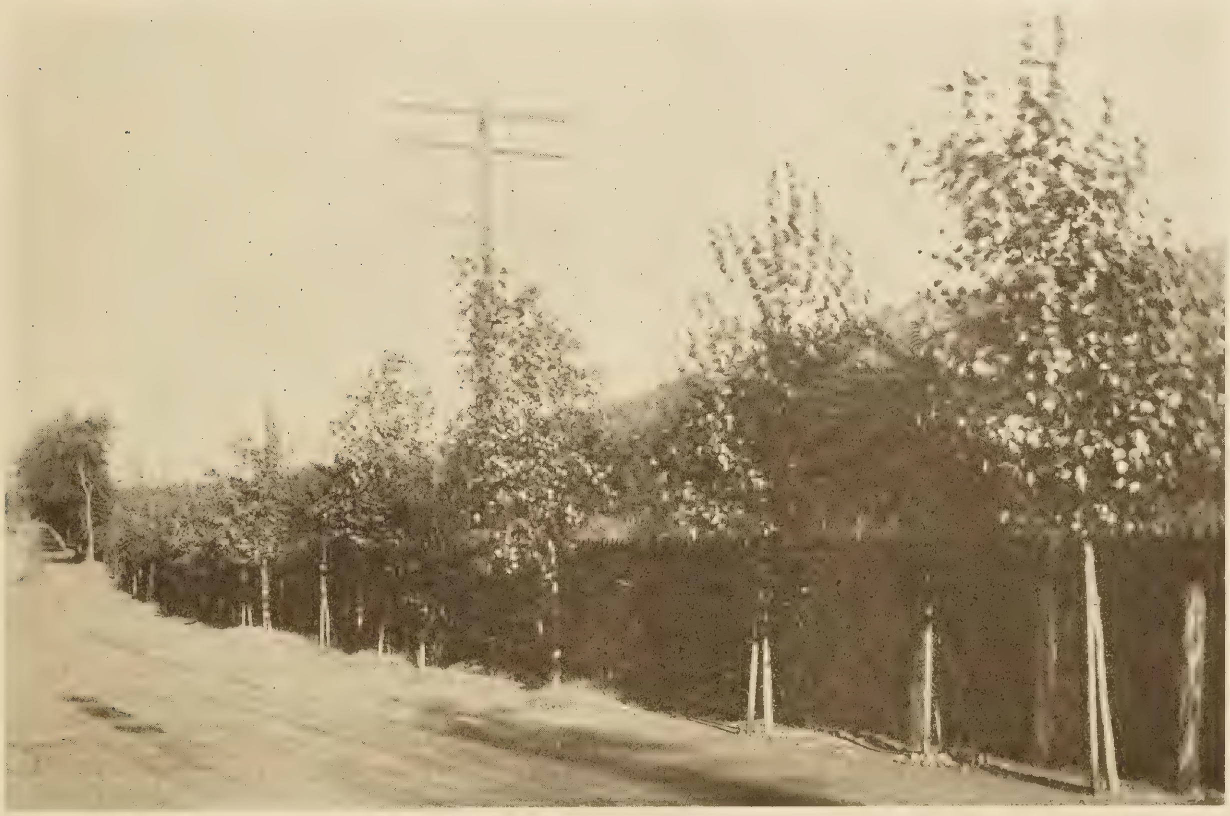
The Elderberry is Worth Saving

Softening the Harsh Lines of Protective Stones

Here and There Evergreen Plantings Liven the Winter Landscape

A Beach Plum Border on Cape Cod

The Glory of Common Things



Landscape Greatly Improved by a Tree Planting Along a Board Fence

An Unsightly Gravel Bank Which Has Been Covered with Honeysuckle

An Example of What Can Be Done by Removal of Telephone Poles and Wires. The Wires Shown in the Upper Picture are Carried in a Cable Shown at the Left in the Lower Picture

## R. W. CRUM APPOINTED DIRECTOR OF HIGHWAY RESEARCH BOARD

Announcement is made by F. H. Eno, chairman of the executive committee of the highway research board of the National Research Council, of the appointment of Roy W. Crum, of Ames, Iowa, as director of the board, effective April 1, 1928.

Mr. Crum's experience in research work well qualifies him for this position. After graduation from the Iowa State College in 1907 he was engaged on the engineer corps of the Pennsylvania Lines, following which he returned to Iowa State College as associate professor of civil engineering. He remained in this position for 12 years, during which time he was engaged on research work for the Iowa experiment station. Since 1919 he has been engineer of materials and tests with the Iowa State Highway Commission where he has conducted many highway research studies. Mr. Crum has been a member of the committee on character and use of road materials since the organization of the board, and in 1925 he was appointed chairman of the culvert investigation conducted by the highway research board.

Mr. Crum is the author of a number of important research papers. He is a member of the American Society of Civil Engineers, the American Society for Testing Materials, and the American Concrete Institute and is active on several research committees of those organizations.

# POWER-SHOVEL OPERATION IN HIGHWAY GRADING

## A REPORT OF OBSERVATIONS MADE ON GOING PROJECTS BY THE DIVISION OF MANAGEMENT, BUREAU OF PUBLIC ROADS

Reported by T. WARREN ALLEN, Chief, Division of Management, and ANDREW P. ANDERSON, Associate Highway Engineer

### PART 3.—HAULING WITH TRUCKS AND LARGE TRACTOR-DRAWN WAGONS

TRUCKS of various kinds are frequently used to transport the output of power shovels on highway work. The bureau's studies indicate that opinion is far from uniform as to the most desirable type of truck or on such points as tire equipment, carrying capacity, dumping arrangement, and body types. Practically all of the common types of trucks now in use for general hauling have been found on grading projects and in capacities ranging from the light 1-ton to the heavy 7-ton truck.

With such diversity of types, it is only natural that wide variations should also be found in the efficiency with which they meet the specialized requirements of highway grading. Moving material from the shovel to the dump is quite different from highway transportation and there is little or no dependable data to guide the grading contractor in selecting trucks for hauling. Both successes and failures have been found during these studies. It appears worth while to discuss in some detail the requirements and conditions under which the truck may be used to good advantage and also the conditions which sometimes make their use inadvisable.

The truck is a well-built, dependable machine, but moving material from the shovel to the dump sometimes offers so many adverse conditions such as soft ground, rough going, and difficult grades that there is probably no field in which operating conditions are more variable and severe. Wear and tear on vehicles is often excessive, the speed much reduced and operating costs abnormally high when compared with production. This is a condition which should not be attributed to shortcomings of the truck as a hauling unit but is due very largely to poor judgment in selecting trucks for jobs to which they are not suited, to selection of the wrong kind of trucks or to lack of ability in their management on the job.

#### TIME CONSTANT FOR TRUCKS STUDIED

The operation characteristics of the truck differ considerably from those of the team and wagon. The first and perhaps the greatest difference is in the time constant, that is, the time required to take on the load, to dump it, and to perform all turning and maneuvering, together with such waits and delays as may be necessary on each round trip. For a two-horse team and wagon the time constant may be as low as one minute and should never exceed two minutes in good common excavation. Tables 1 to 3 show the results of time constant studies on typical jobs using different makes and sizes of trucks, and Table 4 shows the average value of the time constant on each of these jobs.

The loading time is, of course, entirely dependent on the capacity of the hauling vehicle and the rate of shovel output. So long as trucks can be exchanged during the shovel cycle this item need not be given consideration in the selection or control of the hauling equipment. The time required to dump a heavy load is often comparatively large, especially if the material is very sticky. The lightest trucks used in this work are generally equipped with gravity-dump bodies. Practically all others are equipped with a mechanism for raising the front end of the truck body to an angle at which the material is supposed to slide out through the unlatched rear gate. Both the rate at which the hoisting mechanism operates and the angle to which it will tilt the body vary considerably with different makes. During two of the one-hour studies on job No. 44 (Table 1) the average dumping time exceeded two minutes due to adhesive material or large chunks wedging in the body. Tables 1 to 4 show, however, that the dumping time for trucks in good condition and under average operating conditions may be expected to vary between 15 and 25 seconds for light, 1-ton trucks, between 30 and 45 seconds for medium trucks, and from 50 to 80 seconds for heavy trucks.

Roadway in Good Condition and Truck Spotted for Loading at the Side

#### TIME LOSSES DUE TO TURNING AND BACKING GENERALLY AN IMPORTANT ITEM

Trucks must generally be turned around twice with each load carried except on some short haul work. This takes time because under most ordinary conditions some backing is required. The roadway width varies a good deal in different States. A width of about 30 feet is perhaps the most common but it is not unusual to have a width of several feet more or several feet less. Thirty feet of width is sufficient for quick turning if it can all be used, but usually a strip some 5 feet along the edge of the dump is so soft that it will hardly carry the weight of an empty truck. The usable area is often so restricted that the truck has to pull forward and back a number of times before it can complete the turn. In a through cut the condition is not apt to be so bad but even here it is seldom possible to make the turn without some backing. The time used in turning, as obtained on several jobs, is shown in Tables 1 to 4. For the heavier vehicles the total time required for turning and spotting to receive and dump the load during each round trip is rarely less than 75 seconds and may under adverse conditions exceed 3 minutes. Where the operating space is

TABLE 1.—*Time constant studies on two jobs using 3½-ton trucks (make A[1]) and ¾-yard power shovels; each entry is the average of a one-hour study*

JOB NO. 41

[Time constant, 272.1 seconds]

| Dippers per load | Loading | Waiting at dump | Turning at dump | Dumping | Turning at shovel |
|---|---|---|---|---|---|
| *Number* | *Seconds* | *Seconds* | *Seconds* | *Seconds* | *Seconds* |
| 5.0 | 173.5 | 2.5 | 24.5 | 39.2 | 23.0 |
| 5.0 | 127.4 | 23.2 | 30.2 | 56.4 | 25.4 |
| 4.8 | 158.2 | 17.0 | 22.7 | 28.8 | 20.3 |
| 6.0 | 151.7 | .......... | 18.5 | 25.5 | 27.2 |
| 5.8 | 182.2 | .......... | 22.2 | 29.2 | 20.2 |
| 6.0 | 189.0 | 68.0 | 22.0 | 29.3 | 24.5 |
| 6.0 | 190.0 | 17.7 | 24.0 | 31.7 | 24.1 |
| 6.1 | 164.4 | 8.4 | 25.4 | 25.4 | 21.6 |
| 6.1 | 152.0 | 26.5 | 23.7 | 29.0 | 19.8 |
| 6.0 | 213.7 | 4.2 | 26.3 | 37.3 | 23.8 |
| 6.0 | 179.7 | .......... | 25.7 | 28.7 | 24.6 |
| 6.0 | 250.0 | .......... | 21.4 | 35.2 | 29.2 |
| Av. 5.7 | 177.6 | 14.0 | 23.9 | 33.0 | 23.6 |

JOB NO. 44

[Time constant, 290.8 seconds]

| Dippers per load | Loading | Waiting at dump | Turning at dump | Dumping | Turning at shovel |
|---|---|---|---|---|---|
| 3.0 | 78.3 | .......... | 15.3 | 26.3 | 33.0 |
| 3.4 | 82.4 | 428.6 | 15.0 | 132.0 | 40.0 |
| 3.0 | 67.5 | 329.0 | 15.0 | 63.0 | 48.5 |
| 3.3 | 92.3 | 378.3 | 16.0 | 122.0 | 47.6 |
| 3.2 | 72.5 | 6.2 | 15.0 | 53.5 | 15.0 |
| 3.8 | 91.2 | 79.5 | 14.7 | 31.7 | 62.2 |
| 4.0 | 92.0 | .......... | 13.5 | 20.5 | 53.5 |
| 4.0 | 79.0 | 16.2 | 12.6 | 22.6 | 59.4 |
| 4.0 | 74.2 | 3.8 | 10.4 | 22.6 | 25.0 |
| 4.0 | 66.8 | .......... | 11.4 | 21.0 | 42.8 |
| 4.0 | 80.0 | 45.6 | 14.2 | 23.2 | 28.0 |
| 4.0 | 101.0 | 17.4 | 14.6 | 19.8 | 27.8 |
| Av. 3.6 | 81.4 | 108.7 | 14.0 | 46.5 | 40.2 |

[1] In this discussion letters have been substituted for the names of truck manufacturers.

TABLE 2.—*Time constant studies on two jobs using different sizes and makes of trucks; each entry represents a single observation*

3½-TON TRUCKS (MAKE B), LOADED BY A 1-YARD POWER SHOVEL

[Time constant, 274.4 seconds]

| Dippers per load | Loading | Waiting at dump | Turning at dump | Dumping | Turning at shovel |
|---|---|---|---|---|---|
| *Number* | *Seconds* | *Seconds* | *Seconds* | *Seconds* | *Seconds* |
| 5 | 149 | .......... | 27 | 25 | 44 |
| 5 | 130 | .......... | 35 | 16 | 50 |
| 5 | 142 | .......... | 16 | 17 | 35 |
| 6 | 209 | .......... | 53 | 57 | 102 |
| 6 | 236 | .......... | 23 | 57 | 40 |
| 6 | 213 | .......... | 10 | 17 | 26 |
| 5 | 161 | .......... | 21 | 24 | 29 |
| 5 | 170 | .......... | 58 | 40 | 36 |
| 6 | 180 | .......... | 30 | 48 | 32 |
| 5 | 151 | .......... | 17 | 24 | 44 |
| 5 | 146 | .......... | 24 | 21 | 23 |
| 5 | 138 | .......... | 17 | 15 | 49 |
| 5 | 150 | .......... | 40 | 39 | 45 |
| 5 | 170 | .......... | 26 | 19 | 32 |
| 5 | 175 | .......... | 26 | 33 | 56 |
| 5 | 135 | .......... | 42 | 30 | 58 |
| 5 | 165 | .......... | 20 | 15 | 35 |
| 6 | 200 | .......... | 16 | 30 | 30 |
| 6 | 264 | .......... | 41 | 36 | 39 |
| 5 | 175 | .......... | 38 | 20 | 62 |
| Av. 5.3 | 172.9 | .......... | 29.0 | 29.2 | 43.3 |

restricted trucks with a short wheel base have a definite advantage, and save much time.

With rear-wheel drive it is often impossible to take full advatange of the minimum radius on which a truck will turn and this is especially true where ground conditions are bad and the vehicle will stall if the front wheels are cut the maximum amount. For this reason it is not to be expected that a truck will turn on as short a radius under the conditions commonly prevailing on a construction job as it will turn on an improved highway.

TABLE 2.—*Time constant studies on two jobs using different sizes and makes of trucks; each entry represents a single observation*—Con.

