# PUBLIC ROADS

## A JOURNAL OF HIGHWAY RESEARCH

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS

VOL. 5, NO. 5 ▽ JULY, 1924


THE MOTOR TRUCK IS NOW THE MOST IMPORTANT AGENCY TRANSPORTING MILK FROM PRODUCER TO DISTRIBUTOR

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## U. S. DEPARTMENT OF AGRICULTURE
### BUREAU OF PUBLIC ROADS

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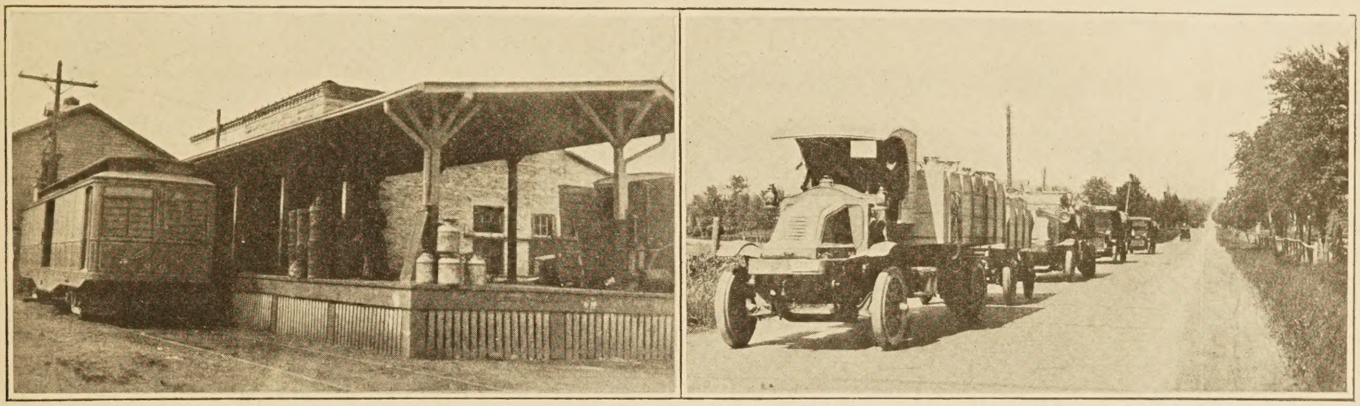
# TRANSPORTATION OF MILK BY MOTOR TRUCK

## RESULTS OF A SURVEY OF MILK TRANSPORTATION FOR EIGHT LARGE CITIES

BY HENRY R. TRUMBOWER, ECONOMIST, U. S. BUREAU OF PUBLIC ROADS [1]



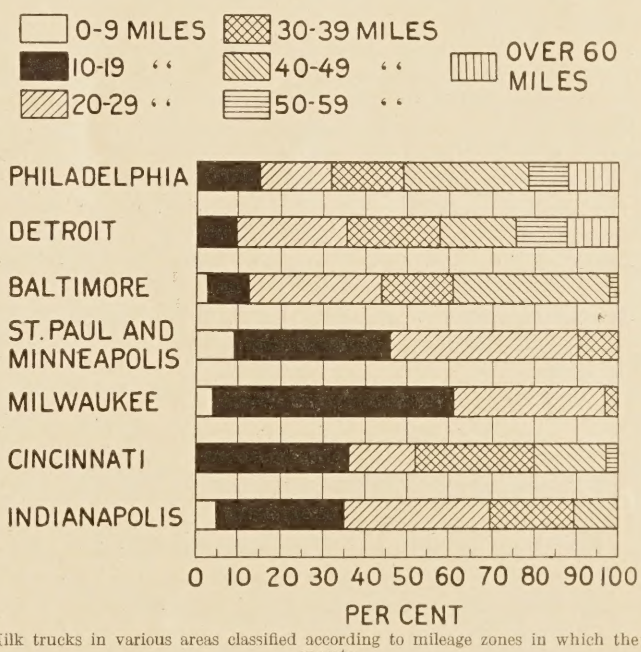
Delivery of milk by motor truck has greatly increased in volume in recent years. Direct movement from producer to city distributor is one of the principal advantages of this method of transportation

IN THE early days milk was transported but short distances from the farms where it was produced to the consumers living in towns and cities. The area in which a city's milk supply was produced, known as its milk shed, was naturally restricted as the horse and wagon was the customary means of bringing the milk into the city. Railroad shipments of milk did not begin until about 1838 when Boston began to be supplied by this new means of transportation.[2] These railroad shipments began in almost all cases by the carrying of a few cans of milk on the front platform of a baggage car.

The increase in the population of the larger cities was such that the farming territory from which the milk could be hauled by horse and wagon was no longer capable of furnishing all of the supply demanded by these large centers of population. Milk was still brought in over the country roads from near-by farms, but the larger portion of the supply came by rail from more distant production areas. After the advent of electric interurban railroads these were used in many cases to bring in milk which had formerly been hauled by the steam railroads or milk which had been taken to the city by wagon.

### HIGHWAY TRANSPORTATION NOW THE MOST IMPORTANT AGENCY FOR MILK DELIVERY TO LARGE CITIES

The use of the motor truck over improved highways has brought about a complete change in conditions. Except for the largest cities of the country the motor truck has now become the important agency in transporting milk from the producers to the city distributors and retailers. In order to determine to what extent the motor truck is used in bringing milk into the cities over the highways a survey and investigation of the transportation of milk by motor truck has been made covering this situation in a number of representative cities. The cities selected are Baltimore, Philadelphia, Cincinnati, Detroit, Milwaukee, St. Paul, Minneapolis, and Indianapolis. In all of these cities except Baltimore and Philadelphia, motor trucks transport approximately 90 per cent of all the milk received. Philadelphia, which is the largest of the cities surveyed, received only 20 per cent of its milk by motor truck. The proportion of Philadelphia's total supply which is shipped




Milk trucks in various areas classified according to mileage zones in which they operate

in by motor truck has been increasing in the last few years, but the percentage is low because the city, on account of its heavy demands, draws its supply from such a large area in which the shipping distances become too great for motor truck hauling. Milwaukee and Cincinnati obtain almost their whole milk supply by motor truck.

[1] The field work on which this report is based was performed by E. L. Browne, Agricultural Economist, U. S. Bureau of Public Roads.
[2] Parker, H. N., City Milk Supply, 1917.