1-TON TRUCKS (MAKE C), LOADED BY A ¾-YARD POWER SHOVEL

[Time constant 114.3 seconds]

| Dippers per load | Loading | Waiting at dump | Turning at dump | Dumping | Turning at shovel |
|---|---|---|---|---|---|
| *Number* | *Seconds* | *Seconds* | *Seconds* | *Seconds* | *Seconds* |
| 1 | 16 | .......... | 24 | 10 | 37 |
| 2 | 60 | .......... | 40 | 55 | 15 |
| 1 | 16 | .......... | 32 | 7 | 56 |
| 1 | 26 | .......... | 17 | 83 | 32 |
| 1 | 6 | 48 | 28 | 13 | 36 |
| 1 | 18 | 78 | 10 | 12 | 24 |
| 2 | 27 | .......... | 28 | 31 | 20 |
| 2 | 31 | 11 | 39 | 26 | 18 |
| 2 | 37 | .......... | 24 | 26 | 21 |
| 2 | 46 | .......... | 36 | 17 | 20 |
| 2 | 47 | .......... | 28 | 24 | 20 |
| 2 | 28 | .......... | 24 | 41 | 21 |
| 2 | 31 | .......... | 25 | 12 | 24 |
| 2 | 42 | [1] 166 | 23 | 10 | 19 |
| 2 | 44 | .......... | 17 | 15 | 21 |
| 2 | 37 | .......... | 22 | 19 | 19 |
| 2 | 29 | .......... | 11 | 13 | 22 |
| 2 | 34 | .......... | 19 | 23 | 17 |
| 2 | 37 | .......... | 28 | 14 | 13 |
| 2 | 54 | .......... | 45 | 40 | 16 |
| Av. 1.75 | 33.3 | 6.9 | 26.0 | 24.5 | 23.6 |

[1] Not included in average.

TABLE 3.—*Time constant study on a job using 5-ton trucks (make D), hauling over an old road surface in good condition, each entry represents the average of a days study*

[Time constant, 536 seconds]

| Dippers per load | Loading | Waiting at dump | Turning at dump | Dumping | Turning at shovel |
|---|---|---|---|---|---|
| *Number* | *Seconds* | *Seconds* | *Seconds* | *Seconds* | *Seconds* |
| 5.0 | 140 | 232 | 57 | 122 | 138 |
| 7.7 | 339 | 14 | 37 | 110 | 98 |
| 7.0 | 261 | 45 | 68 | 88 | 96 |
| 9.3 | 387 | 120 | 89 | 59 | 62 |
| 7.5 | 400 | 298 | 63 | 43 | 64 |
| 6.0 | 222 | 39 | 61 | 68 | 80 |
| 6.7 | 214 | 10 | 95 | 84 | 92 |
| 5.7 | 250 | 37 | 62 | 65 | 58 |
| 6.3 | 250 | 98 | 93 | 64 | 47 |
| 6.7 | 234 | 49 | 118 | 57 | 51 |
| 4.8 | 173 | 17 | 88 | 46 | 53 |
| 5.0 | 187 | 47 | 54 | 65 | 60 |
| 5.3 | 185 | 61 | 44 | 135 | 49 |
| 5.7 | 252 | 7 | 60 | 43 | 46 |
| 6.3 | 257 | 46 | 37 | 53 | 55 |
| 4.3 | 160 | 239 | 76 | 41 | 45 |
| 4.7 | 166 | 187 | 57 | 50 | 45 |
| Av. 6.6 | 240 | 91 | 68 | 70 | 67 |

TABLE 4.—*Average value of time constant with various types of trucks; each entry is average found for a job study*

| Kind of equipment | Dippers per load | Loading | Waiting at dump | Turning at dump | Dumping | Turning at shovel | Total time constant |
|---|---|---|---|---|---|---|---|
| | *Number* | *Seconds* | *Seconds* | *Seconds* | *Seconds* | *Seconds* | *Seconds* |
| 3½-ton, make A | 5.7 | 177.6 | 14.0 | 23.9 | 33.0 | 23.6 | 272.1 |
| 3½-ton, make A | 3.6 | 81.4 | 108.7 | 14.0 | 46.5 | 40.2 | 290.8 |
| 3½-ton, make B | 5.3 | 172.9 | .......... | 29.0 | 29.2 | 43.3 | 274.4 |
| 5-ton, make D | 6.6 | 240.0 | 91.0 | 68.0 | 70.0 | 67.0 | 536.0 |
| 1-ton, make C | 1.75 | 33.3 | 6.9 | 26.0 | 24.5 | 23.6 | 114.3 |

Backing frequently increases the time constant. The backing speed of most trucks is relatively low. In spite of this handicap trucks are quite often backed a much greater distance than is necessary in getting into position at the shovel and are often backed into position at the dump. Some backing may be desirable and it has been pointed out that sufficient attention is seldom given to spotting the trucks at the shovel

Table 5.—*Hauling speed and time constant on a job where 5-ton trucks (make D) with solid tires were used; each entry is the average of one day's study*

[The trucks were backed to the dump down a 11 per cent grade with a good surface. Average time constant 208 seconds]

| Time constant | | | | Round-trip speed | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Time | | Average speed | |
| Dippers per load | Loading | Waiting at dump | Dumping | Haul | Haul in reverse | Return forward | Haul in reverse | Return forward |
| *Number* | *Seconds* | *Seconds* | *Seconds* | *Feet* | *Seconds* | *Seconds* | *Feet per minute* | *Feet per minute* |
| 3.2 | 106 | 60 | 111 | 340 | 146 | 84 | 139 | 243 |
| 3.2 | 77 | -------- | 51 | 360 | 140 | 89 | 154 | 243 |
| 4.0 | 102 | 9 | 93 | 400 | 163 | 83 | 146 | 289 |
| 3.3 | 90 | 55 | 79 | 420 | 177 | 89 | 142 | 283 |
| Av. 3.4 | 94 | 31 | 83 | 380 | 156 | 86 | 145 | 264 |

Table 6.—*Hauling speed on a job where 3½-ton trucks (make A) with solid tires were used; each entry the result of a single observation*

The trucks were backed to the dump down a grade varying from 4 to 10 per cent and from fair to poor condition]

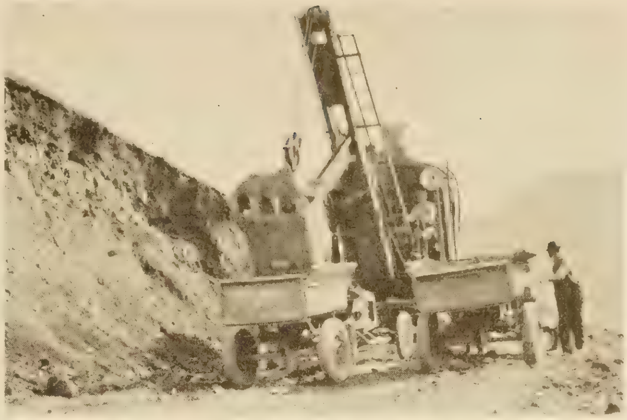
| Dippers per load | Haul | Time | | Average speed | |
|---|---|---|---|---|---|
| | | Haul in reverse | Return forward | Haul in reverse | Return |
| *Number* | *Feet* | *Seconds* | *Seconds* | *Feet per minute* | *Feet per minute* |
| 5 | 630 | 260 | 205 | 145 | 184 |
| 5 | 630 | 232 | 149 | 163 | 253 |
| 5 | 630 | 209 | 150 | 181 | 252 |
| 5 | 630 | 203 | 113 | 186 | 334 |
| 5 | 530 | 165 | 100 | 192 | 318 |
| 5 | 530 | 210 | 150 | 151 | 211 |
| 5 | 530 | 155 | 130 | 205 | 244 |
| 5 | 530 | 210 | 160 | 151 | 198 |
| 5 | 475 | 179 | 84 | 159 | 340 |
| 5 | 475 | 140 | 113 | 204 | 252 |
| 5 | 475 | 171 | 107 | 167 | 267 |
| 5 | 475 | 158 | 83 | 180 | 344 |
| 5 | 475 | 130 | 101 | 219 | 282 |
| 5 | 740 | 235 | 152 | 189 | 292 |
| 5 | 740 | 222 | 178 | 200 | 249 |
| 5 | 740 | 250 | 167 | 178 | 265 |
| 5 | 740 | 265 | 155 | 168 | 286 |
| 5 | 800 | 275 | 171 | 175 | 281 |
| 5 | 800 | 293 | 178 | 164 | 270 |
| 5 | 800 | 272 | 157 | 177 | 311 |
| Total or av ... | 12,375 | 4,234 | 2,803 | 175 | 265 |

Table 7.—*Hauling speed of 3½-ton trucks (make B) equipped with dual pneumatic tires on the rear wheels*

[Loaded trucks moved down grade over a fairly smooth surface]

| Dippers per load | Haul | Time | | Average speed | |
|---|---|---|---|---|---|
| | | Haul | Return | Haul | Return |
| *Number* | *Feet* | *Seconds* | *Seconds* | *Feet per minute* | *Feet per minute* |
| 6 | 1,850 | 149 | 117 | 748 | 950 |
| 5 | 1,850 | 135 | 150 | 821 | 742 |
| 6 | 1,850 | 155 | 125 | 718 | 890 |
| 4 | 1,850 | 105 | 112 | 1,051 | 993 |
| 4 | 1,850 | 97 | 122 | 1,145 | 910 |
| 6 | 1,850 | 137 | 135 | 811 | 821 |
| 5 | 1,850 | 120 | 114 | 927 | 975 |
| 5 | 1,400 | 113 | 115 | 743 | 730 |
| 4 | 1,400 | 87 | 101 | 965 | 808 |
| 4 | 1,400 | 80 | 134 | 1,050 | 626 |
| 5 | 1,400 | 80 | 97 | 1,050 | 867 |
| 5 | 1,400 | 105 | 141 | 800 | 595 |
| 4 | 1,400 | 79 | 122 | 1,064 | 688 |
| 5 | 1,400 | 103 | 140 | 816 | 600 |
| 5 | 1,400 | 95 | 128 | 886 | 656 |
| Total or av. 73 | 24,150 | 1,640 | 1,856 | 883 | 781 |

Note.—At one time the trucks were required to turn and back to shovel, a distance of 475 feet. The average speed in reverse was 400 feet per minute. Operation in this manner not included in above table.



Typical Operation with Light Trucks on Pneumatic Tires. The Lower Picture Illustrates a Case Where Shuttling Can Be Practiced to Advantage

so as to take advantage of the greater production which is possible when loading at the side instead of behind the shovel.

### BACKING LOADED TRUCKS TO DUMP SOMETIMES ADVANTAGEOUS

On short-haul work—hauls up to 400, 500, or 600 feet—much time can often be saved by shuttling trucks—that is, backing them under load to the dump and driving them forward to the shovel. A skillful truck driver will soon learn to back a truck to the dump almost as easily and accurately as he can drive it forward. The distance over which it pays to shuttle trucks depends on whether the time lost due to slow speed in backing is compensated for by the saving in turning time. In theory there is a wide difference between normal driving speed ahead and in reverse. In practice the observed backing speed is usually relatively high when compared with the forward hauling speed as indicated by Tables 5, 6, and 7. Where this is true and the turning time is large, the distance over which shuttling can be done to advantage is considerable.

Shuttling is not resorted to as often as it ought to be nor to as great a distance. Under the conditions given in Tables 5, 6, and 7, shuttling could have been practiced up to a distance of about 700 feet in each case. On short hauls—that is, on hauls up to 200 or 300 feet—shuttling the trucks sometimes nearly doubles their output. It also improves operating conditions, as where trucks are turning both at the dump and at the shovel it is hard to manage the trucks so that they will not interfere with each other.

Road Conditions Have an Important Bearing on the Efficiency of Truck Hauling, Particularly with the Larger Sizes of Trucks

### PNEUMATIC TIRES BETTER THAN SOLID TIRES FOR OPERATION ON SOFT GROUND

Heavy trucks are apt to mire down in soft ground and they are not well adapted to the conditions prevailing when layer dumping is required unless the material compacts easily. End dumping is much better suited to truck hauling. Even then, for fast truck operation the load must be dumped some little distance from the edge and then pushed over with a bulldozer. The increased confidence with which the trucks can be handled when they are not required to drive close to the end of the fill, to say nothing of the accidents which occur on such work, generally reduce the average time per load enough to more than pay the extra cost of the bulldozer.

Soft ground on the dump and around the shovel causes many delays. In a deep cut the moisture content of the soil at the bottom of the cut is apt to be high. Clay is often in a plastic condition, a good deal like stiff putty and yields readily under heavy loads. In the fill the same condition is retained and is made worse by every rain. Trucks may be mired down, causing a loss of time not only for the mired truck but also for those sent to its assistance. Much of this difficulty is due to the use of trucks where a careful examination would have indicated that other hauling

Table 8.—*Hauling speed of 3½-ton trucks (make A) with solid tires over a rough road; each entry is the average of a one-hour study*

JOB NO. 41

[Average round-trip speed, 271 feet per minute]

| Dippers per load | Haul | Time | | Average speed | |
|---|---|---|---|---|---|
| | | Haul | Return | Haul | Return |
| *Number* | *Feet* | *Seconds* | *Seconds* | *Feet per minute* | *Feet per minute* |
| 6.1 | 700 | 217.5 | 123.2 | 192 | 342 |
| 6.1 | 550 | 130.7 | 85.2 | 253 | 388 |
| 6.1 | 500 | 126.0 | 83.0 | 238 | 362 |
| 6.0 | 420 | 90.0 | 76.7 | 280 | 329 |
| 6.0 | 420 | 99.7 | 81.7 | 253 | 309 |
| 5.8 | 400 | 79.0 | 59.6 | 304 | 403 |
| 6.0 | 400 | 114.8 | 84.8 | 209 | 283 |
| 6.0 | 400 | 168.2 | 85.2 | 143 | 282 |
| 4.8 | 360 | 60.6 | 41.6 | 358 | 520 |
| 6.0 | 360 | 67.8 | 54.7 | 319 | 395 |
| 5.0 | 350 | 77.7 | 48.5 | 270 | 433 |
| 6.0 | 350 | 139.0 | 69.7 | 151 | 301 |
| 5.0 | 320 | 81.8 | 99.0 | 236 | 195 |
| Total or av. 74.9 | 5,530 | 1,452.8 | 992.9 | 228 | 334 |

JOB NO. 44

[Average round-trip speed, 369 feet per minute]

| | | | | | |
|---|---|---|---|---|---|
| 3.3 | 1,900 | 356.7 | 246.3 | 320 | 463 |
| 3.0 | 1,800 | 267.3 | 228.3 | 404 | 474 |
| 3.4 | 1,800 | 298.2 | 209.0 | 362 | 508 |
| 3.0 | 1,800 | 375.0 | 244.5 | 288 | 442 |
| 4.0 | 1,200 | 201.8 | 149.8 | 358 | 480 |
| 3.8 | 1,100 | 178.5 | 143.7 | 371 | 460 |
| 4.0 | 1,100 | 165.2 | 156.2 | 401 | 423 |
| 3.2 | 1,000 | 271.7 | 237 7 | 221 | 252 |
| 4.0 | 900 | 174.5 | 180.5 | 309 | 299 |
| 4.0 | 700 | 134.4 | 70.8 | 313 | 593 |
| 4.0 | 700 | 147.0 | 81.0 | 286 | 520 |
| 4.0 | 450 | 67.4 | 49.8 | 400 | 540 |
| 4.0 | 450 | 93.2 | 52.6 | 290 | 514 |
| 4.0 | 300 | 59.6 | 55.4 | 302 | 324 |
| 3.0 | 150 | 53.0 | 46.3 | 170 | 195 |
| Total or av. 54.7 | 15,350 | 2,843.5 | 2,152.9 | 320 | 423 |

Table 9.—*Hauling speed with 1-ton trucks (make C) with pneumatic tires operating over a good road; each entry is the result of a single observation*

[Average round-trip speed, 362 feet per minute]

| Dippers per load | Haul | Time | | Average speed | |
|---|---|---|---|---|---|
| | | Haul | Return | Haul | Return |
| *Number* | *Feet* | *Seconds* | *Seconds* | *Feet per minute* | *Feet per minute* |
| 2 | 300 | 75 | 45 | 240 | 400 |
| 2 | 300 | 67 | 40 | 269 | 450 |
| 2 | 300 | 72 | 52 | 250 | 347 |
| 2 | 300 | 75 | 55 | 240 | 328 |
| 2 | 500 | 74 | 75 | 406 | 400 |
| 2 | 500 | 77 | 99 | 390 | 303 |
| 2 | 500 | 88 | 71 | 341 | 423 |
| 2 | 525 | 94 | 90 | 335 | 350 |
| 2 | 525 | 87 | 100 | 362 | 315 |
| 2 | 450 | 90 | 79 | 300 | 342 |
| 2 | 450 | 83 | 80 | 326 | 338 |
| 2 | 500 | 97 | 91 | 319 | 330 |
| 2 | 450 | 85 | 74 | 318 | 365 |
| 2 | 550 | 106 | 99 | 312 | 334 |
| 2 | 500 | 95 | 91 | 316 | 330 |
| 2 | 500 | 84 | 78 | 357 | 384 |
| 2 | 500 | 93 | 80 | 322 | 375 |
| 1 | 700 | 78 | 80 | 539 | 525 |
| 1 | 700 | 92 | 72 | 457 | 584 |
| 1 | 750 | 107 | 79 | 421 | 570 |
| Total or av. 1.85 | 9,800 | 1,719 | 1,530 | 342 | 384 |

TABLE 10.—*Hauling speed with 5-ton trucks (make D) with solid tires over a good surface; each entry represents the average for one day's study*

[Average round-trip speed, 508 feet per minute]

| Dippers per load | Haul | Time | | Average speed | |
|---|---|---|---|---|---|
| | | Haul | Return | Haul | Return |
| *Number* | *Feet* | *Seconds* | *Seconds* | *Feet per minute* | *Feet per minute* |
| 5.0 | 2,850 | 284 | 271 | 610 | 630 |
| 5.7 | 2,975 | 260 | 239 | 686 | 747 |
| 7.5 | 3,175 | 365 | 347 | 522 | 550 |
| 7.7 | 3,200 | 332 | 285 | 578 | 674 |
| 4.8 | 3,225 | 367 | 341 | 528 | 568 |
| 7.0 | 3,250 | 293 | 246 | 665 | 792 |
| 5.7 | 3,250 | 424 | 299 | 460 | 652 |
| 6.3 | 3,275 | 461 | 344 | 427 | 672 |
| 4.3 | 3,350 | 669 | 591 | 301 | 340 |
| 9.3 | 3,525 | 509 | 421 | 417 | 504 |
| 5.3 | 3,550 | 425 | 343 | 502 | 621 |
| 4.7 | 3,575 | 745 | 639 | 288 | 336 |
| 5.0 | 3,750 | 444 | 393 | 507 | 573 |
| 6.7 | 3,875 | 413 | 332 | 563 | 700 |
| 6.7 | 3,900 | 478 | 466 | 490 | 505 |
| 6.3 | 3,950 | 436 | 324 | 544 | 732 |
| 6.0 | 4,275 | 622 | 519 | 418 | 495 |
| Total or av.. 6.1 | 58,950 | 7,527 | 6,400 | 470 | 553 |

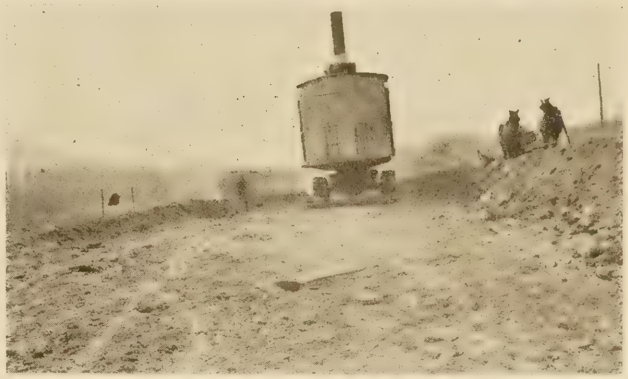
equipment should be used On the other hand, while the presence of a large amount of such material should suggest the use of equipment other than trucks, there are relatively few large projects which have no material of this general nature. If it is decided to use trucks in such a case, dual pneumatic tire equipment is a decided advantage. The trucks can then travel repeatedly over ground which could not be traversed with solid tires.

The cost of using the dual pneumatic tires is doubtless more than that for solid tires where the same rate of production can be maintained with either type but it should be remembered that a very small difference in output will cover the difference in operating cost. With excavation at 50 cents a cubic yard, and the trucks hauling 2 cubic yards per load, a difference of a few loads a day in favor of the dual pneumatic tires will justify their use. Table 7 shows the speed it is possible to maintain under favorable conditions on long-haul work with trucks equipped with these tires.

#### TRUCK SPEED GOVERNED BY ROAD CONDITIONS

The performance of trucks is governed largely by the supporting power of the ground at the shovel and at the dump. Generally, the traveled way between the shovel and the dump is more compact and easier to maintain. The exact soil condition which will be encountered at the bottom of a deep cut is naturally a matter of conjecture until the work is well under way. With this uncertainty it seems that more stress could well be placed on the necessity of having all trucks equipped with the most favorable type of tires. Observations made on a number of projects on which trucks were used indicate that several which were handled at little or no profit could have been converted into profitable undertakings by merely adjusting this one item in the equipment. Such a change would have enabled the trucks not only to operate over the soft ground but would also have reduced the turning time and materially increased the operating speed, an important item on all long-haul work.

Tables 7 to 10 show the results of observations as to the speed of trucks of various types. In practice the working speed seldom, if ever, reaches the rated speed of the truck. No job has yet been found where the trucks were consistently working at anywhere near their rated full-load speed. The job speed appears to be governed partly by the load but more definitely by the road conditions. Bad going and overloaded trucks are the rule. Overloading appears to be due in part to attempts to counteract the effect of low speed by carrying larger loads. Generally this makes road conditions still worse, necessitating even lower speed, and finally, as the roads become still worse, smaller loads at very low speeds. It appears that this problem can best be solved with adequate tire equipment, proper loads, and reasonable attention to maintenance of the roads. This would more often permit a normal operating speed.



SMOOTH ROADWAY SURFACE LEFT BY A CAREFUL SHOVEL OPERATOR

Tire equipment suited to road conditions on highway construction will considerably simplify keeping the traveled way in good condition. The matter should not, however, rest here. When the hauling must be done over a yielding surface, ruts are inevitable unless a blade grader or drag is kept at work most of the time. Filling depressions before they become large will generally keep the surface in reasonably good condition except in very wet or very dry weather. In dry weather bad places can usually be patched, if an occasional load of moist clay be placed so that it can be bladed gradually into the ruts. The tendency is to put off blading until the ruts become so deep that they obviously hinder the trucks. When this point has been reached, it is difficult, if not impossible, to correct it. There is some danger in filling very deep ruts with a drag or grader because the material is seldom stable until it has been driven over a good many times. The worst holes are hidden so that there is more danger of damaging the trucks immediately after the ruts are filled than there was before. Maintenance to be effective must be used as a preventive rather than as a cure. Next to the use of suitable tires, continuous maintenance is probably the most important item in securing a profitable output where trucks are used.

Road conditions between the shovel and the dump may often be improved by more careful work by the shovel operator and grade foreman. Occasionally a foreman will be found who sets grade targets at the height of the operator's eye, so that the operator can tell at all times just how closely he is cutting to grade and can leave the floor of the cut behind him reasonably smooth and close to grade. Excavation conducted in this manner leaves a much better surface for vehicles to travel over and enables a greater speed to be maintained.

### MANY CONTRACTORS BEGIN OPERATION TOO SOON AFTER A RAIN

Another factor in the creation of bad hauling conditions is the operation of trucks too soon after rains. This raises the question of idle time losses which was discussed in connection with the operation of wagons. In principle the solution of the problem is along the same lines, but the relation of idle-time cost to operating cost is here so different that the result is materially changed. Take, as an illustration, a shovel at $50 a day, operations at the dump at $25 a day, and four trucks at $25 a day each—giving a total operation cost of $175 per day. As a rule no stock is used on such a job, and, particularly in the East, no camp is maintained. The only full-time men are the job foreman, the shovel runner, watchman, and perhaps a timekeeper. Ordinarily the idle-time cost will not exceed $30 or $40 a day and the difference between the cost of working and of remaining idle will be from $135 to $145 a day, or roughly four-fifths of the average daily operating cost.

On typical truck-haul jobs it is generally cheaper to remain idle than it is to work unless the output which can be secured is near 80 per cent of that which is required to pay the full operating expenses under normal working conditions. When teams are being used, it is desirable to work whenever it is at all possible, whereas when trucks are being operated profit is almost certain to be reduced by operating before at least three-fourths of the yardage necessary to pay the full cost of normal operation can be secured. This deduction is based only on the relation between idle-time cost and operating cost. It is strongly supported by the fact that beginning operation too soon after rains creates road conditions which slow down subsequent operations and also damage the hauling equipment. These facts strongly emphasize the general observation that there is a prevailing tendency to operate truck jobs too soon after rains with the result that much profit is needlessly dissipated.

Where heavy trucks are used, loading is generally done behind the shovel, but it could frequently be done at the side. In loading at the side there is the problem of truck substitution without delaying the shovel. This can be done readily enough if the bottom of the cut is solid and the shovel has cleaned up carefully. If, however, the bottom of the cut is none too good and the clean-up has been careless, it may be difficult to spot the replacement truck until the loaded truck has moved completely out of the way. This frequently delays the shovel, but if as many as five dipper loads are placed on a truck the shorter shovel cycle is almost certain to more than compensate for any ordinary delay due to the drive-in. The remedy for slow drive-in lies in a careful clean-up and in the maintenance of working conditions suitable for the operation of trucks.

### METHOD OF DETERMINING TRUCK SUPPLY DISCUSSED

The number of trucks the contractor should send out with his shovel in order to complete a job at the lowest possible cost deserves much more scientific attention than is usually given the matter. Heavy trucks are usually considered to be worth from $2.50 to $3 per hour. They are too expensive to warrant the use of more than are really necessary. On the other hand a shortage of only one truck on a moderate haul may readily reduce shovel production as much as 20 or 30 per cent. But practically all grading jobs have hauls which vary more or less erratically in length. The number of trucks which a contractor should send to a job is a question which has a very direct relation to the profits.

A general method of determining the number of hauling units which should be sent out on a job with fluctuating hauls was discussed in part 2.[1] These principles are equally applicable to the truck providing data which correctly represent the actual operating characteristics are used. Tables 11 and 12 show the method of finding the cost of completing two particular jobs when varying numbers of three different types of trucks are sent out and maintained with the shovel until the job is completed. The quantities and haul distances are the same as those used in the case of horse-drawn vehicles. It may be well to repeat that the basic data to be used is that relating to the particular job in question and aside from quantities and haul is dependent on the size of the shovel and its rate of operation, the loading, speed, and other operating characteristics of the trucks, together with the relative daily or hourly cost of operating the shovel and the trucks and the distribution of the haul. The actual figures used in these two examples are therefore only illustrative and can not be applied to other jobs unless it is definitely known that all field conditions are practically identical.

Sometimes, especially on large jobs, the hauls may be so distributed that it will prove worth while to vary the number of trucks used from section to section. It may be that the hauls on the first section are such that six trucks are required. The following section, because of shorter hauls or because of more difficult materials, may require only four trucks. At the completion of the first section two trucks should then be either laid up or transferred to other work. It will often be preferable to begin work on the sections with shortest hauls and move in succession to the next longer hauls. This permits a gradual and steady expansion of the organization and is particularly advantageous on jobs with a wide range in haul distances.

Referring to Tables 11 and 12, it will be noted that the larger and more expensive the truck the more important it is to use exactly the proper number. For the light trucks one vehicle more or less than the proper number does not affect the cost so seriously, but for the larger and more expensive vehicles one vehicle either more or less than the optimum is sufficient to affect profits rather seriously, while a difference of two trucks may turn an otherwise profitable job into a definite loss.

Summarizing briefly, the heavy truck is a sturdy, dependable piece of equipment capable of doing good work and a great deal of it. On the other hand, it is an expensive piece of equipment with a large operating expense and the output per truck must be high if its use is to prove profitable. A good many jobs present the appearance of mere replacement of wagons with trucks in which the style of operation still retains all of the characteristics of the wagon job. Under such conditions the use of trucks is apt to be a failure. Trucks can be operated after a fashion even under very adverse conditions, but to work at a profit the conditions must be such that speed as well as carrying capacity can be utilized without serious loss of time due to unnecessary backing, slow turning, and pulling

[1] See Public Roads vol. 9, No. 1, March, 1928.

TABLE II.—*Determination of most economical number of trucks to send out on a given job where the cost of operating shovel and dump is estimated at $75 per 10-hour day*

| Quantity | Haul | Days work at full production (720 cu. yds. per day) | Light trucks, pneumatic tires [1] | | | | | | Heavy-duty trucks, solid tires [2] | | | | | | | | Heavy-duty trucks, pneumatic tires [3] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Trucks required to maintain full shovel production | 9-truck basis | 10-truck basis | 11-truck basis | 12-truck basis | 13-truck basis | Trucks required to maintain full shovel production | 4-truck basis | 5-truck basis | 6-truck basis | 7-truck basis | 8-truck basis | 9-truck basis | 10-truck basis | Trucks required to maintain full shovel production | 3-truck basis | 4-truck basis | 5-truck basis | 6-truck basis | 7-truck basis |
| | | | | Days required | | | | | | Days required | | | | | | | | Days required | | | | |
| *Cu. yds.* | *Feet* | | | | | | | | | | | | | | | | | | | | | |
| 7,200 | 500 | 10 | 5.3 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 3.2 | 10 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10 | 2.5 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| 18,720 | 600 | 26 | 5.9 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 3.4 | 26 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26 | 2.6 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 |
| 14,400 | 900 | 20 | 7.5 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 4.2 | 20 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20 | 3.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| 10,800 | 1,200 | 15 | 9.1 | 15.1 | 15.0 | 15.0 | 15.0 | 15.0 | 5.0 | 20 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15 | 3.4 | 17.1 | 15.0 | 15.0 | 15.0 | 15.0 |
| 5,760 | 1,500 | 8 | 10.7 | 9.5 | 8.2 | 8.0 | 8.0 | 8.0 | 5.8 | 16 | 9.6 | 8.0 | 8.0 | 8.0 | 8.0 | 8 | 3.8 | 10.6 | 8.0 | 8.0 | 8.0 | 8.0 |
| 10,080 | 1,800 | 14 | 12.3 | 19.0 | 17.2 | 15.5 | 14.3 | 14.0 | 6.6 | 30 | 19.0 | 15.7 | 14.0 | 14.0 | 14.0 | 14 | 4.2 | 20.0 | 15.0 | 14.0 | 14.0 | 14.0 |
| 7,200 | 2,400 | 10 | 15.7 | 17.2 | 15.5 | 14.1 | 12.9 | 11.9 | 8.2 | 27 | 16.0 | 13.3 | 11.4 | 10.0 | 10.0 | 10 | 5.0 | 16.7 | 12.5 | 10.0 | 10.0 | 10.0 |
| 7,200 | 3,000 | 10 | 18.7 | 20.7 | 18.7 | 17.0 | 15.6 | 14.4 | 9.7 | 33 | 20.0 | 16.7 | 14.3 | 12.5 | 11.1 | 10 | 5.8 | 20.0 | 15.0 | 12.0 | 10.0 | 10.0 |
| 14,400 | 4,000 | 20 | 24.0 | 53.4 | 48.0 | 43.4 | 40.0 | 36.8 | 12.4 | 80 | 48.0 | 40.0 | 34.3 | 30.0 | 26.7 | 24 | 7.1 | 46.7 | 35.0 | 28.0 | 23.3 | 20.0 |
| 10,800 | 4,600 | 15 | 27.2 | 45.3 | 40.8 | 37.0 | 34.0 | 31.5 | 13.9 | 70 | 42.0 | 35.0 | 30.0 | 26.2 | 23.3 | 21 | 7.9 | 40.0 | 30.0 | 24.0 | 20.0 | 17.1 |
| Total, 106,560 | -------- | 148 | -------- | 236.2 | 219.4 | 206.0 | 195.8 | 187.6 | -------- | 332 | 225.6 | 199.7 | 183.0 | 171.7 | 164.1 | 158 | -------- | 227.1 | 186.5 | 167.0 | 156.3 | 150.1 |
| Coast per day | | | | $183 | $195 | $207 | $219 | $231 | -------- | $175 | $200 | $225 | $250 | $275 | $300 | $325 | -------- | $165 | $196 | $225 | $255 | $285 |
| Total cost of job | | | | 43,225 | 42,783 | 42,642 | 42,880 | 43,336 | -------- | 58,100 | 45,120 | 44,933 | 45,600 | 47,218 | 49,230 | 51,350 | -------- | 37,472 | 36,368 | 37,865 | 39,857 | 42,779 |

[1] Estimate on basis of light trucks at $12 per day to carry 2 dippers per load, round trip speed 500 feet per minute, loading time three-quarters minute; total time constant 2 minutes.
[2] Estimate on basis of heavy-duty trucks at $25 per day to carry 5 dippers per load, round-trip speed 400 feet per minute, loading time 1.9 minutes, and total time constant 3.5 minutes.
[3] Estimate on basis of heavy-duty trucks with pneumatic tires at $30 per day to carry 5 dippers per load at 800 feet per minute, loading time 1.9 minutes, and total time constant 3.5 minutes.