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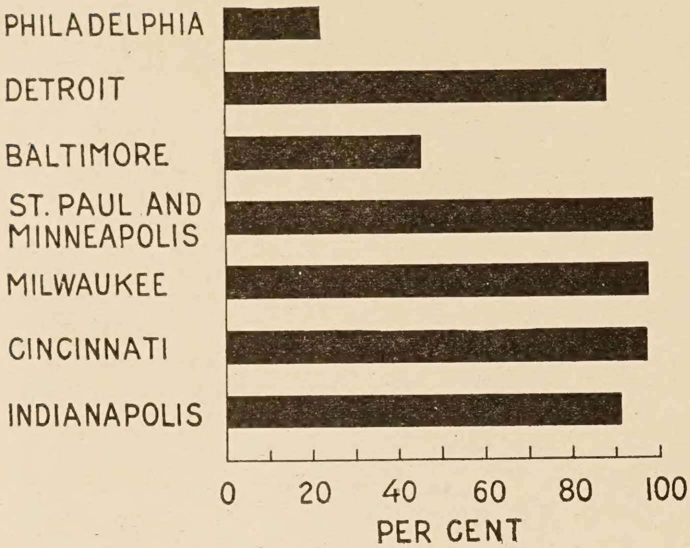



Percentage of total milk supply of eight cities delivered by motor truck

### SUMMARY OF PRACTICE IN MILK TRANSPORTATION

For the eight cities studied a total of 633 motor trucks were engaged in the transportation of milk; 65.6 per cent of these trucks operated within the 0–29 mile zone; 27.6 per cent in the 30–49 mile zone; and the rest, 6.8 per cent, traveled routes 50 miles and over in length. A large part of this movement is over comparatively short distances. In a number of cities the use of the motor truck has tended to draw in the boundaries of the city's milk shed and has stimulated the dairy industry in sections closer to the city because of the more convenient method of transportation.

The motor trucks engaged in this business are for the most part of the smaller capacity type; the 1 to 2 ton trucks constitute 57.1 per cent of the total number. The trucks over 4-ton capacity amount to only 7.3 per cent. Detroit is the only city which shows a very large development in the use of the tank truck. This type of equipment is used only in connection with the transportation of milk from receiving or collecting plants in the country to the city dairies and is usually operated over fairly long routes. It is not adapted for use in connection with pick-up movements.

There is a lack of uniformity in the rates charged by the motor trucks for this service. In each city there are independent truck operators charging different rates for hauling the same distance. When a rate comparison is attempted for the several cities even greater differentials are noted. In individual cases truck operators will charge higher rates where the whole route or a part of it is over poor or unimproved roads. This differential in most cases ranges between 5 and 6 cents per 100 pounds. For distances from 30 to 39 miles the motor truck rate ranges from 35 cents to 40 cents per 100 pounds, or the equivalent of about 20 cents per ton-mile. For shorter distances the rate is higher. It is the uniform practice for the rate charged to include the return movement of empty cans. In very few cases has any attempt been made by motor truck operators to develop return loads of merchandise and other commodities destined for points in the country.

The operation of the motor trucks engaged in this traffic is almost wholly in the hands of individuals owning one or two trucks who live in rural sections where the milk is produced. Very few of the city dairy companies and city retailers have taken up the task of transporting milk from the country to the city. Only in cases where they operate receiving stations do they perform any of this hauling themselves or engage motor-truck transportation concerns to do it for them by contract.

Where railroad rates were compared with motor-truck rates it was usually found that the motor-truck rates were the same as the railroad rates or somewhat higher. Even though the truck rates are higher the tendency is to ship by motor trucks where the distances are not too great for trucks to operate. Use of the motor truck in shipping milk eliminates the city terminal transportation costs which have to be met where shipments are made by railroad. The milk producer is also saved the cost and time which is involved where he is required to take his milk to the rural railroad stations if he can ship directly from his farm by motor truck.

Cooperative transportation organizations have not been developed to any great extent in the areas surrounding cities studied in this investigation. The only motor trucks operated by farmers upon a cooperative basis were found in the Baltimore area where several organizations of this kind have entered this field and made a success of it.

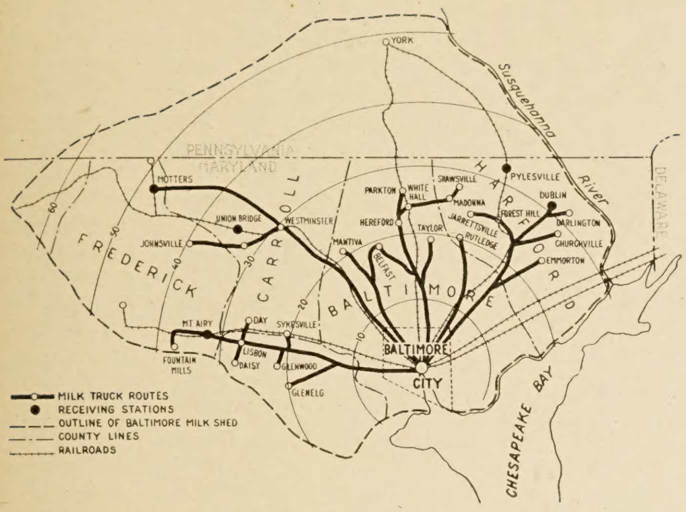
### TRUCK TRANSPORTATION IN BALTIMORE AREA HAS INCREASED STEADILY SINCE 1915

In 1915, according to the records of the health department, Baltimore received approximately 25 per cent of its milk supply by wagons and motor trucks operating over the highways from producing centers close by, and 75 per cent was received over the lines of several railroads. Prior to that time trucks had not entered the field. The amount of milk brought into Baltimore by these several means of transportation for the period 1912–1923 is shown in the following tabulation:

*Milk transportation into Baltimore by railroad, wagon, and motor truck for the years 1912–1923*

| Year | Railroad | | Wagon | | Motor truck | | Total for year |
|---|---|---|---|---|---|---|---|
| | Amount for year | Per cent of total | Amount for year | Per cent of total | Amount for year | Per cent of total | |
| | *Gallons* | | *Gallons* | | *Gallons* | | *Gallons* |
| 1912 | 8,862,868 | 80 | 2,190,000 | 20 | | | 11,052,838 |
| 1913 | 9,345,860 | 81 | 2,190,000 | 19 | | | 11,535,860 |
| 1914 | 9,723,718 | 84 | 1,825,000 | 16 | | | 11,548,718 |
| 1915 | 9,525,707 | 76 | 2,190,000 | 17 | 751,990 | 7 | 12,467,697 |
| 1916 | 9,305,778 | 73 | 1,825,000 | 14 | 1,649,225 | 13 | 12,780,003 |
| 1917 | 8,990,850 | 72 | 1,825,000 | 14 | 1,748,847 | 14 | 12,564,697 |
| 1918 | 10,146,237 | 73 | 1,825,000 | 14 | 1,747,370 | 13 | 13,718,607 |
| 1919 | 10,866,692 | 70 | 1,825,000 | 12 | 2,798,540 | 18 | 15,490,232 |
| 1920 | 12,002,655 | 65 | 1,825,000 | 10 | 4,507,612 | 25 | 18,335,267 |
| 1921 | 12,219,462 | 68 | | | 5,573,325 | 32 | 17,792,787 |
| 1922 | 12,055,906 | 64 | | | 6,736,675 | 36 | 18,792,581 |
| 1923 | 10,940,107 | 55 | | | 8,944,285 | 45 | 19,884,392 |

The amount of milk brought in by wagon was of necessity estimated; but the motor-truck and railroad shipments appear to be accurately reported. The amount of milk shipped by railroad increased steadily until a maximum was reached in 1921; since then there has been a noticeable decline. Consumption of milk in the city has increased each year, reaching a total of 19,884,392 gallons in 1923. Of this amount 45 per cent was transported by motor truck from near-by producing points and 55 per cent was shipped by railroad. Since 1920 the milk brought in by wagon has




Map of Baltimore milk shed showing routes and mileage zones.

become a negligible quantity. In 1923 practically the same amount was shipped by railroad as in 1919 yet the consumption had increased by more than 4,000,000 gallons. The burden of supplying the increased consumption has been taken up by the motor truck. The tendency is for the motor truck to bring in a larger and larger percentage of the city's total milk supply.