TABLE 12.—*Determination of most economical number of trucks to send out on a given job where the cost of operating shovel and dump is estimated at $75 per 10-hour day*

| Quantity | Haul | Days' work at full production (720 cu. yds. per day) | Light trucks [1] | | | | | | Heavy-duty trucks, solid tires [2] | | | | | Heavy-duty trucks, pneumatic tires [3] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Trucks required to maintain full shovel production | 5-truck basis | 6-truck basis | 7-truck basis | 8-truck basis | 9-truck basis | Trucks required to maintain full shovel production | 2-truck basis | 3-truck basis | 4-truck basis | 5-truck basis | Trucks required to maintain full shovel production | 2-truck basis | 3-truck basis | 4-truck basis |
| | | | | Days required | | | | | | Days required | | | | | Days required | | |
| *Cu. yds.* | *Feet* | | | | | | | | | | | | | | | | |
| 14,400 | 500 | 20 | 5.3 | 21.3 | 20.0 | 20.0 | 20.0 | 20.0 | 3.2 | 31.6 | 21.0 | 20.0 | 20 | 2.5 | 25.0 | 20.0 | 20 |
| 10,800 | 600 | 15 | 5.9 | 17.6 | 15.0 | 15.0 | 15.0 | 15.0 | 3.4 | 25.6 | 17.1 | 15.0 | 15 | 2.6 | 19.8 | 15.0 | 15 |
| 7,200 | 700 | 10 | 6.4 | 12.8 | 10.6 | 10.0 | 10.0 | 10.0 | 3.7 | 18.5 | 12.3 | 10.0 | 10 | 2.8 | 13.8 | 10.0 | 10 |
| 10,800 | 800 | 15 | 6.9 | 20.8 | 17.3 | 15.0 | 15.0 | 15.0 | 3.9 | 30.0 | 20.0 | 15.0 | 15 | 2.9 | 21.7 | 15.0 | 15 |
| 5,760 | 900 | 8 | 7.5 | 11.9 | 10.0 | 8.5 | 8.0 | 8.0 | 4.2 | 16.8 | 11.2 | 8.4 | 8 | 3.0 | 12.2 | 8.0 | 8 |
| 7,200 | 1,100 | 10 | 8.5 | 17.0 | 14.2 | 12.2 | 10.7 | 10.0 | 4.7 | 23.7 | 15.8 | 11.8 | 10 | 3.3 | 16.5 | 11.0 | 10 |
| 10,800 | 1,200 | 15 | 9.1 | 27.2 | 22.7 | 19.4 | 17.0 | 15.1 | 5.0 | 37.5 | 25.0 | 18.8 | 15 | 3.4 | 25.6 | 17.1 | 15 |
| Total, 66,960 | -------- | 93 | -------- | 128.6 | 109.8 | 100.1 | 95.7 | 93.1 | -------- | 183.7 | 123.4 | 99.0 | 93 | -------- | 134.6 | 96.1 | 93 |
| Cost per day | | | | $135 | $147 | $159 | $171 | $183 | -------- | $125 | $150 | $175 | $200 | -------- | $135 | $165 | $195 |
| Cost to complete job | | | | 17,361 | 16,141 | 15,916 | 16,365 | 17,037 | -------- | 23,963 | 18,510 | 17,325 | 18,600 | -------- | 18,171 | 15,857 | 18,125 |

[1] Estimate on basis of light trucks at $12 per day carrying 2 dippers per load, round-trip speed 500 feet per minute, loading time three-fourths minute, total time constant 2 minutes.
[2] Estimate on basis of heavy-duty trucks at $25 per day, carrying 5 dippers per load, round-trip speed 400 feet per minute, loading time 1.9 minutes, total time constant 3½ minutes.
[3] Estimate on basis of trucks with dual-pneumatic tires, carrying 5 dippers per load, $30 per day, loading time 1.9 minutes, total time constant 3½ minutes, round-trip speed 800 feet per minute.

out of holes. To make the use of trucks profitable, their characteristics must be studied, the proper type selected, and the job conditions then adjusted and maintained so as to meet these requirements.

### LARGE TRACTOR-DRAWN WAGONS NOW USED

Large dump wagons drawn by crawler-type tractors have recently come into considerable use with power shovels. The merit of this combination appears to be due to the following facts: (1) The crawler-type tractor can be operated effectively over a wide range of road conditions such as are found in grading work; (2) it can be maneuvered readily on steep grades, over rough or soft ground and among stumps, rocks, and other obstructions; (3) it can maintain a relatively high draw-bar pull under these conditions and can haul comparatively large loads; and (4) the wagons which have been studied were strongly constructed and well adapted to operate under severe field conditions and were equipped with a simple and effective dumping mechanism.

Under normal working conditions a heavy tractor can draw two of these dump wagons, each having a capacity of 5 or 6 cubic yards. If the haul is down very heavy grades, it is sometimes necessary to limit the train to one wagon because at present wagons are not equipped with brakes. Tables 13 to 17, inclusive, indicate that where ground conditions are fair and the road of sufficient width, two wagons can be handled almost as speedily as one, not only in the operations of dumping, turning, and maneuvering, but also in the direct haul. The use of two wagons is clearly an advantage if all loading is done at the rear of the shovel instead of the more logical method of loading the vehicles at the side. A one-wagon train can be backed with ease and dispatch, but to back a two-wagon train requires con siderable skill and time. A partial solution of this difficulty might be found in the use of a larger shovel. The handicap of a long swing would still remain, but a smaller number of dippers would be required to load each train.

#### FAST TURNING AND DUMPING POSSIBLE WITH TRACTOR TRAINS

The various operations of turning, dumping, and maneuvering are comparatively fast in the hands of a skillful operator. The exact time for each of these operations is shown more fully in Tables 13 to 16. Tables 14 to 17 show the hauling speed for various lengths of haul and under the varying conditions on different jobs. These tables will indicate to some extent what can be expected from this type of equipment as well as the amount of the time losses most likely to be chargeable to its use.

Of the items which make up the time constant, it will be observed that the loading time is long. This is inevitable on account of the large amount of material carried per load. The loading time is usually from five to seven minutes for a train of two 5-yard wagons. With a standard ¾-yard shovel, from 7 to 10 dippers are required to load each wagon, and, if the shovel is working at a rate of three dipper loads per minute, from two and one-third to three and one-third minutes will be taken up in loading each wagon. If the cut is narrow so that the turning radius is short it may be necessary to use the shovel in getting the second wagon into loading position as on short turns it does not follow around perfectly. On wide roads this extra operation is not necessary, nor is it required in loading at the side of the shovel. Any conditions which extend the dipper cycle beyond 20 seconds—stiff clay, badly shot rock, stumps, etc.—will also extend the loading period so that digging conditions must be

TABLE 13.—*Time constant studies of crawler tractors, each drawing one 5-yard steel wagon. Loading done by a ¾-yard shovel*

[Time constant, 219.1 seconds]

| Dippers per load | Loading | Waiting at dump | Turning at dump | Dumping | Turning at shovel |
|---|---|---|---|---|---|
| *Number* | *Seconds* | *Seconds* | *Seconds* | *Seconds* | *Seconds* |
| 6 | 152 | ---------- | 14 | 7 | 16 |
| 6 | 151 | ---------- | 11 | 9 | 10 |
| 7 | 168 | ---------- | 9 | 10 | 13 |
| 5 | 121 | ---------- | 12 | 9 | 13 |
| 7 | 177 | ---------- | 8 | 8 | 15 |
| 7 | 179 | ---------- | 9 | 8 | 15 |
| 7 | 165 | ---------- | 14 | 12 | 14 |
| 7 | 182 | ---------- | 19 | 15 | 14 |
| 7 | 174 | ---------- | 44 | 10 | 15 |
| 7 | 167 | ---------- | 14 | 7 | 16 |
| 8 | 209 | ---------- | 17 | 7 | 14 |
| 7 | 167 | ---------- | 15 | 10 | 11 |
| 7 | 180 | 14 | 22 | 10 | 14 |
| 8 | 188 | ---------- | 15 | 7 | 12 |
| 8 | 216 | 13 | 14 | 8 | 15 |
| 7 | 195 | 10 | 17 | 7 | 22 |
| 8 | 204 | ---------- | 17 | 9 | 14 |
| 8 | 182 | ---------- | 16 | 8 | 16 |
| 8 | 209 | ---------- | 15 | 9 | 17 |
| 7 | 175 | ---------- | 10 | 6 | 20 |
| Av. 7.1 | 178 | 1.9 | 15.6 | 8.8 | 14.8 |

TABLE 14.—*Comparison of operating speed of crawler tractors drawing 1-wagon and 2-wagon trains*

[The wagons were 5-yard capacity and were loaded by a ¾-yard shovel. Operation in late fall and winter over roads in fair and poor condition]

| Operation | Time for 1-wagon train [1] | Time for 2-wagon train [2] |
|---|---|---|
| | *Seconds* | *Seconds* |
| Loading | 186.0 | 398.5 |
| Waiting at dump | 67.6 | 86.3 |
| Turning at dump | 20.8 | 22.8 |
| Dumping load | 17.4 | 20.7 |
| Turning at shovel | 21.0 | 17.5 |
| Spotting second wagon | ---------- | 13.8 |
| Total | 312.8 | 559.6 |

[1] Results are the average for 153 round trips. Average round-trip speed on hauls from 300 to 3,000 feet was 300 feet per minute.
[2] Results are the average for 84 round trip. Average round-trip speed on hauls from 200 to 2,000 feet was 285 feet per minute.

TABLE 15.—*Typical studies of operation of crawler tractors drawing two 5-yard wagons. Loading done by ⅞-yard shovels*

JOB No. 39

| Haul | Loading | Hauling to dump | Turning at dump | Waits and delays | Dumping load | Returning to shovel | Turning at shovel | Speed loaded [1] | Speed empty [1] |
|---|---|---|---|---|---|---|---|---|---|
| Most of hauling over rough and rocky roads with steep grades | | | | | | | | | |
| *Feet* | *Seconds* | *Seconds* | *Seconds* | *Seconds* | *Seconds* | *Seconds* | *Seconds* | *Feet per minute* | *Feet per minute* |
| 1,200 | 288 | 275 | 22 | 37 | 19 | 292 | 14 | 261 | 246 |
| 1,400 | 307 | 220 | 19 | 30 | 18 | 250 | 14 | 380 | 336 |
| 1,425 | 346 | 312 | 19 | 48 | 9 | 298 | 12 | 274 | 287 |
| 1,425 | 291 | 234 | 23 | 44 | 12 | 279 | 17 | 365 | 306 |
| 1,425 | 324 | 247 | 13 | 32 | 8 | 268 | 13 | 346 | 319 |
| 1,450 | 287 | 256 | 22 | 42 | 13 | 272 | 21 | 339 | 320 |
| 1,450 | 395 | 255 | 17 | 94 | 14 | 259 | 53 | 341 | 336 |
| 1,450 | 254 | 261 | 21 | 75 | 15 | 260 | 55 | 333 | 334 |
| 1,450 | 361 | 288 | 28 | 72 | 19 | 283 | 19 | 302 | 307 |
| 1,500 | 272 | 319 | 18 | 268 | 15 | 317 | 14 | 282 | 283 |
| 1,500 | 284 | 269 | 12 | 34 | 8 | 322 | 24 | 334 | 279 |
| 1,500 | 252 | 322 | 19 | 82 | 10 | 320 | 14 | 279 | 281 |
| 1,500 | 282 | 288 | 17 | 46 | 10 | 312 | 14 | 312 | 288 |
| 1,500 | 346 | 263 | 18 | 58 | 16 | 299 | 14 | 341 | 300 |
| 1,550 | 277 | 292 | 25 | 92 | 14 | 303 | 16 | 318 | 306 |
| 1,550 | 288 | 318 | 16 | 74 | 29 | 319 | 16 | 292 | 291 |
| 1,600 | 300 | 390 | 20 | 45 | 21 | 421 | 10 | 246 | 228 |
| 1,650 | 298 | 306 | 19 | 34 | 17 | 306 | 8 | 323 | 323 |
| 1,650 | 320 | 372 | 21 | 28 | 38 | 390 | 13 | 266 | 253 |
| 1,650 | 322 | 359 | 21 | 38 | 35 | 364 | 18 | 276 | 272 |
| Total, 29,825 | 6,094 | 5,746 | 390 | 1,263 | 340 | 6,134 | 378 | ------- | ------- |
| Av. 1,491 | 305 | 287 | 19.5 | 63 | 17 | 307 | 19 | 311 | 292 |
| Short hauls over rough and rocky ground. Shovel operating in frozen ground | | | | | | | | | |
| 350 | 544 | 105 | 28 | 33 | 24 | 175 | 28 | 200 | 120 |
| 350 | 398 | 102 | 34 | 548 | 22 | 192 | 32 | 206 | 110 |
| 375 | 422 | 122 | 28 | 112 | 18 | 181 | 29 | 185 | 124 |
| 375 | 727 | 130 | 29 | 12 | 26 | 184 | 28 | 173 | 122 |
| 400 | 375 | 124 | 31 | 48 | 23 | 190 | 39 | 193 | 126 |
| 400 | 491 | 113 | 19 | 14 | 18 | 183 | 28 | 212 | 131 |
| 425 | 365 | 116 | 28 | 21 | 15 | 170 | 40 | 220 | 150 |
| 450 | 405 | 118 | 26 | 5 | 28 | 217 | 25 | 229 | 125 |
| 500 | 381 | 145 | 35 | 5 | 30 | 172 | 31 | 207 | 174 |
| 550 | 511 | 156 | 25 | 9 | 20 | 213 | 26 | 212 | 155 |
| Total 4,175 | 4,619 | 1,231 | 283 | 807 | 224 | 1,877 | 304 | ------- | ------- |
| Av. 417 | 462 | 123 | 28 | 81 | 22 | 188 | 30 | 204 | 133 |

JOB NO. 35

| Haul | Loading | Hauling to dump | Turning at dump | Waits and delays | Dumping load | Returning to shovel | Turning at shovel | Speed loaded [1] | Speed empty [1] |
|---|---|---|---|---|---|---|---|---|---|
| Hauling over road in fair to poor condition with steep grades | | | | | | | | | |
| 875 | 307 | 195 | 22 | ------- | 7 | 229 | 19 | 270 | 229 |
| 900 | 305 | 207 | 30 | 30 | 11 | 198 | 12 | 261 | 272 |
| 950 | 273 | 215 | 13 | 40 | 10 | 205 | 15 | 270 | 283 |
| 950 | 285 | 207 | 22 | 63 | 5 | 204 | 13 | 280 | 284 |
| 1,000 | 288 | 186 | 17 | ------- | 34 | 207 | 11 | 322 | 290 |
| 1,050 | 312 | 208 | 24 | 80 | 10 | 214 | 13 | 302 | 294 |
| 1,100 | 304 | 214 | 22 | ------- | 12 | 228 | 12 | 308 | 289 |
| 1,150 | 285 | 203 | 26 | ------- | 11 | 252 | 22 | 340 | 274 |
| 1,200 | 335 | 242 | 16 | ------- | 14 | 241 | 10 | 297 | 298 |
| 1,250 | 361 | 250 | 22 | ------- | 19 | 257 | 9 | 300 | 292 |
| 1,300 | 299 | 266 | 26 | 22 | 16 | 304 | 12 | 293 | 255 |
| 1,350 | 332 | 275 | 27 | 195 | 28 | 321 | 27 | 295 | 252 |
| 1,375 | 300 | 275 | 29 | 143 | 25 | 301 | 19 | 300 | 274 |
| 1,400 | 347 | 277 | 28 | 99 | 31 | 317 | 33 | 303 | 265 |
| 2,000 | 294 | 318 | 36 | ------- | 23 | 412 | 28 | 378 | 292 |
| 2,050 | 365 | 366 | 23 | 65 | 30 | 410 | 11 | 336 | 300 |
| 2,050 | 314 | 357 | 29 | 99 | 35 | 425 | 17 | 345 | 289 |
| 2,100 | 372 | 358 | 27 | 45 | 38 | 443 | 21 | 352 | 284 |
| 2,100 | 457 | 409 | 25 | 103 | 36 | 441 | 16 | 308 | 286 |
| 2,150 | 409 | 383 | 24 | 34 | 29 | 423 | 15 | 336 | 305 |
| 2,150 | 298 | 431 | 17 | 35 | 23 | 445 | 11 | 300 | 290 |
| 2,200 | 323 | 403 | 20 | 54 | 24 | 410 | 12 | 327 | 322 |
| 2,200 | 292 | 425 | 21 | 177 | 26 | 466 | 20 | 310 | 283 |
| 2,250 | 309 | 416 | 22 | 76 | 12 | 438 | 10 | 324 | 307 |
| 2,300 | 276 | 425 | 29 | 179 | 34 | 458 | 13 | 325 | 301 |
| Total 39,400 | 8,042 | 7,511 | 597 | 1,539 | 543 | 8,249 | 401 | ------- | ------- |
| Av. 1,576 | 321.7 | 300.2 | 23.8 | 61.5 | 21.7 | 329.9 | 16 | 315 | 286 |

[1] On both jobs the haul was down a grade, resulting in a higher speed while loaded than while empty.

Typical Operation with Tractors Hauling Large-Capacity Dump Wagons

Table 16.—*Hauling speed of crawler tractors with one 5-yard wagon with road conditions varying from good to very poor with deep mud*

| Round trips timed | Distance | Haul to dump | Speed loaded | Return to shovel | Speed empty |
|---|---|---|---|---|---|
| *Number* | *Feet* | *Seconds* | *Feet per minute* | *Seconds* | *Feet per minute* |
| 6 | 475 | 116.0 | 246 | 153.0 | 186 |
| 9 | 550 | 137.0 | 241 | 161.0 | 205 |
| 8 | 300 | 73.0 | 247 | 83.0 | 217 |
| 8 | 390 | 87.5 | 268 | 96.0 | 244 |
| 6 | 510 | 107.7 | 284 | 118.3 | 258 |
| 3 | 700 | 138.7 | 303 | 156.7 | 268 |
| 6 | 375 | 104.5 | 215 | 134.1 | 167 |
| 2 | 550 | 118.0 | 280 | 130.0 | 254 |
| 10 | 90 | 46.4 | 148 | 42.8 | 164 |
| 10 | 740 | 199.2 | 223 | 148.7 | 298 |
| 7 | 1,050 | 241.7 | 260 | 207.3 | 303 |
| 5 | 1,025 | 202.2 | 305 | 184.0 | 334 |
| 6 | 785 | 215.7 | 219 | 142.1 | 331 |
| Total 86 | 47,215 | 11,531.4 | ---------- | 11,182.2 | ---------- |
| Average---- | ---------- | ---------- | 246 | ---------- | 253 |

fairly good and ample turning space must be available if a two-wagon train is to be loaded every six minutes with the ordinary ¾-yard shovel.

At the dump, layer or end dumping can be used with almost equal facility. With ordinary materials the load as it is dumped is spread over a length of some 20 feet. In layer dumping these piles can be spread either by a heavy blade grader or by a bulldozer, and the material compacts without serious difficulty under the tractors and wagons as the work progresses. Where this practice is followed the dumping time is almost negligible as the train need hardly come to a full stop in order to make the dump. Dumping the load is often merely a part of the general operation of turning at the dump. Where end dumping is practiced, the loads are dropped in the same general way as the turn is being made and then a bulldozer or other equipment is used to push the dumped piles over the bank.

Table 17.—*Hauling speed of crawler tractors with one 5-yard wagon with road conditions as noted*

| Dippers per load | Length of haul | Time | | Average speed | | Remarks |
|---|---|---|---|---|---|---|
| | | Haul | Return | Haul | Return | |
| *Number* | *Feet* | *Seconds* | *Seconds* | *Feet per minute* | *Feet per minute* | |
| 8 | 300 | 73 | 89 | 247 | 203 | Haul down 8 per cent grade with mud hub deep. |
| 8 | 300 | 60 | 74 | 300 | 243 | |
| 8 | 300 | 65 | 76 | 277 | 237 | |
| 7 | 300 | 64 | 74 | 282 | 243 | |
| 9 | 300 | 82 | 83 | 220 | 214 | |
| 6 | 300 | 72 | 92 | 250 | 196 | |
| 7 | 200 | 71 | 65 | 169 | 185 | Muddy, grade light. |
| 6 | 200 | 69 | 64 | 174 | 188 | |
| 8 | 200 | 74 | 65 | 162 | 185 | |
| 7 | 200 | 79 | 62 | 152 | 194 | |
| 7 | 150 | 51 | 57 | 177 | 158 | Road good, easy grades; more trains on job than needed. |
| 7 | 150 | 52 | 51 | 172 | 177 | |
| 7 | 150 | 47 | 61 | 192 | 145 | |
| 8 | 150 | 52 | 57 | 172 | 158 | |
| 6 | [1] 50 | 38 | 36 | 79 | 83 | Road good, easy grades. |
| 6 | [1] 50 | 43 | 46 | 70 | 65 | |
| 7 | [1] 50 | 37 | 42 | 81 | 72 | |
| 6 | [1] 50 | 40 | 39 | 75 | 77 | |
| 7 | 575 | 140 | 215 | 246 | 140 | Mud hub deep. |
| 7 | 575 | 155 | 200 | 222 | 155 | |
| 7.1 | 4,350 | 1,206 | 1,251 | 216 | 209 | |

[1] Not included in averages.

Turning is fast. Crawler-type tractors can usually work close to the edge of a fill, so that a train of two wagons can ordinarily be turned on a 25-foot embankment without backing. Turning time at both the dump and the cut is therefore low, as shown in Tables 13 to 15. At the shovel the turning is usually done so quickly that the drive-in can be made within a normal dipper cycle. Under fair operating conditions the average time required for turning at the dump, dumping the load, and turning again at the shovel, should not exceed a total of one minute, and under adverse conditions should not exceed a total of one and one-half minutes.

#### PRODUCTION OBTAINED BY LARGE LOADS RATHER THAN SPEED

The rate of travel of tractor trains is only a little greater than that of teams—from 275 to 325 feet per minute under favorable conditions, and it may fall as low as 200 feet per minute under adverse conditions. Because of this low speed and the wide distribution of the tractor load on the road, the cost and difficulty of maintaining a satisfactory roadway is seldom as great as is found necessary for the successful operation of heavy trucks. Trucks must normally obtain their production by maintaining a good rate of speed—8 to 10 miles an hour—when carrying a reasonable load. The tractor train obtains its production by taking out a large load at a low hauling speed but with little time loss in dumping and turning.

Dependability is, of course, an important item in selecting hauling equipment and is particularly so in the case of tractor trains as many outfits use only two or three units and the failure of one will reduce the output by 33 or 50 per cent. During the studies few delays were noted and these were very largely chargeable to carelessness or indifference on the part of the operators. From extended observation it is believed that only high-grade operators should be employed and systematic attention should be given to maintaining proper operation practices and to keeping the equipment in first-class condition.

#### NUMBER OF HAULING UNITS USED OF GREAT IMPORTANCE

Use of a proper number of hauling units is of outstanding importance. A tractor and two 5-yard wagons represents quite an investment. The operating cost per train is also high and is made up approximately as follows:

| | |
|---|---|
| Driver | $7 |
| Depreciation | 13 |
| Gasoline and oil | 7 |
| Repairs | 3 |
| Total | 30 |

TABLE 18.—*Analysis to determine the most economical number of tractor trains for use on a given job*

| Quantities | Haul | Days work at full shovel production | Number of 2-wagon tractor trains [1]: Number required to maintain full shovel production | 1 | 2 | 3 | Number of 1-wagon tractor trains [2]: Number required to maintain full shovel production | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Days required | | | | Days required | | | |
| *Cubic yards* | *Feet* | | | | | | | | | | |
| 14,400 | 500 | 20 | 1.9 | 38.0 | 20.0 | 20.0 | 2.6 | 26.1 | 20.0 | 20.0 | 20.0 |
| 10,800 | 600 | 15 | 2.0 | 30.0 | 15.0 | 15.0 | 2.8 | 21.2 | 15.0 | 15.0 | 15.0 |
| 7,200 | 700 | 10 | 2.1 | 21.1 | 10.6 | 10.0 | 3.1 | 15.3 | 10.2 | 10.0 | 10.0 |
| 10,800 | 800 | 15 | 2.2 | 33.3 | 16.7 | 15.0 | 3.3 | 24.6 | 16.4 | 15.0 | 15.0 |
| 5,760 | 900 | 8 | 2.3 | 18.7 | 9.3 | 8.0 | 3.5 | 14.0 | 9.5 | 8.0 | 8.0 |
| 7,200 | 1,100 | 10 | 2.6 | 25.6 | 12.8 | 10.0 | 4.0 | 19.7 | 13.2 | 10.0 | 10.0 |
| 10,800 | 1,200 | 15 | 2.7 | 40.0 | 20.0 | 15.0 | 4.2 | 31.2 | 20.8 | 15.6 | 15.0 |
| Total 66,960 | | 93 | | 202.7 | 104.4 | 93.0 | | 152.1 | 105.1 | 93.6 | 93.0 |
| Cost per day | | | | $105 | $135 | $165 | | $129 | $156 | $183 | $210 |
| Cost to complete job | | | | 21,284 | 14,094 | 15,345 | | 19,621 | 16,396 | 17,129 | 19,530 |

[1] Tractors drawing two 5-cubic yard steel wagons, $30 per day, speed 300 feet per minute, loading time 6 minutes per train, and total time constant 8 minutes.
[2] Tractors drawing one 5-cubic yard steel wagon, $27 per day, speed 300 feet per minute, loading time 3 minutes, total time constant 4½ minutes.

TABLE 19.—*Analysis to determine the most economical number of units for use on a given job with considerable variation in haul distance*

| Quantities | Haul | Days work at full shovel production | Number of 2-wagon tractor trains [1]: Number required to maintain full shovel production | 2 | 3 | 4 | 5 | 6 | Number of 1-wagon tractor trains [2]: Number required to maintain full shovel production | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Days required | | | | | | Days required | | | | | |
| *Cubic yards* | *Feet* | | | | | | | | | | | | | | |
| 7,200 | 500 | 10 | 1.9 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 2.6 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| 18,720 | 600 | 26 | 2.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 2.8 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 |
| 14,400 | 900 | 20 | 2.3 | 23.3 | 20.0 | 20.0 | 20.0 | 20.0 | 3.5 | 23.3 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| 10,800 | 1,200 | 15 | 2.7 | 20.0 | 15.0 | 15.0 | 15.0 | 15.0 | 4.2 | 20.8 | 15.6 | 15.0 | 15.0 | 15.0 | 15.0 |
| 5,760 | 1,500 | 8 | 3.0 | 12.0 | 8.0 | 8.0 | 8.0 | 8.0 | 4.8 | 12.9 | 9.7 | 8.0 | 8.0 | 8.0 | 8.0 |
| 10,080 | 1,800 | 14 | 3.3 | 23.3 | 15.6 | 14.0 | 14.0 | 14.0 | 5.5 | 26.1 | 19.3 | 15.4 | 14.0 | 14.0 | 14.0 |
| 7,200 | 2,400 | 10 | 4.0 | 20.0 | 13.3 | 10.0 | 10.0 | 10.0 | 6.8 | 22.8 | 17.1 | 13.7 | 11.4 | 10.0 | 10.0 |
| 7,200 | 3,000 | 10 | 4.7 | 23.3 | 15.6 | 11.7 | 10.0 | 10.0 | 8.1 | 27.2 | 20.4 | 16.3 | 13.6 | 11.7 | 10.2 |
| 14,400 | 4,000 | 20 | 5.8 | 57.8 | 38.5 | 28.9 | 23.1 | 20.0 | 10.4 | 69.3 | 51.9 | 41.6 | 34.6 | 29.6 | 26.0 |
| 10,800 | 4,600 | 15 | 6.4 | 48.3 | 32.2 | 24.2 | 19.3 | 16.1 | 11.5 | 58.6 | 44.0 | 35.2 | 29.3 | 25.1 | 22.0 |
| Total, 106,560 | | 148 | | 264.0 | 194.2 | 167.8 | 155.4 | 149.1 | | 297.0 | 234.0 | 201.2 | 181.9 | 169.4 | 161.2 |
| Cost per day | | | | $135 | $165 | $195 | $225 | $255 | | $156 | $183 | $210 | $237 | $264 | $291 |
| Total cost of job | | | | 35,640 | 32,043 | 32,721 | 34,965 | 38,021 | | 46,332 | 42,822 | 42,252 | 43,110 | 44,722 | 46,909 |

[1] Tractor to draw two 5-cubic yard steel wagons, $30 per day, speed 300 feet per minute, loading time 6 minutes, total time constant 8 minutes.
[2] Tractors drawing one 5-cubic yard steel wagon, $27 per day, speed 300 feet per minute, loading time 3 minutes, total time constant 4½ minutes.