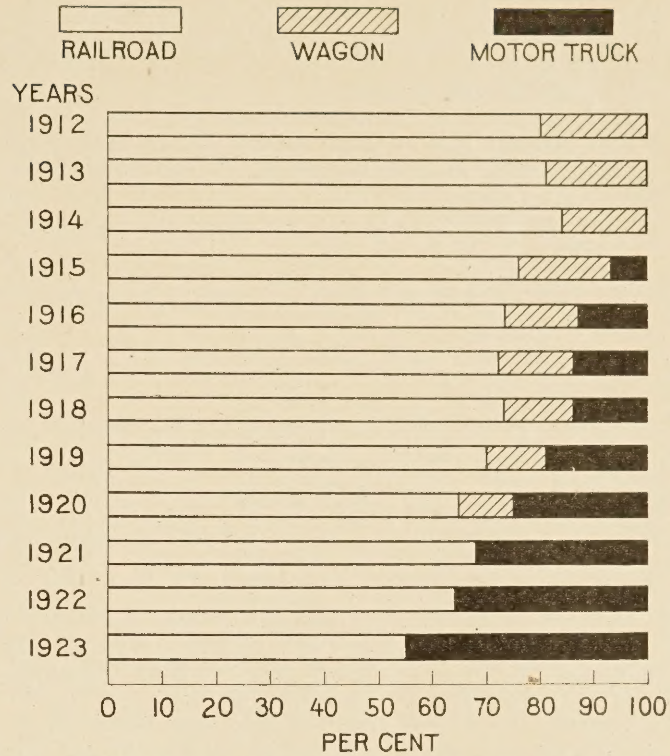
### ZONES OF OPERATION AND KINDS OF TRUCKS USED

At the close of 1923 there were 41 motor trucks engaged in the transportation of milk which brought in an average total of 23,720 gallons of milk a day. The distances over which these trucks operated ranged from 6 miles to 53 miles. In the following table are shown the number of trucks and also the mileage zones.

| Zone | Number of trucks | Per cent | Zone | Number of trucks | Per cent |
|---|---|---|---|---|---|
| *Miles* | | | *Miles* | | |
| 0–9 | 1 | 2.4 | 40–49 | 15 | 36.6 |
| 10–19 | 4 | 9.8 | 50–59 | 1 | 2.4 |
| 20–29 | 13 | 31.7 | | | |
| 30–39 | 7 | 17.1 | Total | 41 | 100.0 |

It is noteworthy that only five trucks, or about 12 per cent, come from points less than 20 miles away. Approximately 85 per cent of the trucks come from points 20 to 49 miles distant; only one truck has its point of origin over 50 miles distant. A study of the character of the agricultural land tributary to the Baltimore market indicates that the farm lands beyond the 20-mile zone lend themselves more readily to the dairy industry and the production of milk. This seems to account, at least partially, for the concentration of the industry in these more or less distant zones.

The motor trucks engaged in this kind of transportation are of varying capacities, ranging from 1 ton to 5 tons. There are one or two trucks of three-fourth-ton capacity used as feeder trucks in bringing milk in from side roads to the main highways where the milk is picked up by the larger trucks which run all the way into the city. A complete classification of trucks as to their capacities is shown in the following table.

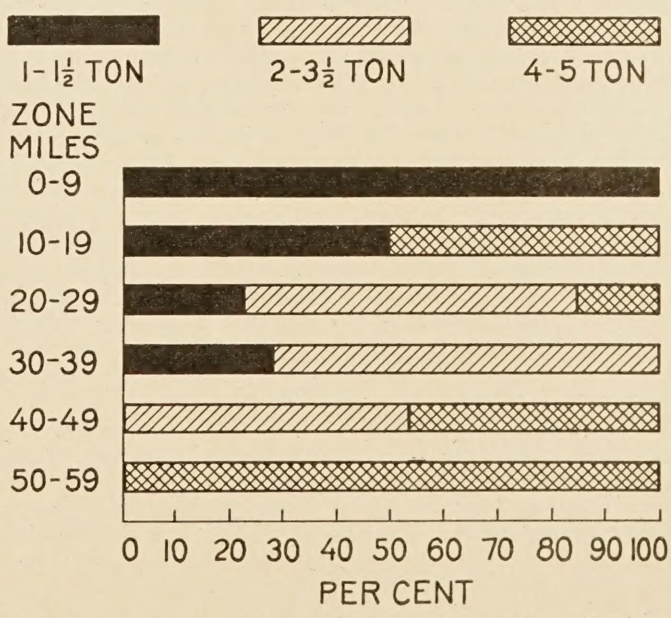



Percentage of milk transported into Baltimore by railroad, wagon, and motor truck, 1912–1923

*Classification by capacity of trucks operating in Baltimore area*

| Capacity | Number | Per cent | Capacity | Number | Per cent |
|---|---|---|---|---|---|
| *Tons* | | | *Tons* | | |
| 1 | 3 | 7.3 | 3½ | 1 | 2.4 |
| 1½ | 5 | 12.2 | 4 | 4 | 9.8 |
| 2 | 5 | 12.2 | 5 | 8 | 19.6 |
| 2½ | 3 | 7.3 | | | |
| 3 | 12 | 29.2 | Total | 41 | 100.0 |

The largest number of trucks of any one capacity is found in the 3-ton class; 12 trucks compose this class or 29.2 per cent of the total number. Approximately




Percentage of motor trucks of different capacities in various mileage zones, Baltimore area two-thirds of all the trucks are of 3-ton capacity and less. Heavy trucks of 4 and 5 ton capacity are not used as extensively in this type of hauling as trucks of lighter weight and capacity.

It is of interest to ascertain to what extent the trucks of large and of small capacities are used in the several mileage zones. In making this comparison the trucks are grouped into three classes; trucks from 1 to $1\frac{1}{2}$ ton capacity, 2 to $3\frac{1}{2}$ ton capacity, and 4 to 5 ton capacity.