A high output per unit is necessary to justify this expenditure. Obviously, the minimum hauling equipment which can maintain full shovel production is two trains. Under ordinary conditions two trains of two wagons each should be able to maintain full production for a ¾-yard shovel up to a haul of 600 or 700 feet, depending on the exact rate of shovel operation. The minimum cost per day for a grading outfit provided with this equipment is about $135 (shovel, $50; two trains, $60; dump, $25). At a haul of about 700 or 800 feet a third unit will be needed, and if there is much hauling beyond 1,600 or 1,800 feet a fourth train may prove desirable. Tables 18 and 19 are developments of the same data as those given previously in connection with the discussion of team and truck hauling. They show how the total cost of the job is affected by using various numbers of one-wagon and two-wagon tractor trains. It will be noted that the use of one-wagon trains is much more expensive than two-wagon trains except for hauls less than about 400 feet. Using this method of analysis and the prices investigation and experience indicate for the particular job, the contractor can determine within reasonable limits not only what type of equipment is preferable but also the number of units which will prove most economical to place on the job.

Where two-wagon trains are used, each additional hauling unit after the first two extends the limit to which full shovel production can be maintained considerably—under favorable operating conditions about 900 feet—and if shovel operation is slow or difficult the distance may be much greater. The daily operating cost of each train is high and it is not always easy to decide just when an additional train would prove economical. Assume that two tractor trains of two wagons each can maintain full shovel production up to a haul of 600 feet, and that three trains could maintain full production up to a haul of 1,500 feet, and that the daily cost of operating with the two trains is $135 per day and that the additional train will cost $30 per day. An additional unit should be added at the point where increased production is proportional to the increased cost. In this case it should be added at the haul distance corresponding to the theoretical train requirement, $N$, as determined by equating the cost ratio to the production ratio, $\frac{135}{165}=\frac{2}{N}$, which results in the value, $N=2.44$ trains. The additional train requirement varies from 0 to 1 over a distance of 900 feet and the theoretical requirement of 0.44 of a train will be at a distance of 396 feet. The additional two-wagon train should therefore be added at a haul of approximately 1,000 feet.

Under the conditions prevailing on the jobs given in Tables 18 and 19 there is a decided advantage in using two-wagon trains, particularly on the long-haul job in Table 19. No allowance has been made in the examples for the possible saving on short hauls where a portion of the equipment will not be needed. Some saving is possible in operating expense, even though drivers must be paid. Where horses and wagons are used, feeding the horses and the drivers when work is shut down generates an idle-time cost which is at least half of the operating cost. With tractors or trucks the machines can be protected to avoid depreciation costs; there is no charge for gasoline, oil, or repairs and the driver may be laid off if the shutdown for that unit is likely to be long. It seems to be practical to carry mechanical hauling equipment much more nearly in balance with the maximum length of haul than can be done where teams are used.

On the other hand, profits are seriously affected by using more tractors than are actually needed at any particular time. If two trains can haul all the material the shovel can dig and three are used, then the daily cost of operation is raised from $135 to $165. If full shovel production is at the rate of 720 cubic yards per day, then with two trains working, the unit cost is 18¾ cents per cubic yard, while with three trains working it will be $22\frac{11}{12}$ cents per cubic yard, an increase of over 22 per cent.

The use of too few hauling units may affect profits even more than the use of too many. In the case given in Table 18 the most advantageous number of two-wagon trains is two. The use of only one train would increase the cost of the job nearly $7,200, and the use of one train more than the proper number would increase the cost about $1,250. With one-wagon trains, three is the most advantageous number, and if either two or four are used the cost is increased $3,225 and $733, respectively.

The advisability of laying off surplus units at any time depends entirely on the frequency with which haul distances fluctuate. Opportunities will exist to a considerable degree on some jobs, while on others they will be entirely absent. In making the calculations for any particular job these facts should be kept in mind and all possibilities utilized. On some of the jobs studied where two-wagon trains were used, the trains were reduced to one-wagon on the shorter hauls. The net operating cost remained nearly as high as before.

#### NOT ADVISABLE TO WORK WITH TRACTOR TRAINS WHEN WEATHER CONDITIONS REDUCE PRODUCTION MUCH BELOW NORMAL

Where tractor trains are used for hauling, the direct cost of keeping the outfit idle is so low that there is more danger of operating too soon after rain than there is of delaying too long. When idle the tractor trains as well as the shovel generate practically no cost except interest which is a relatively small factor as compared with the total daily operating cost. When working, each train costs about $30 a day. Full-time men about the shovel and general job overhead generate a cost not far from $40 a day. If three trains are normally required in order to maintain production, the daily cost of operating is about $165. Under such conditions (providing no penalties are involved) a yardage of nearly three-fourths of that required to pay the cost of normal production is necessary in order to justify working at all.

There is no great danger that working too soon after rains will create road conditions likely to interfere with the work for some days. Road conditions must be such that they would be considered bad for most types of hauling equipment before the rate of operation of tractor trains is much affected. How soon work shall begin after a storm is, in general, dependent on the conditions at the dump and at the shovel rather than on the condition of the roadway. The fact that this type of hauling equipment can operate successfully where hauling conditions are below normal does not mean that attention to the roadway can safely be neglected. The increased cost of fuel and the wear and tear on the equipment on a bad road is naturally much greater than on a good road. If the job is to be made to yield a satisfactory profit, high-grade management is perhaps even more necessary where tractors and heavy wagons are employed than where ordinary team hauling is used.

# MOTOR-VEHICLE REGISTRATIONS, 1927 [1]

[Compiled from reports of State authorities]

| State | Registered motor vehicles, individually and commercially owned [2] | | | Other registered vehicles | | Tax-exempt official motor cars and motor cycles | | | Number of licenses or permits (autos) | | | Total registered motor cars and trucks, 1926 | Year's change in motor-vehicle registration | | State |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total registered motor cars and trucks | Passenger automobiles, taxis, and busses | Motor trucks and road tractors | Trailers [3] | Motor cycles | United States cars | State and local cars | Motor cycles (official) | Dealers | Operators | Chauffeurs | | Number increase or decrease (−) | Per cent | |
| Alabama | 243,539 | 211,633 | 31,906 | 1,472 | 420 | 167 | | | 3,919 | | 1,630 | 225,930 | 17,609 | 7.8 | Alabama. |
| Arizona | 81,047 | 79,802 | 1,245 | | 271 | 176 | 815 | | 212 | 400 | 401 | 73,682 | 7,365 | 10.0 | Arizona. |
| Arkansas | 206,568 | 174,524 | 32,044 | 1,977 | 303 | 39 | 736 | 21 | 479 | | 4,932 | 209,419 | −(2,851) | −1.4 | Arkansas. |
| California | 1,693,195 | [4] 1,479,411 | [4] 213,784 | 34,126 | 9,444 | 1,217 | [5] 23,214 | 461 | 3,270 | 129,792 | 111,193 | 1,600,475 | 92,720 | 5.8 | California. |
| Colorado | 268,492 | 245,107 | 23,385 | 88 | 1,362 | 283 | | | | | | 248,613 | 19,879 | 8.0 | Colorado. |
| Connecticut | 281,521 | 238,509 | 43,012 | 150 | 3,083 | 71 | 2,459 | 281 | 5,600 | [6] 323,881 | | 263,235 | 18,286 | 6.9 | Connecticut. |
| Delaware | 47,124 | 38,037 | 9,087 | 243 | 313 | 44 | | | 438 | [6] 51,945 | | 44,834 | 2,290 | 5.1 | Delaware. |
| Florida | 394,734 | 332,979 | [7] 61,755 | [7] 1,000 | 1,243 | 75 | 3,451 | 206 | 2,547 | | 4,949 | 401,562 | −(6,828) | −1.7 | Florida. |
| Georgia | 300,635 | 262,630 | 38,005 | | 909 | 934 | | | 792 | | 2,553 | 277,468 | 23,167 | 8.4 | Georgia. |
| Idaho | 101,336 | 91,306 | 10,030 | 186 | 440 | 103 | 1,210 | | 406 | | 476 | 94,760 | 6,576 | 6.9 | Idaho. |
| Illinois | 1,438,985 | [4] 1,254,421 | [4] 184,564 | 3,489 | 6,135 | 979 | (8) | | 4,594 | | 100,398 | 1,370,503 | 68,482 | 5.0 | Illinois. |
| Indiana | 813,637 | 697,359 | 116,278 | 6,599 | 3,501 | 3,184 | 4,083 | | 2,584 | | 39,212 | 277,326 | 41,311 | 5.3 | Indiana. |
| Iowa | 704,203 | 649,309 | 54,894 | 170 | 1,787 | 44 | 2,827 | | 2,531 | 2,964 | | 698,998 | 5,205 | .7 | Iowa. |
| Kansas | 501,901 | 447,273 | 54,628 | | 1,218 | 192 | 2,360 | | 2,525 | | | 491,276 | 10,625 | 2.2 | Kansas. |
| Kentucky | 285,621 | 255,892 | 29,729 | | 693 | 90 | 1,742 | 59 | 1,051 | | 8,410 | 281,557 | 4,064 | 1.4 | Kentucky. |
| Louisiana | 255,000 | 216,000 | 39,000 | 3,500 | 510 | 209 | | | 487 | | 14,177 | 239,500 | 15,500 | 6.5 | Louisiana. |
| Maine | 163,623 | 132,927 | 30,696 | 1,012 | 1,245 | 64 | 1,173 | 66 | 1,297 | 188,975 | 7,309 | 151,486 | 12,137 | 8.0 | Maine. |
| Maryland | 270,935 | 265,768 | 5,167 | 616 | 2,415 | 1,969 | 950 | | 6,788 | 33,814 | 40,679 | 252,852 | 18,083 | 7.1 | Maryland. |
| Massachusetts | 694,107 | 614,359 | 79,748 | 443 | 7,245 | 556 | 800 | | 2,048 | 102,285 | | 690,190 | 3,917 | .6 | Massachusetts. |
| Michigan | 1,154,773 | [4] 998,781 | [4] 155,992 | 17,853 | 3,585 | 371 | (8) | | 2,128 | 220,954 | 76,483 | 1,118,785 | 35,988 | 3.2 | Michigan. |
| Minnesota | 646,682 | 565,401 | 81,281 | 3,286 | 2,295 | 252 | 2,450 | | 2,087 | | 17,988 | 630,285 | 16,397 | 2.6 | Minnesota. |
| Mississippi | 218,043 | 196,239 | 21,804 | 2,317 | 83 | 74 | | | 656 | | | 205,200 | 12,843 | 6.2 | Mississippi. |
| Missouri | 682,419 | 610,303 | 72,116 | 1,739 | 1,835 | 311 | 1,428 | 3 | 2,387 | 5,230 | 26,269 | 654,554 | 27,865 | 4.2 | Missouri. |
| Montana | 112,735 | 94,733 | 18,002 | | 156 | 229 | 1,158 | 9 | 481 | | 338 | 103,958 | 8,777 | 8.4 | Montana. |
| Nebraska | 373,912 | [4] 342,357 | [4] 31,555 | 1,828 | 1,109 | 226 | 1,029 | | 3,052 | | | 366,773 | 7,139 | 1.9 | Nebraska. |
| Nevada | 25,776 | 20,414 | 5,362 | 104 | 99 | 42 | | | 533 | | | 24,014 | 1,762 | 7.3 | Nevada. |
| New Hampshire | 96,009 | 83,415 | 12,594 | 565 | 1,387 | 22 | | | 541 | 73,474 | 43,242 | 89,001 | 7,008 | 7.9 | New Hampshire. |
| New Jersey | 712,396 | 586,510 | 125,886 | 1,827 | 6,857 | 708 | 6,294 | 913 | 2,917 | 814,593 | 6,422 | 651,415 | 60,981 | 9.4 | New Jersey. |
| New Mexico | 59,291 | 57,643 | 1,648 | 193 | 170 | 156 | 630 | | 170 | | | 54,996 | 4,295 | 7.8 | New Mexico. |
| New York | 1,937,918 | 1,624,535 | 313,383 | 6,936 | 16,347 | 1,666 | 12,116 | 1,262 | 4,482 | 1,701,383 | 616,025 | 1,815,434 | 122,484 | 5.7 | New York. |
| North Carolina [9] | [9] 430,499 | 390,223 | 40,276 | 1,618 | 1,194 | 429 | 5,419 | | 6,330 | | | [9] 385,047 | 45,452 | 11.8 | North Carolina. |
| North Dakota | 160,701 | 144,830 | 15,871 | | 277 | 3 | | | | | | 157,822 | 2,879 | 1.8 | North Dakota. |
| Ohio | 1,570,734 | 1,374,402 | 196,332 | 12,134 | 7,749 | 2,362 | 9,067 | | 26,997 | | | 1,480,246 | 90,488 | 6.1 | Ohio. |
| Oklahoma | 503,126 | 437,776 | 65,350 | | 1,200 | 530 | | | | | | 499,938 | 3,188 | .6 | Oklahoma. |
| Oregon | 244,572 | 223,582 | 20,990 | | 2,030 | 141 | 1,132 | | 604 | 39,355 | 15,769 | 233,568 | 11,004 | 4.7 | Oregon. |
| Pennsylvania | 1,554,915 | 1,354,548 | 200,367 | 3,780 | 14,267 | 1,383 | 942 | | 28,347 | 1,564,161 | | 1,455,184 | 99,731 | 6.9 | Pennsylvania. |
| Rhode Island | 118,014 | 98,861 | 19,153 | 57 | 1,250 | 56 | 671 | 87 | 300 | 136,860 | | 110,746 | 7,268 | 6.6 | Rhode Island. |
| South Carolina | 199,635 | 179,571 | 20,064 | 1,387 | 325 | 91 | | | 508 | | | 181,189 | 18,446 | 10.2 | South Carolina. |
| South Dakota | 169,552 | 153,019 | 16,533 | | 229 | 85 | 1,019 | | | | | 168,230 | 1,322 | .8 | South Dakota. |
| Tennessee | 294,567 | 269,086 | 25,481 | (3) | 904 | 132 | 2,914 | | 632 | | | 279,639 | 14,928 | 5.3 | Tennessee. |
| Texas | 1,111,407 | 996,397 | 115,010 | 9,826 | 3,081 | 2,505 | | | 3,323 | 41,775 | 11,490 | 1,049,869 | 61,538 | 5.9 | Texas. |
| Utah [10] | 93,976 | 80,731 | 13,245 | | 531 | 173 | | | | | | 85,380 | 8,596 | 10.1 | Utah. |
| Vermont | 79,527 | 73,308 | 6,219 | | 601 | 28 | | | 658 | | | 74,063 | 5,464 | 7.4 | Vermont. |
| Virginia | 337,607 | 288,666 | 48,941 | 466 | 2,025 | 1,141 | | 253 | 2,950 | | 8,450 | 322,614 | 14,993 | 4.6 | Virginia. |
| Washington | 384,583 | 326,667 | 57,916 | 2,072 | 2,501 | 637 | 4,682 | 144 | 4,879 | 397,975 | | 363,279 | 21,304 | 5.9 | Washington. |
| West Virginia | 245,819 | 217,689 | 28,130 | 392 | 1,431 | 33 | 1,862 | | 13,701 | 61,600 | 25,200 | 227,836 | 17,983 | 7.9 | West Virginia. |
| Wisconsin | 698,289 | 609,795 | 88,494 | | 2,963 | 92 | 668 | 79 | 2,949 | | | 662,282 | 36,007 | 5.4 | Wisconsin. |
| Wyoming | 51,955 | 45,539 | 6,416 | | 134 | 209 | 257 | | 306 | | | 49,883 | 2,072 | 4.2 | Wyoming. |
| District of Columbia | 111,680 | 98,162 | 13,518 | | 1,151 | 837 | 2,131 | 212 | 1,958 | 57,014 | 1,581 | 111,497 | 183 | .2 | District of Columbia. |
| Total | 23,127,315 | 20,230,429 | 2,896,886 | 123,451 | 120,303 | [11] 33,179 | 101,689 | 4,056 | 155,444 | 5,948,430 | 1,185,576 | 22,001,393 | 1,125,922 | 5.1 | Total. |

[1] All States report for calendar year except North Carolina which reports only 6 months totals (July 1 to Dec. 31), as their fiscal year for registration ended June 30.

[2] The first 3 columns record the regularly registered motor cars and trucks which pay the regular license fees eliminating reregistrations and registration of cars owned by nonresidents. Some States, as noted, classify busses with trucks. Tables showing the extent and kinds of bus service (from nongovernment sources) can be found in the February, 1928, issue of "Bus transportation."

[3] Some States include trailers with motor trucks, other States do not register trailers.

[4] Busses included with trucks.

[5] Includes over 8,000 cars and trucks of public-service corporation exempt by law.

[6] Includes chauffeurs.

[7] Trailers (1,000 estimated) excluded from trucks.

[8] Official cars included in first 3 columns as $2 fee charged.

[9] Last six months of year's registration only as year commenced July 1.

[10] Preliminary data, subject to revision.

[11] As reported in 1925 by Bureau of Budget, and includes 7,959 "Cars-at-large," not allocated to any State.

# MOTOR VEHICLE REGISTRATION FEES, ETC., 1927 [1]

[Compiled from reports of State authorities]

| State | Total gross receipts | Registration receipts [2]: Motor car receipts: Total from motor cars | Passenger cars and busses | Trucks and tractors | Other vehicles: Trailers | Motor-cycles | Miscellaneous receipts: Dealers' license | Chauffeur and operator permits | Other mis-cellaneous | Disposition of gross receipts: Collection and admin-istration | For rural highway purposes: State highways | Local roads | State and county road bonds | For other purposes | State |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alabama | $3,127,000 | $3,109,976 | | | | | $3,919 | $8,246 | $4,859 | $125,956 | $843,850 | $609,765 | $1,547,429 | | Alabama. |
| Arizona | 454,429 | 443,084 | | | | $531 | 3,356 | 1,528 | 5,930 | | 454,429 | | | | Arizona. |
| Arkansas | 3,662,272 | 3,619,482 | | | | | 5,469 | 23,338 | 13,983 | 73,246 | 805,700 | 476,095 | [3] 2,307,231 | | Arkansas. |
| California | 8,796,348 | 7,492,228 | $4,851,767 | $2,640,461 | $258,980 | 33,735 | 45,858 | 290,323 | 675,224 | 1,243,924 | 3,775,453 | 3,775,453 | | [4] 1,518 | California. |
| Colorado | 1,600,222 | 1,499,784 | 1,248,325 | 251,459 | 1,410 | 2,303 | | | 96,725 | 80,011 | 760,106 | 760,105 | | | Colorado. |
| Connecticut | 6,805,664 | 5,196,922 | 3,894,856 | 1,302,066 | 274 | 14,121 | 72,776 | 979,629 | 541,942 | | 6,805,664 | | | | Connecticut. |
| Delaware | 846,289 | 673,682 | 489,004 | 184,678 | 3,619 | 1,284 | 7,685 | 158,637 | 1,382 | | 846,289 | | | | Delaware. |
| Florida | 5,692,128 | 5,600,653 | 4,077,130 | 1,523,523 | | 5,971 | 33,860 | 9,325 | 42,319 | 584,154 | 3,829,579 | 1,276,526 | | [5] 1,869 | Florida. |
| Georgia | 3,712,978 | 3,658,646 | 3,039,048 | 619,598 | | 4,222 | 40,260 | 4,998 | 4,852 | 114,730 | 3,598,248 | | | | Georgia. |
| Idaho | 1,502,185 | 1,458,694 | 1,211,031 | 247,663 | 3,793 | 2,195 | 24,225 | 952 | 12,326 | | 156,269 | 1,345,916 | | | Idaho. |
| Illinois | 14,839,593 | 13,929,037 | 10,635,412 | 3,293,625 | 61,930 | 20,644 | 89,860 | 353,472 | 384,650 | | 9,191,015 | | 5,606,010 | [6] 42,568 | Illinois. |
| Indiana | 5,430,806 | 5,069,422 | 3,914,846 | 1,154,576 | 31,406 | 6,414 | 52,030 | 36,955 | 234,579 | 251,341 | 5,179,465 | | | | Indiana. |
| Iowa | 10,371,699 | 9,742,671 | 8,785,993 | 956,678 | 3,322 | 6,354 | 78,604 | 77,593 | 463,155 | 414,070 | 9,604,549 | 353,080 | | | Iowa. |
| Kansas* | 6,518,622 | | | | | | | | | 252,822 | 3,934,480 | 2,331,320 | | | Kansas.* |
| Kentucky | 4,365,062 | 4,304,022 | 3,375,500 | 928,522 | | 5,262 | 29,888 | 16,143 | 9,747 | 224,289 | 3,676,512 | 464,261 | | | Kentucky. |
| Louisiana* | 4,199,347 | | | | | | | | | | 4,199,347 | | | | Louisiana.* |
| Maine | 2,558,046 | 1,980,811 | 1,535,384 | 445,427 | 3,375 | 6,733 | 48,683 | 405,848 | 112,596 | 201,546 | [7] 1,370,251 | | 986,249 | | Maine. |
| Maryland | 2,987,912 | 2,347,223 | 2,070,731 | 276,492 | 16,029 | 10,933 | 31,349 | 189,665 | 392,713 | 298,791 | 2,151,297 | | | [8] 537,824 | Maryland. |
| Massachusetts | 13,136,442 | 10,557,782 | 7,318,651 | 3,239,131 | 19,468 | 32,177 | 60,990 | 1,628,188 | 837,837 | 1,266,525 | 10,821,659 | | 1,048,258 | | Massachusetts. |
| Michigan | 17,984,210 | 16,527,569 | 12,464,719 | 4,062,850 | 200,949 | 13,658 | 94,568 | 249,812 | 897,654 | [9] 1,117,214 | 9,784,936 | 6,000,000 | [3] 1,082,060 | | Michigan. |
| Minnesota | 10,233,644 | 10,110,633 | 8,210,901 | 1,899,732 | 14,277 | 8,781 | 38,535 | 20,330 | 41,088 | | 6,449,904 | | [3] 3,763,410 | [6] 20,330 | Minnesota. |
| Mississippi | 2,556,627 | 2,220,942 | | | | | | | 335,685 | 125,602 | 202,077 | 2,228,948 | | | Mississippi. |
| Missouri* | 8,253,009 | | | | | | | | | 401,822 | [10] 2,715,162 | | 5,136,025 | | Missouri.* |
| Montana | 1,136,103 | 1,039,235 | 855,491 | 183,744 | | 1,087 | 37,078 | 676 | 58,027 | 30,858 | | 1,105,245 | | | Montana. |
| Nebraska | 3,740,553 | 3,574,994 | 3,016,632 | 558,362 | 5,079 | 3,728 | 43,919 | | 112,833 | 111,983 | 1,088,571 | 2,539,999 | | | Nebraska. |
| Nevada | 229,839 | 229,124 | | | | 495 | | | 220 | 9,872 | 89,870 | | 130,097 | | Nevada. |
| New Hampshire | 1,915,291 | 1,536,502 | | | | 7,540 | 28,690 | 264,055 | 78,504 | 156,044 | 1,759,247 | | | | New Hampshire. |
| New Jersey | 12,963,541 | 9,293,964 | 5,680,418 | 3,613,546 | 66,552 | 13,714 | 72,775 | 2,450,201 | 1,066,335 | 532,755 | 7,900,000 | 4,530,786 | | | New Jersey. |
| New Mexico | 528,193 | 502,447 | 444,401 | 58,046 | 2,621 | 527 | 8,759 | | 13,839 | 53,795 | 316,265 | 158,133 | | | New Mexico. |
| New York | 31,757,889 | 28,375,610 | 20,140,775 | 8,234,835 | 76,825 | 70,654 | 188,907 | 2,465,776 | 580,117 | 1,922,049 | 22,072,465 | 4,743,169 | | [11] 3,020,206 | New York. |
| North Carolina* | [12] 3,246,853 | | | | | | | | | [13] 150,000 | [13] 2,331,853 | | [13] 765,000 | | North Carolina.* |
| North Dakota | 1,595,442 | 1,570,120 | 1,338,798 | 231,322 | | 1,362 | | | 23,960 | 170,000 | [14] 777,721 | 647,721 | | | North Dakota. |
| Ohio | 10,745,471 | 10,398,977 | | | | 23,014 | 124,302 | 9,979 | 189,199 | 366,883 | 5,128,532 | 5,250,056 | | | Ohio. |
| Oklahoma* | 5,753,912 | | | | | | | | | | 2,301,565 | 3,452,347 | | | Oklahoma.* |
| Oregon | 6,527,341 | 6,325,637 | 5,408,300 | 917,337 | | 11,209 | 29,312 | 66,636 | 94,547 | 367,341 | 1,356,800 | | [3] 4,803,200 | | Oregon. |
| Pennsylvania | 26,017,495 | 19,693,780 | 13,734,183 | 5,959,597 | 41,031 | 35,775 | 330,316 | 2,325,947 | 3,590,646 | 1,565,703 | 15,048,520 | 1,501,550 | 7,800,447 | [15] 101,275 | Pennsylvania. |
| Rhode Island | 2,093,309 | 1,693,999 | 1,265,199 | 428,800 | 1,034 | 4,438 | 13,440 | 273,720 | 106,678 | 179,304 | 1,914,005 | | | | Rhode Island. |
| South Carolina | 2,187,290 | 2,078,546 | 1,771,878 | 306,668 | 22,386 | 1,293 | 23,457 | | 61,608 | | 2,178,290 | 9,000 | | | South Carolina. |
| South Dakota | 2,491,981 | 2,472,926 | 2,142,266 | 330,660 | | 1,072 | | | 17,983 | 67,463 | 1,236,999 | 1,187,519 | | | South Dakota. |
| Tennessee* | 3,765,775 | | | | | | | | | 92,850 | 3,672,925 | | | | Tennessee.* |
| Texas | 15,626,531 | 15,045,978 | 12,583,812 | 2,462,166 | 117,998 | 12,024 | 55,872 | 69,678 | 324,981 | 598,805 | 10,884,403 | 4,143,323 | | | Texas. |
| Utah* | 672,403 | | | | | | | | | 132,000 | | | 540,403 | | Utah*. |
| Vermont | 1,878,950 | 1,610,899 | 1,385,081 | 225,818 | | 4,146 | 30,350 | 203,187 | 30,368 | 119,619 | 1,759,331 | | | | Vermont. |
| Virginia | 5,235,953 | 4,840,384 | 4,143,391 | 696,993 | 4,692 | 6,863 | 61,354 | 39,445 | 283,215 | 257,790 | 4,978,163 | | | | Virginia. |
| Washington | 6,482,354 | 5,930,338 | 4,606,495 | 1,323,843 | 44,869 | 13,454 | 86,833 | 399,517 | 7,343 | 248,977 | 4,940,884 | 892,976 | | [16] 399,517 | Washington. |
| West Virginia | 4,004,391 | 3,605,153 | 3,084,218 | 520,935 | 3,396 | 5,587 | 54,089 | 136,696 | 199,470 | 256,888 | 1,390,324 | | 2,320,000 | [15] 37,179 | West Virginia. |
| Wisconsin | 9,772,887 | 9,518,220 | 7,872,419 | 1,645,801 | | 17,655 | 36,354 | 103,655 | 97,003 | 550,000 | 5,428,287 | 3,794,600 | | | Wisconsin. |
| Wyoming | 525,807 | 515,019 | 404,275 | 110,744 | | 638 | 9,500 | | 650 | | 274,028 | | 251,779 | | Wyoming. |
| District of Columbia | 531,044 | 120,279 | 99,026 | 21,253 | | 1,151 | 1,958 | 185,271 | 222,385 | 159,388 | | | | [17] 371,656 | District of Columbia. |
| Detailed totals [2] | 268,651,211 | 239,515,394 | (18) | (18) | 1,005,315 | 412,744 | 1,999,180 | 13,449,421 | 12,269,157 | | | | | | Detailed totals.[2] |
| Grand total | 301,061,132 | | | | | | | | | 14,876,410 | 189,985,289 | 53,577,893 | 38,087,598 | 4,533,942 | Grand total. |

[1] All States report amounts for calendar year except North Carolina, which reports for 6 months, July 1 to Dec. 31, for registration for last half of year.
[2] The States starred do not show complete receipt details and are not included in totals under first 9 columns, shown as "Detailed total." The disposition of total gross receipts is shown for all States and such totals are shown in the last 5 columns.
[3] County bond payments in Arkansas amounted to $2,124,118; in Oregon, $1,540,000, and in Michigan the full amount shown.
[4] Undistributed receipts.
[5] Unpaid claims.
[6] To State general fund.
[7] Includes $140,000 for State police.
[8] For Baltimore city streets.
[9] Does not include part of collection expense paid from State appropriations.
[10] Includes $1,006,128 for administration of State highway department.
[11] New York City general fund.
[12] Second half of year only as fiscal year changed to agree with calendar year in 1928.
[13] Gross receipts (with motor fuel taxes) form State highway fund used for: Administration, financing highway obligations, maintenance and construction of State highway system. The data is estimated on a pro rata basis here.
[14] Includes $130,000 of special bridge fund.
[15] Refunds.
[16] Highway safety fund derived from operators' permits.
[17] For repair and construction of Washington streets, if so appropriated by Congress.
[18] Only 35 States report details of motor car registration receipts, which total here as follows: Passenger cars and busses, $167,100,356; trucks and tractors, $50,856,951; making a combined total of $217,957,307.