*Motor trucks of different capacities in various mileage zones—Baltimore*

| Mileage zone | 1 to 1½ ton | | 2 to 3½ ton | | 4 to 5 ton | |
|---|---|---|---|---|---|---|
| | Number | Per cent | Number | Per cent | Number | Per cent |
| 0–9 | 1 | 100 | | | | |
| 10–19 | 2 | 50 | | | 2 | 50 |
| 20–29 | 3 | 23.1 | 8 | 61.6 | 2 | 15.3 |
| 30–39 | 2 | 28.6 | 5 | 71.4 | | |
| 40–49 | | | 8 | 53.3 | 7 | 46.7 |
| 50–59 | | | | | 1 | 100.0 |

It is the tendency to use trucks of large capacity for the longer hauls. Of the trucks of 4 to 5 ton capacity, eight are used in the zones of 40 miles and over, while only four are used in the zones up to 30 miles. The trucks of 2 to $3\frac{1}{2}$ ton capacity, of which there are the largest number, operate in the 20–50 mile zone. The trucks of smaller capacity are used only within the 40-mile zone. The trucks of larger capacity can ordinarily be operated over a greater distance more economically because there are certain items of expense, chief of which is labor, which are approximately the same regardless of the distance and the capacity of the truck.

## COVERED TRUCKS USED TO MEET HEALTH DEPARTMENT RULES

Of the 41 trucks operating in the Baltimore area, 39 are equipped with solid tires; one truck is fully equipped with pneumatic tires and one has pneumatic tires on the front wheels. The types of bodies used on the milk trucks have largely changed from the open stake body to the van or enclosed type, principally on account of the requirements of the city health department. The rules of the health department provide that the milk cans shall not be exposed to the sun or dust in transit or while the milk is standing on the platforms awaiting the arrival of the truck. While a complete covering of the cans in transit with a heavy canvas meets the requirements, nevertheless a majority of the trucks are of the inclosed type. Out of the 41 motor trucks engaged in this kind of hauling, 30 are of the van type, 8 have open bodies, and 3 are tank trucks. The fact that a considerable number of the trucks engaged in the transportation of milk are also used in the return load movement is another reason for the preponderance of the van type of truck. Where various kinds of merchandise make up the return load, a truck with an inclosed body has advantages over a truck with an open or a stake body.

The health department's order also requires covered loading platforms in the country where the trucks receive the milk from the farmers. These platforms are built at convenient intervals along the highway covered by the truck routes. Where it is possible one platform is built to accommodate several producers, thereby eliminating the too-frequent stopping of the truck. Trucks were at first loaded from the rear by backing up to the loading platforms and dropping down the end gate. This method was satisfactory where there was sufficient space to back the truck around, but difficulties were encountered on narrow highways. Recently the idea of a side gate or a side door in the truck body has been developed and is rapidly gaining favor with motor-truck operators because of the greater ease and saving of time in loading, and also because of the greater ease in unloading in the narrow streets and alleys adjoining the city milk plants. The use of side gates also facilitates the handling of the empty cans in connection with a return load of merchandise; the empty cans can be distributed more easily along the route without disturbing or rearranging the return load of freight. The empty cans are piled on their sides the full height of the truck at one end of the body, leaving the maximum amount of room for freight. Some of the trucks have the side gates on the right side only; others have them on both sides. Icing of milk hauled by motor trucks in the summer months has never been practiced to any great extent, although a $1\frac{1}{2}$-ton truck iced during the entire summer of 1923 brought very gratifying results. The bacteria count was greatly reduced and practically no sour milk had to be returned.

At the present time only three tank trucks are operated regularly in the Baltimore territory. These are used by two large city dairies in hauling milk from several of their receiving stations in the country to their city plants. Glass-lined tanks of 1,000-gallon capacity are mounted on 3-ton and 5-ton chasses. The use of this class of equipment is limited to the transporting of milk from country receiving stations to city plants. In the Baltimore area most of the milk shipped by motor truck is sent directly from the producer to the city distributor, which accounts for the fact that the tank truck is not used to a greater extent.

## FOUR CLASSES OF OPERATORS ENGAGED IN MILK TRANSPORTATION.

The owners and operators of trucks engaged in the transportation of milk can be divided into four classes. First, those individuals and companies which operate their trucks as common carriers under permits secured from the public service commission; second, milk producers organized as cooperative associations for the purpose of transporting and marketing their milk; third, individuals who buy milk from producers and transport it and sell it to city dealers; fourth, retail dealers and dairies who collect milk directly or through receiving stations from producers and distribute it through their own organizations. This classification is shown in the following table both as to the number of owners and operators comprising each group and the number of trucks in operation.

*Number of operators in each class of ownership and number of trucks operated in each class, Baltimore area*

| Group | Operators | | Trucks | |
|---|---|---|---|---|
| | *Number* | *Per cent* | *Number* | *Per cent* |
| Public service | 11 | 48.0 | 20 | 48.7 |
| Cooperative | 7 | 30.5 | 13 | 31.8 |
| Individuals | 1 | 4.2 | 3 | 7.3 |
| Dairies | 4 | 17.3 | 5 | 12.2 |
| Total | 23 | 100.0 | 41 | 100.0 |

That 23 operators own the 41 trucks which are engaged in this kind of business shows that there is little, if any, concentration of ownership. The largest number of trucks operated by one concern is five, which are all listed as common-carrier trucks. Approximately half of the trucks are operated under permits issued by the public service commission, which restricts them to definite routes and schedules and makes the owners file their rates and charges, which are subject to public regulation. There are seven cooperative organizations operating 13 milk trucks. Under the laws of the State these trucks have been exempt from the provisions of the public service regulation statute, but recently this has been amended so that even cooperative associations will have to obtain permits and will have to pay the license fees which are exacted from these types of carriers. Only four dairies are engaged in hauling or bringing in milk which they use in their plants. It is rather significant that the retail dealers take little part in the business of transporting milk to their plants. This is largely accounted for by the fact that the movement of milk from receiving stations is limited in quantity.

A number of cooperative associations have been in existence for some time. One of them dates back to 1917, when it was organized for the purpose of hauling milk by motor truck to Baltimore. The rates charged the stockholders are usually the same that commercial-truck operators charge for similar service. Some of the associations, which were organized with sufficient capital, are able to pay dividends to their stockholders in addition to setting aside sufficient funds to replace worn out and retired equipment. Other associations were organized with small amounts of capital and secured the money for the purchase of the original equipment largely through loans. These associations use the balance of their earnings over and above operating expenses to pay off their indebtedness and to add to their equipment. There is one cooperative association which now possesses rolling stock valued at about $20,000, most of which was purchased with surplus earnings.

### COMPARISON OF MOTOR-TRUCK AND RAILROAD RATES IN BALTIMORE AREA

The rates charged for transporting milk conform fairly closely to the rates charged by the railroads. As a matter of fact the rail rates were the basis for making charges for truck hauling when the motor truck first entered this business. No case was found where the truck rate was less than the railroad rate, a great many cases were found where the railroad rate and the truck rate were the same for like distances, and in some instances it was found that the truck rates exceeded the rail rates. The railroad rates are proportional to the length of the haul to a greater degree than the truck rates. The railroad tariffs frequently name a different rate for each shipping point along a certain line, while the truck rates are largely of the "blanket" type. The blanket rate is also frequently found in railroad rates as is seen in the table below in which comparisons of railroad and motor-truck rates are made for like mileage zones. The railroad rates are taken from the milk tariffs of the Western Maryland Railroad which carries approximately 57 per cent of the railroad shipments and 29 per cent of the total milk shipments into Baltimore. This railroad serves the territory lying to the north and northwest of Baltimore. The truck rates are typical rates from points in the several mileage zones in that same general territory.