UNITED STATES DEPARTMENT OF AGRICULTURE

## BUREAU OF PUBLIC ROADS

# STATUS OF FEDERAL AID HIGHWAY CONSTRUCTION

AS OF

## MARCH 31, 1928

| STATES | FISCAL YEARS 1917-1927 | | | FISCAL YEAR 1928 | | | | | | | | | BALANCE OF FEDERAL AID FUND AVAILABLE FOR NEW PROJECTS | STATES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PROJECTS COMPLETED PRIOR TO JULY 1, 1927 | | | PROJECTS COMPLETED SINCE JUNE 30, 1927 | | | *PROJECTS UNDER CONSTRUCTION | | | PROJECTS APPROVED FOR CONSTRUCTION | | | | |
| | TOTAL COST | FEDERAL AID | MILES | TOTAL COST | FEDERAL AID | MILES | ESTIMATED COST | FEDERAL AID ALLOTTED | MILES | ESTIMATED COST | FEDERAL AID ALLOTTED | MILES | | |
| Alabama | $ 20,061,371.68 | $ 9,615,099.94 | 1,400.2 | $ 1,504,368.28 | $ 712,525.58 | 108.6 | $ 9,869,103.11 | $ 4,811,329.02 | 505.3 | $ 448,457.56 | $ 222,863.69 | 35.1 | $ 2,082,339.77 | Alabama |
| Arizona | 11,809,950.70 | 6,447,189.27 | 800.8 | 624,598.32 | 451,055.92 | 15.7 | 1,087,792.63 | 827,674.26 | 66.1 | 91,051.43 | 58,152.85 | 0.5 | 3,949,271.70 | Arizona |
| Arkansas | 22,337,014.63 | 9,525,192.75 | 1,560.6 | 194,319.25 | 92,922.87 | 18.4 | 4,730,594.98 | 2,109,648.77 | 246.0 | 792,660.15 | 396,330.06 | 26.0 | 2,041,390.55 | Arkansas |
| California | 35,128,269.04 | 16,967,026.82 | 1,306.3 | 4,417,161.29 | 2,016,680.89 | 103.1 | 7,698,201.52 | 3,582,214.87 | 156.1 | 258,464.56 | 155,078.73 | 9.3 | 4,321,665.69 | California |
| Colorado | 15,497,121.91 | 7,934,298.91 | 829.0 | 865,092.55 | 461,241.53 | 53.6 | 6,425,353.98 | 3,098,699.84 | 235.8 | 373,548.50 | 207,336.94 | 18.0 | 3,384,155.78 | Colorado |
| Connecticut | 6,397,392.29 | 2,444,000.54 | 137.3 | 2,475,774.50 | 677,628.04 | 35.4 | 4,979,858.22 | 1,363,375.63 | 57.4 | 1,056,062.72 | 190,461.17 | 11.8 | 605,113.62 | Connecticut |
| Delaware | 6,237,026.55 | 2,345,572.42 | 159.5 | 646,927.21 | 303,850.84 | 34.4 | 762,279.37 | 209,908.50 | 11.3 | 209,132.53 | 104,566.27 | 8.0 | 241,409.97 | Delaware |
| Florida | 7,476,856.31 | 3,627,912.60 | 245.1 | 4,232,517.04 | 2,026,119.95 | 83.1 | 5,946,374.95 | 2,484,574.58 | 152.7 | 1,013,889.63 | 387,752.10 | 27.8 | 1,359,356.77 | Florida |
| Georgia | 31,951,436.50 | 15,101,232.40 | 2,173.6 | 6,819,785.06 | 3,239,437.32 | 236.0 | 4,797,661.00 | 2,380,582.20 | 200.8 | 1,043,454.68 | 485,312.12 | 42.3 | 1,184,612.96 | Georgia |
| Idaho | 13,225,515.45 | 7,075,527.16 | 835.5 | 1,672,690.67 | 1,050,478.15 | 114.3 | 2,191,398.81 | 1,314,265.44 | 151.7 | 545,138.29 | 323,950.12 | 16.0 | 663,561.13 | Idaho |
| Illinois | 48,538,982.16 | 22,781,516.60 | 1,530.8 | 1,894,920.13 | 912,725.80 | 67.9 | 15,446,195.78 | 7,243,789.27 | 498.6 | 6,284,544.12 | 3,130,922.31 | 207.5 | 2,052,898.02 | Illinois |
| Indiana | 23,372,717.74 | 11,238,568.20 | 732.5 | 5,296,637.76 | 2,471,687.84 | 166.7 | 12,374,897.93 | 5,958,406.82 | 378.2 | 2,853,698.89 | 1,403,931.83 | 102.3 | 979,995.31 | Indiana |
| Iowa | 34,306,138.86 | 14,395,603.75 | 2,484.4 | 6,996,585.23 | 3,191,018.55 | 393.4 | 8,992,222.99 | 3,998,183.03 | 223.5 | 3,491,634.63 | 1,485,053.09 | 14.6 | 495,994.58 | Iowa |
| Kansas | 37,442,061.61 | 14,730,829.48 | 1,495.2 | 5,480,095.37 | 2,386,970.38 | 354.7 | 10,783,105.20 | 4,249,046.52 | 538.5 | 134,207.72 | 52,000.00 | 10.2 | 2,176,292.62 | Kansas |
| Kentucky | 23,216,600.53 | 9,510,694.75 | 874.9 | 2,834,753.13 | 1,284,212.39 | 122.6 | 7,996,278.00 | 3,802,380.70 | 349.6 | 357,363.44 | 178,681.72 | 23.5 | 1,275,815.44 | Kentucky |
| Louisiana | 15,877,552.20 | 7,093,892.21 | 1,178.7 | 1,332,121.58 | 597,801.48 | 48.6 | 5,723,321.13 | 2,709,183.03 | 196.0 | 1,343,267.77 | 531,344.70 | 51.8 | 372,776.58 | Louisiana |
| Maine | 10,564,800.06 | 4,858,452.67 | 357.6 | 2,087,386.84 | 732,746.76 | 61.7 | 1,108,176.91 | 453,994.44 | 33.9 | 87,912.01 | 43,956.00 | 5.6 | 1,737,903.13 | Maine |
| Maryland | 11,790,203.93 | 5,524,938.27 | 477.8 | 1,468,140.87 | 684,194.40 | 71.2 | 724,190.14 | 357,376.05 | 33.4 | | | | 628,573.28 | Maryland |
| Massachusetts | 20,670,246.02 | 7,425,928.15 | 410.4 | 773,728.83 | 158,264.74 | 9.6 | 7,334,334.71 | 2,087,701.70 | 130.5 | 78,146.64 | 31,500.00 | 2.1 | 2,583,239.41 | Massachusetts |
| Michigan | 31,977,248.37 | 14,328,484.99 | 1,084.2 | 5,967,450.00 | 2,652,420.04 | 192.9 | 10,729,924.21 | 4,712,891.31 | 273.1 | 4,554,964.10 | 1,807,202.00 | 103.6 | 1,265,653.66 | Michigan |
| Minnesota | 45,099,648.47 | 19,046,145.67 | 3,643.5 | 5,852,424.86 | 2,001,398.90 | 248.7 | 4,027,299.75 | 1,203,100.00 | 216.7 | 3,239,964.75 | 1,037,000.00 | 124.7 | 537,471.43 | Minnesota |
| Mississippi | 18,331,230.75 | 9,004,294.62 | 1,314.1 | 3,087,377.78 | 1,523,013.55 | 166.8 | 5,457,654.81 | 2,667,145.37 | 256.5 | 943,319.66 | 471,348.54 | 43.8 | 1,079,823.92 | Mississippi |
| Missouri | 42,389,290.41 | 19,681,026.48 | 1,944.8 | 4,759,322.06 | 2,091,099.82 | 169.2 | 6,362,830.48 | 2,737,541.91 | 206.3 | 1,568,314.45 | 670,397.18 | 58.9 | 2,415,892.61 | Missouri |
| Montana | 12,854,995.72 | 7,287,288.69 | 1,151.6 | 618,400.67 | 421,911.70 | 67.9 | 3,986,705.92 | 2,807,171.20 | 318.6 | 1,820,260.29 | 1,020,333.45 | 189.2 | 4,992,254.96 | Montana |
| Nebraska | 16,157,040.25 | 7,739,386.39 | 2,246.6 | 5,557,738.17 | 2,688,847.30 | 575.8 | 10,730,638.65 | 5,286,555.43 | 1,036.7 | 309,459.37 | 154,167.91 | 30.7 | 1,936,396.97 | Nebraska |
| Nevada | 10,421,349.31 | 7,589,168.68 | 853.6 | 646,706.06 | 553,479.11 | 78.1 | 1,743,076.97 | 1,524,773.83 | 195.8 | 169,673.10 | 146,534.92 | 15.8 | 887,763.46 | Nevada |
| New Hampshire | 5,868,897.76 | 2,778,928.05 | 264.8 | 848,508.33 | 372,238.38 | 27.8 | 780,437.14 | 352,772.73 | 22.0 | 181,498.06 | 83,607.66 | 1.8 | 313,195.18 | New Hampshire |
| New Jersey | 22,228,240.08 | 7,495,364.48 | 316.3 | 4,173,354.17 | 1,109,130.00 | 74.0 | 3,769,538.68 | 797,536.52 | 52.2 | 905,480.02 | 177,210.00 | 13.5 | 757,912.00 | New Jersey |
| New Mexico | 13,336,250.94 | 7,937,598.06 | 1,505.2 | 1,365,495.65 | 882,413.37 | 99.9 | 2,866,074.58 | 2,265,180.28 | 181.3 | 163,241.87 | 102,868.80 | 12.9 | 2,160,449.49 | New Mexico |
| New York | 54,183,085.44 | 21,693,955.65 | 1,439.3 | 8,270,394.76 | 2,710,163.93 | 174.7 | 39,107,536.00 | 9,370,761.45 | 584.3 | 6,486,600.00 | 1,325,902.50 | 85.9 | 6,209,507.47 | New York |
| North Carolina | 35,295,849.21 | 14,518,903.16 | 1,460.1 | 3,072,681.24 | 1,431,904.59 | 112.9 | 1,870,962.46 | 882,448.18 | 43.1 | 1,679,658.00 | 824,764.14 | 64.4 | 1,488,451.93 | North Carolina |
| North Dakota | 15,881,558.55 | 7,746,293.68 | 2,715.6 | 3,729,358.44 | 2,054,168.62 | 488.9 | 3,505,711.40 | 1,731,661.61 | 551.5 | 1,176,967.61 | 516,945.47 | 171.6 | 1,087,980.62 | North Dakota |
| Ohio | 52,621,391.49 | 19,331,376.76 | 1,515.0 | 6,914,056.19 | 2,908,029.57 | 231.9 | 7,863,330.64 | 2,989,049.92 | 185.5 | 5,035,607.20 | 1,942,336.26 | 124.8 | 4,081,176.49 | Ohio |
| Oklahoma | 30,381,957.08 | 14,117,589.21 | 1,268.1 | 1,385,066.33 | 617,029.12 | 57.6 | 6,685,912.08 | 3,003,684.98 | 388.1 | 731,835.42 | 357,640.14 | 27.5 | 1,464,800.55 | Oklahoma |
| Oregon | 19,583,584.76 | 10,041,452.94 | 1,055.0 | 591,912.35 | 325,162.75 | 16.5 | 2,550,851.18 | 1,327,846.88 | 71.2 | 455,302.65 | 242,118.11 | 8.2 | 1,314,675.32 | Oregon |
| Pennsylvania | 77,726,174.22 | 26,317,620.32 | 1,534.3 | 7,360,151.05 | 2,253,430.31 | 153.1 | 14,791,021.30 | 4,526,930.97 | 276.2 | 7,036,164.38 | 2,096,799.98 | 133.5 | 2,813,520.42 | Pennsylvania |
| Rhode Island | 5,233,413.38 | 1,998,479.06 | 116.0 | 700,482.52 | 227,205.00 | 15.1 | 1,446,803.79 | 389,422.41 | 24.2 | 569,048.13 | 138,825.00 | 9.2 | 644,887.53 | Rhode Island |
| South Carolina | 17,002,039.93 | 7,526,988.80 | 1,568.4 | 2,521,297.49 | 1,198,355.38 | 70.7 | 9,674,988.58 | 2,659,986.16 | 263.1 | 2,224,496.47 | 377,000.00 | 36.4 | 153,714.66 | South Carolina |
| South Dakota | 19,262,063.24 | 9,507,525.54 | 2,502.9 | 1,249,757.94 | 678,550.24 | 232.0 | 4,272,577.06 | 2,258,582.25 | 629.6 | 501,856.08 | 265,882.37 | 95.5 | 900,294.60 | South Dakota |
| Tennessee | 24,283,035.03 | 11,551,457.55 | 868.7 | 3,549,497.62 | 1,590,594.64 | 96.3 | 7,460,398.22 | 3,128,728.14 | 210.8 | 3,814,138.67 | 1,404,251.65 | 36.1 | 832,337.02 | Tennessee |
| Texas | 78,190,246.37 | 31,566,960.45 | 5,466.4 | 9,235,029.21 | 4,227,105.34 | 355.8 | 14,551,547.16 | 6,168,325.15 | 431.3 | 3,610,194.77 | 1,455,687.46 | 137.5 | 6,188,200.60 | Texas |
| Utah | 9,154,377.33 | 5,767,079.95 | 628.9 | 1,519,607.25 | 1,122,910.11 | 128.8 | 2,427,042.97 | 1,677,878.04 | 133.9 | 444,885.71 | 344,705.72 | 33.1 | 601,204.18 | Utah |
| Vermont | 5,037,118.23 | 2,348,856.01 | 152.7 | 2,058,524.16 | 804,449.43 | 42.8 | 1,271,358.62 | 446,721.78 | 28.8 | 213,383.29 | 48,140.00 | 4.4 | 351,589.78 | Vermont |
| Virginia | 26,844,025.24 | 12,537,143.25 | 1,168.9 | 1,904,466.28 | 824,401.18 | 51.7 | 3,801,229.62 | 1,531,148.07 | 77.7 | 3,428,027.16 | 842,658.64 | 89.4 | 646,424.86 | Virginia |
| Washington | 18,184,505.97 | 8,246,551.95 | 711.1 | 2,976,519.51 | 1,306,714.32 | 62.1 | 2,644,260.16 | 1,134,600.00 | 83.6 | 2,555,139.78 | 784,000.00 | 49.4 | 948,667.73 | Washington |
| West Virginia | 10,424,847.32 | 4,573,748.01 | 419.4 | 3,998,929.96 | 1,561,360.55 | 110.6 | 4,432,608.90 | 1,969,333.43 | 176.2 | 164,340.61 | 67,899.94 | 4.4 | 767,601.07 | West Virginia |
| Wisconsin | 27,891,502.16 | 11,847,858.90 | 1,729.5 | 7,124,245.54 | 3,373,834.65 | 274.0 | 5,125,553.60 | 2,231,821.76 | 190.9 | 1,214,073.39 | 577,000.00 | 44.9 | 3,142,966.69 | Wisconsin |
| Wyoming | 12,650,712.15 | 7,139,267.05 | 1,315.9 | 1,655,408.97 | 1,051,830.11 | 102.8 | 2,058,725.51 | 1,322,970.11 | 217.4 | 82,443.28 | 52,928.57 | | 873,194.16 | Wyoming |
| Hawaii | 343,664.15 | 97,440.00 | 6.5 | 866,148.12 | 275,109.33 | 14.1 | 1,217,433.12 | 337,110.89 | 18.9 | | | | 1,121,742.78 | Hawaii |
| TOTALS | 1,154,740,601.48 | 510,007,691.24 | 60,957.6 | 155,177,916.59 | 68,289,824.77 | 6,592.5 | 306,185,374.92 | 126,486,015.43 | 11,510.8 | 75,742,973.54 | 28,725,350.11 | 2,363.5 | 84,116,118.45 | TOTALS |

* Includes projects reported completed (final vouchers not yet paid) totaling: Estimated cost $ 87,211,295.12 Federal aid $36,351,738.01 Miles 3,178.9