According to the table the railroad rate is "blanketed" from 20 to 50 miles at 3 cents. In this zone the truck rates vary from 3 cents to 4.5 cents per gallon. In the 15–19 mile zone the railroad rate is 2.5 cents, whereas the truck rate is 3 to 3.5 cents. In this zone the trucks are serving milk shippers who are not closely situated to railroads and are not readily served by them.

*Comparative railroad and motor-truck rates for like mileage zones, Baltimore area*

| Railroad shipping point | Truck shipping point | Distance to Baltimore | Rate per gallon: Railroad | Rate per gallon: Truck |
|---|---|---|---|---|
| | | *Miles* | *Cents* | *Cents* |
| Glyndon | | 15–19 | 2.5 | |
| | Hypsie's Store | | | 3.0 |
| | Taylor | | | [1] 3.0–3.5 |
| | Marble Hill | | | 3.0 |
| Falls | | 20–24 | 3.0 | |
| | Hereford | | | 3.0 |
| | Sykesville | | | 3.0 |
| | Belfast | | | 3.0 |
| | Rutledge | | | 3.5 |
| | Lutherville | | | 4.0 |
| | Tracey's Shop | | | 4.0 |
| Patapsco | | 25–29 | 3.0 | |
| | Lisbon | | | 3.0 |
| | Eldersburg | | | 3.0 |
| | Parkton | | | 4.0 |
| Westminster | | 30–34 | 3.0 | |
| | Westminster | | | 3.0 |
| | Glenwood | | | 3.0 |
| | Emmorton | | | 3.0 |
| | Mount Airy | | | 3.0 |
| | Day | | | 3.0 |
| | Forest Hill | | | 4.0 |
| Wakefield | | 35–39 | 3.0 | |
| | Churchville | | | 3.0 |
| New Windsor | | 40–44 | 3.0 | |
| | Belfast Church | | | 3.0 |
| | Darlington | | | 3.5 |
| | Fountain Mills | | | 4.0 |
| | Shawsville | | | 4.0 |
| Union Bridge | | 45–49 | 3.0 | |
| | Johnsville | | | [1] 4.0–4.5 |

[1] Oct. 1 to Mar. 31.

While certain truck rates shown in the table appear to be out of line with other truck rates in the same zone, an investigation has revealed that some of these truck routes follow rather poor roads which are at times difficult to travel, thus accounting for the higher rates. In two instances the rates for the winter months are higher than the rates for the summer solely because of bad road conditions. This shows in a very substantial way the value of improved roads to the farmer. Practically a truck load of milk is collected along 5 miles of unimproved highway where for a six months' period 3.5 cents is charged for transporting milk and for the rest of the year only 3 cents. The farmers and milk producers are required to pay $5 a day additional transportation charges on 1,000 gallons of milk because of the inferior type of highway. This amounts to $900 for the six months' period. Based on this actual outlay, the farmers could afford to make road improvements to the extent of $3,600 a mile if no other traffic were benefited at all besides this one truck load of milk.

The milk tariffs of the Baltimore & Ohio Railroad are fixed according to distance to a much greater degree than the Western Maryland. The following is taken from its tariff:

*Baltimore & Ohio Railroad milk rates to Baltimore*

| From— | Distance | Rate per 10-gallon can |
|---|---|---|
| | *Miles* | *Cents* |
| Woodstock | 21.7 | 27.0 |
| Henryton | 25.2 | 28.0 |
| Gaither | 30.1 | 29.5 |
| Waterville | 36.6 | 30.0 |
| Bartholow | 43.1 | 31.0 |
| Monrovia | 46.7 | 32.5 |
| Ijamsville | 50.2 | 34.0 |

### ADVANTAGES OFFERED BY MOTOR-TRUCK TRANSPORTATION

In comparing motor-truck rates with railroad rates one must not lose sight of the fact that the motor-truck rates include pick-up service in many cases and in all cases delivery service at the city milk plant. When shipping by railroad farmers have to haul their milk varying distances from the farm to the station and the dairy or city milk dealer is obliged to haul the milk shipped by railroad from the city terminal to his manufacturing or distributing plant. The dealers in Baltimore estimate that it costs them from 0.5 cent to 1 cent per gallon for this terminal hauling which is entirely eliminated where the milk is brought directly to the plant from the points of production in the country. These costs naturally vary for different dealers, depending largely upon the distances they are removed from the railroad terminals. In Baltimore not one of the dairies is located directly on a railroad sidetrack, so that in each case trucking, either by horses or by motor truck, is necessary to get the milk from the railroad car or platform to the plant.

The saving in time and expense to producers who ship by motor truck is shown by the following sample data which were secured from questionnaires filled out by milk producers shipping by truck and milk producers shipping by railroad. Forty-eight replies from each class of shippers were tabulated. Of the 48 shippers by truck, 23, or approximately 50 per cent, were located on truck routes and did not have to do any hauling. The remaining 25 hauled their milk to convenient points on truck routes a total of 22.43 miles, or each one hauled his milk an average of 0.86 mile. If these same 48 shippers who shipped by motor truck had all taken their milk to the nearest railroad stations they would have had to haul a total distance of 117.25 miles. The actual saving to all of these shippers was 94.82 miles or an average of 1.98 miles for each shipper.

The 48 shippers who shipped their milk by railroad hauled it a total distance of 61.45 miles or an average of 1.28 miles each. The average hauling on the part of the 48 shippers who shipped by truck was 0.47 mile each. The average saving in hauling distance which the truck shippers enjoyed over the same number of railroad shippers was 0.81 mile each.

It should be noted that this analysis shows also that the milk producers who are most likely to ship by truck are those who are more distantly removed from their respective railroad stations. Shippers who made use of the motor truck were on an average 2.44 miles removed from the railroad, whereas those who shipped by railroad were on the average 1.28 miles distant. To those shippers who are the greatest distance from the railroads and who live on or near roads which are adapted to truck routes the motor trucks bring the greatest benefits. Through the use of motor trucks operating over improved highways the dairy industry is promoted and developed in regions which hitherto were too far removed from railroads to be developed practically as producing areas for fluid milk destined for the city market.

### PERSONAL SERVICE OF TRUCK OPERATORS A VALUABLE CONSIDERATION

One of the reasons given by milk producers for preferring to ship by motor truck rather than by railroad is the personal service which truck operators are able to give in looking after the interests of the shipper. It has been claimed that the percentage of cans lost in truck shipment is less than in railroad shipment on account of the direct daily return of cans. The 48 motor-truck shippers and 48 railroad shippers were asked for data with reference to these claims. The results of their answers are shown in the following tabulation:

*Number of cans used and lost by railroad shippers and by motor truck shippers*

| Shippers | Average number of cans shipped daily | Total number of cans used by shippers | Total number of cans lost during year | Per cent of cans lost |
|---|---|---|---|---|
| 48 truck shippers | 225 | 517 | 19 | 3.6 |
| 48 railroad shippers | 211 | 661 | 83 | 12.5 |

The railroad shipper must have a larger number of cans in use to ship approximately the same quantity of milk on account of the irregular return of empty milk cans by the railroad. A more significant fact is that the shipper by railroad suffers an annual loss of 12.5 per cent of his supply of cans, whereas the truck shipper loses only 3.6 per cent. The truck driver serves to a certain extent as the shipper's representative from the time the milk cans leave the farmer's gate or loading platform until the empty cans are returned later in the day. Responsibility is centered in one person for taking care of the shipper's property and the handling of the cans is limited to the one or more persons in charge of the truck. Shipments by railroad are handled more often and by a greater number of individuals who are employees of the railroad and the city dealers. Obviously the chances for losses are multiplied.

In order to give an idea of the time consumed in shipping milk by motor truck and the operations involved, there is presented below a day's log showing the operation of a representative motor truck engaged in the transportation of milk. The one-way distance covered is 27.5 miles. The truck after delivering its load of milk proceeded to a central freight depot for its return load.

*Detailed log of a milk truck*

| Time | Miles | Operation | Elapsed time |
|---|---|---|---|
| 6.30–7.30 m | 8.0 | Picking up milk | 1 hour. |
| 7.30–9.10 a. m | 17.0 | Run to city dairy | 1 hour, 40 minutes. |
| 9.10–9.22 a. m | | Unloading milk | 12 minutes. |
| 9.22–9.40 a. m | | Loading empty cans | 18 minutes. |
| 9.40–10 a. m | 2.5 | Run to freight depot | 20 minutes. |
| 10–11.30 a. m | | Central freight depot, idle | 1 hour, 30 minutes. |
| 11.30–12 a. m | | Loading freight | 30 minutes. |
| 12–12.30 p. m | | Driver and helper at lunch | 30 minutes. |
| 12.30–2.30 p. m | 19.5 | Return run to first shipper | 2 hours. |
| 2 30–3.30 p. m | 8.0 | Unloading cans and freight | 1 hour. |
| Total | 55.0 | | 9 hours. |

The truck for which these data were obtained was a 4-ton truck of the van or inclosed-body type and carried a load of 120 cans of milk containing 1,200 gallons. The truck was away from its terminal garage a total of nine hours; six hours, or 66 per cent of the total time, were consumed by actual truck movement in picking up the load of milk from farmers along the route and in making the run to the city dairy plant, to the freight depot, and back again to the point of departure. In picking up the milk 18 stops were made and that many shippers served. It should be observed that for only three hours, or 33 per cent of the operating time, the truck was not in motion and a part of this time was taken up in unloading the milk and getting back the empty cans and in obtaining a return load of freight.

The records of the dairy plants in Baltimore show that the motor trucks engaged in this business of transporting milk from the country to the city operate with a great degree of regularity. Snow removal on the Maryland highways is well taken care of, so that the main highways are seldom if ever closed on account of snow. Records are not available for all of the motor trucks as to regularity of operation. It was found, however, that for 24 trucks not a single trip had been missed in the years 1922 and 1923. This does not mean that each one of these individual trucks was operated daily. Emergency trucks may have been used at times, but no trip was missed on account of unfavorable weather conditions, and continuous and regular service was afforded to the shippers and to the public.

Flexibility of operating schedules is an advantage which motor-truck operators claim for their method of transportation. The time of departure in the morning is usually an hour later in the winter than in the summer months, which is a great convenience to the shippers. The earlier operation in the summer months makes it possible for the milk to be brought to the city before the heat of the day sets in.

### REVENUE AND OPERATING COSTS AT BALTIMORE

Little data can be found relative to the revenues and expenses of individual operators, a condition which prevails quite generally in all kinds of motor trucking. From one of the city dairies information was obtained for 21 trucks, covering the yearly receipts, miles operated, loads carried, and truck capacities. This is given in the following table:

*Revenues and operating data for 21 motor trucks, 1923*

| Truck capacity | Number of trucks | Average number gallons hauled per trip per truck | Average yearly mileage per truck | Average yearly revenues from milk per truck |
|---|---|---|---|---|
| | | *Gallons* | *Miles* | |
| 2 tons | 2 | 387 | 16, 425 | $5, 179 |
| 2½ tons | 6 | 450 | 25, 246 | 5, 946 |
| 3 tons | 5 | 620 | 23, 600 | 6, 716 |
| 3½ tons | 5 | 830 | 24, 820 | 8, 869 |
| 4 tons | 1 | 575 | 20, 075 | 6, 296 |
| 5 tons | 2 | 913 | 18, 980 | 9, 991 |
| Average | | 625 | 23, 070 | 7, 154 |

The average revenue received from the transportation of milk amounted to $7,154 per truck, or an average of 3.1 cents per gallon. The receipts of the 5-ton trucks were the largest, on account of the larger loads carried. In the case of the two 5-ton trucks the average yearly mileage per truck was less than in the case of most of the other trucks of smaller capacity. This furnishes the basis for computing the average receipts per ton-mile. The weight of the average load of 625 gallons, including cans, is 3.53 tons. The weight of the average load of returned cans is 0.6 tons. The number of ton-miles of both the milk and the empty cans is 47,639. In arriving at this figure it is assumed that the loads are carried for the whole distance, which is not exactly the case, inasmuch as the full load is not obtained at the very beginning of the trip. Without making any adjustment for this, we arrive at the average receipts per ton-mile of 15 cents.

For one of these trucks it was possible to obtain complete data covering operating expenses and revenues. This information is for a 5-ton, solid-tire truck operating on a milk route 22 miles one way over an improved highway. The total receipts were $10,014.40, consisting of $8,485 from the transportation of milk and $1,529.40 derived from return loads of freight and merchandise. The total operating expenses were $7,636.75, leaving $2,377.65 as the year's profit. It should be noted that fully 65 per cent of these profits were derived from return-load earnings. It appears therefore, highly desirable that this part of the business be developed to the fullest extent in order to have this type of transportation yield the maximum returns.

The year's operating expenses are fully segregated and analyzed in the following statement.

*Cost analysis of year's operation of a 5-ton motor truck*

| Item | | |
|---|---|---|
| 1. | Total investment (chassis, body, freight) | $5, 884. 00 |
| 2. | Tire cost, 36″ by 6″ and 40″ by 6″ solid | 304. 50 |
| 3. | Investment less tire cost (amount to be depreciated) | 5, 579. 50 |
| | OVERHEAD COSTS | |
| 4. | Interest on total investment per year (6 per cent on item 1) | $353. 04 |
| 5. | Taxes | 147. 10 |
| 6. | License | 1, 026. 48 |
| 7. | Insurance | 588. 40 |
| 8. | Garage | 240. 00 |
| 9. | Pay-roll costs | 2, 616. 00 |
| 10. | Total overhead | 4, 971. 02 |
| | RUNNING COSTS PER MILE | |
| 11. | Depreciation | $0. 0732 |
| 12. | Tires | . 0200 |
| 13. | Oil | . 0035 |
| 14. | Fuel | . 0400 |
| 15. | Repairs and maintenance | . 0302 |
| 16. | Total running cost | . 1669 |
| | PAY-ROLL COSTS | |
| 17. | Driver's wages per week | $27. 00 |
| 18. | Driver's overtime | |
| 19. | Helper's wages per week | 19. 00 |
| 20. | Supervision per week | 4. 3075 |
| 21. | Weekly pay roll | 50. 3075 |
| 22. | Yearly pay roll, item 24 by item 21 | 2, 616. 00 |
| 23. | Days operated per year | 363 |
| 24. | Weeks operated | 52 |
| 25. | Total overhead cost per day | $13. 70 |
| 26. | Miles operated per day | 44 |
| 27. | Miles operated per year | 15, 972 |
| 28. | Total overhead cost per mile | $0. 311 |
| 29. | Total overhead costs per mile | $0. 311 |
| 30. | Total running costs per mile | . 1669 |
| 31. | Total cost per mile | . 4779 |
| | TOTAL COSTS | |
| 32. | Total overhead costs | $4, 971. 02 |
| 33. | Total running costs, item 16 by item 27 | 2, 665. 73 |
| 34. | Total costs | 7, 636. 75 |

### DAILY OPERATION OF MILK TRUCKS FAVORABLE TO LOW COSTS

The milk trucks make a good showing when subjected to a cost analysis because of the daily operation throughout the year which tends to spread the fixed charges over a relatively large mileage. Next to the pay-roll costs the license fee in this case is the largest item of overhead costs amounting to $1,026.48. This particular truck is licensed as a common carrier and is obliged to pay fees which exceed the license fees which the ordinary truck has to pay.

According to the law in effect up to this time motor trucks operated as common carriers on designated routes and schedules are divided into three classes. Class X includes all those trucks weighing 3 tons and less including carrying capacity which are charged one-fifth cent per ton multiplied by the number of miles the truck is operated in a year over the public highways of the State. Class Y includes those trucks in the 3 to 6 ton class which are charged two-fifths cent per ton-mile. Class Z includes those trucks in the 7 to 10 ton class which are charged three-fifths cent per ton-mile. The truck covered by this cost analysis was in the Z class and paid a license fee of three-fifths cent per ton-mile. The same kind of truck operated not as a common carrier would have had to pay only $150 a year without any restrictions as to mileage or distance. This large differential in license fees tends to limit the number of motor trucks engaged in the transportation as common carriers and probably accounts for the rather large number of trucks cooperatively owned which are in this service because cooperatively owned trucks have been exempted from the provisions of the public service laws relating to motor trucking. The legislature in its last session amended the law so as to include cooperatively owned trucks in the definition of common-carrier trucks. This change will take effect next year. It should be noted in this connection that this truck, the operating costs of which have just been analyzed, paid over 10 per cent of its gross earnings in taxes and license fees.

Return loads collected at a central depot have proven profitable to truck operators in the Baltimore area. Such business has not been developed extensively in other sections

One of the cooperative associations published a report of its financial operations for the year which is summarized as follows:

| | |
|---|---|
| Revenue from milk transportation | $15, 032. 91 |
| Revenue from other freight | 6, 069. 70 |
| Total | 21, 102. 61 |
| Operating expenses, taxes, and depreciation | 18, 597. 37 |
| Net revenues | 2, 505. 24 |

This organization operated two trucks. Attention should again be called to the large revenues which were derived from freight hauled back into the country from the city. Had it not been for these earnings the association could not have shown any net revenues at the end of the year. The importance of obtaining return loads is recognized by most of the motor-truck operators. The revenue derived from the return load is regarded as just that much additional income which involves little or no additional costs.

In order to secure return loads a number of motor-truck concerns are maintaining jointly a central freight depot in the central part of the city's business section. Any freight or merchandise which is to be shipped to points and individuals along the different milk routes is concentrated at this depot. After the truck has unloaded its load of milk at the city dairy it swings around to the central depot to ascertain what freight is on hand for country points along its route.

### CENTRAL DEPOT SOLVES RETURN LOAD PROBLEM

The central-depot idea appears to be a great success according to all the truck operators who make use of it. It does away with the hit-and-miss system of collecting merchandise all over the city from many business and manufacturing concerns. Such concerns maintain a city-delivery system of their own and can just as conveniently make deliveries at the central depot where the merchandise in turn is picked up by the milk trucks which are about to proceed on their return journey.

The larger trucks are generally operated by two men; one acting as the driver and the other as the helper. In the following table is shown the number of trucks operated by one man and by two according to truck capacity:

*Number of men employed in operating trucks of various capacities*

| Truck capacity | Number of trucks employing 1 man | Number of trucks employing 2 men | Total number of men employed | Truck capacity | Number of trucks employing 1 man | Number of trucks employing 2 men | Total number of men employed |
|---|---|---|---|---|---|---|---|
| *Tons* | | | | *Tons* | | | |
| 1 | 3 | | 3 | 3½ | | 1 | 2 |
| 1½ | 5 | | 5 | 4 | | 4 | 8 |
| 2 | 5 | | 5 | 5 | 2 | 6 | 14 |
| 2½ | 2 | 1 | 4 | | | | |
| 3 | 2 | 10 | 22 | Total | 19 | 22 | 63 |

On the 3-ton trucks and trucks of larger capacities it is the practice to employ two men. In the above tabulation there are two 5-ton trucks in operation with only one man. Both of these are tank trucks which do not need the extra man.

The average hauling rate of approximately 3 cents per gallon is in the last analysis only a small part of what the city consumer pays for his milk. In December, 1923, the retail price of milk in Baltimore was 14 cents per quart, or 56 cents per gallon, delivered to his house in bottles. Of this amount the producer received 28 cents, the producer's association 1 cent as a brokerage charge, the city dealer 24 cents and the motor-truck operator 3 cents. The dealer's margin consists of 42.8 per cent of the retail price, the milk-truck operator receives 5.4 per cent, the producer's association 1.8 per cent and the farmer who produces the milk 50 per cent of what the consumer pays for his milk.

#### MILK SUPPLY TRANSPORTED BY MOTOR TRUCK INCREASING ANNUALLY IN PHILADELPHIA

Although the largest part of the milk received in Philadelphia is shipped by railroad the amount which is brought in by motor truck has shown a considerable increase in the last few years. Up to 1921 steam railroads and the electric railroads carried approximately 95 per cent of the city's total milk supply. In 1921 the amount brought in by motor truck showed substantial gains. The 1923 records show that a little over 20 per cent of the city's milk supply was received by motor truck. The detailed shipments are given in the following table:

*Amount of milk shipped by rail and motor truck, Philadelphia area*

| | 1921 | | 1922 | | 1923 | |
|---|---|---|---|---|---|---|
| | Amount | Per cent | Amount | Per cent | Amount | Per cent |
| | *Gallons* | | *Gallons* | | *Gallons* | |
| Steam railroad | 53, 159, 943 | 88. 2 | 53, 856, 060 | 84. 0 | 55, 273, 056 | 78. 5 |
| Electric railroad | 1, 382, 517 | 2. 2 | 1, 190, 911 | 1. 9 | 922, 501 | 1. 3 |
| Motor truck | 5, 778, 285 | 9. 6 | 9, 015, 026 | 14. 1 | 14, 162, 289 | 20. 2 |
| Total | 60, 320, 745 | 100. 0 | 64, 061, 997 | 100. 0 | 70, 357, 846 | 100. 0 |

During this period there was a substantial increase in the amount of milk received. The motor truck took care of the greatest part of this increased supply although the steam railroads showed an increase in the amount which they handled. On the other hand the amount shipped over the electric interurban lines showed a falling off. In 1923 the motor trucks transported into the city slightly over 20 per cent of the total supply whereas less than 10 per cent was brought in by that means in 1921. The steam railroads' share of this traffic was 78.5 per cent in 1923 compared with 88.2 per cent in 1921. The investigation showed that the motor trucks took care of that part of the city's milk supply which was taken away from the electric interurban lines. The large volume of milk consumed in Philadelphia requires a milk shed extensive in area. A part of this area is so distant from the city that motor trucks can not successfully compete with the railroads for the business. Shipments are made by producers in New York, Pennsylvania, Maryland, Delaware, and New Jersey. The same situation prevails here as in other large cities such as New York and Boston. Although large quantities of milk are produced within a radius of 50 or 60 miles, all of this production does not find its way to the Philadelphia market because a large number of cities and populous communities derive their supplies of milk from the same territory.

#### LARGE-CAPACITY TRUCKS NUMEROUS

The number of motor trucks delivering milk in the city of Philadelphia and the distances over which they operate are given in the following table:

*Number of trucks operating in various mileage zones, Philadelphia area*

| Mileage zones | Number of trucks | Per cent | Mileage zones | Number of trucks | Per cent |
|---|---|---|---|---|---|
| 0- 9 | 0 | 0 | 60–69 | 3 | 6 |
| 10–19 | 7 | 15 | 70–79 | 2 | 4 |
| 20–29 | 8 | 17 | 80–89 | 1 | 2 |
| 30–39 | 8 | 17 | | 47 | 100 |
| 40–49 | 14 | 30 | | | |
| 50–59 | 4 | 9 | | | |

It is to be noted that of 47 trucks engaged in this business over 50 per cent operate over routes 40 miles and over in length. Thirty per cent of the trucks operate in the 40–49 mile zone. A truck starting at Churchville, Md., 81 miles distant, travels the greatest distance. This truck, at the time the survey was made, had been operating only a short time. It leaves Churchville at 9 a. m. and picks up its load of milk and arrives at the city dairy at about 4.30 p. m. and does not get back to its point of origin until about midnight. It is not believed that this operation can continue any length of time; at least, difficulties will be encountered in the summer months when heavy icing will be required. The long hours may also make two sets of drivers necessary. The two trucks which operate in the 70–79 mile zone leave the city in the morning and go out to receiving stations for their loads, and get back late in the afternoon.

The capacity of the motor trucks engaged in these operations is shown in the table below.

*Classification of trucks by capacity, Philadelphia area*

| Capacity in tons | Number | Per cent | Capacity in tons | Number | Per cent |
|---|---|---|---|---|---|
| 2 | 2 | 4 | 5 | 29 | 62 |
| 3 | 11 | 23 | 7½ | 1 | 2 |
| 3½ | 4 | 9 | | 47 | 100 |

Trucks of small capacity are lacking. Only two trucks of the 2-ton type are found. The 5-ton truck predominates, 62 per cent of the total number belonging to this class. In the following table it is shown that the trucks of larger capacity operate in the longer mileage zones:

*Number and capacity of trucks operating in various mileage zones, Philadelphia area*

| Mileage zone | 2-ton | 3-ton | 3½-ton | 5-ton | 7½-ton | Total |
|---|---|---|---|---|---|---|
| 0- 9 | | | | | | |
| 10–19 | 2 | 1 | | 4 | | 7 |
| 20–29 | | 2 | 4 | 2 | | 8 |
| 30–39 | | 3 | | 5 | | 8 |
| 40–49 | | 4 | | 10 | | 14 |
| 50–59 | | | | 3 | 1 | 4 |
| 60–69 | | | | 3 | | 3 |
| 70–79 | | | | 2 | | 2 |
| 80–89 | | 1 | | | | 1 |
| Total | 2 | 11 | 4 | 29 | 1 | 47 |

#### RECEIVING STATIONS MAKE LARGE TRUCKS PRACTICABLE

The trucks of 3½-ton capacity and less do not operate over routes more than 50 miles in length. Over half of the 5-ton trucks operate from points more than 40 miles distant. The fact that a large part of the milk transported by motor truck into Philadelphia is milk which is collected at receiving stations and then hauled by truck directly to the city plants accounts partially for the larger trucks used and also for the greater distances. These receiving stations are operated by the dairies. To them the farmers bring their milk by motor truck or by wagon just as they haul it to the railroad stations or creameries. There are, however, a few receiving stations operated by dairy companies which collect the milk from the producers. The milk collected at these receiving stations comes from within a radius of 10 miles of the station. In the Philadelphia milk shed 15 receiving stations and 3 bottling stations are operated, from which the milk is transported by motor truck to the city distributing plants.

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Out of the 47 trucks delivering milk to the city 26 haul directly from receiving stations and bottling plants and 21 pick up their loads from the producers. The average amount of milk transported from the receiving stations is 25,140 gallons per day. This is an average load of 967 gallons per truck. The 21 trucks engaged in hauling milk directly from the producer to the city plants transport 13,580 gallons per day or an average load of 647 gallons per truck. The milk transported from the receiving stations is all hauled by trucking concerns which have contracts with the dairies or by the dairy companies themselves. The large number of trucks of large capacity in this territory is to a great extent explained by the fact that such a large portion of the milk is transported from these receiving stations where full loads are available and where the carrying of large loads appears to be the most economical way of doing it.

### CLASSIFICATION OF MILK TRUCKS ACCORDING TO OWNERSHIP

In the Philadelphia territory no cooperative associations are found engaged in hauling milk for groups of producers, nor was any development of the return load found. Those engaged in the transportation of milk by motor truck may be divided into three classes: First, the dairy companies which own their trucks and use them in hauling milk from the country receiving stations which they operate to their city plants; second, individuals or companies which enter into contracts to haul milk from the receiving stations to to the city plants (only one of these hauling contractors does any pick-up business); third, individuals who operate trucks from the country to the city plants and pick up the milk from producers who live along the routes over which they operate. The individual haulers all live and have their points of origin in the country. The hauling contractors and dairies go out into the country and bring in their supply of milk. In the following table is shown the number of those engaged in hauling milk divided into the above-mentioned classes and also the number and capacity of trucks operated by them.

*Classification by capacity of truck operated by different classes of owners*

| Class | Number of trucks operated | | | | | |
|---|---|---|---|---|---|---|
| | 2-ton | 3-ton | 3½-ton | 5-ton | 7½-ton | Total |
| Dairy companies | | | 4 | 7 | | 11 |
| Hauling contractors | | | | 19 | 1 | 20 |
| Individuals | 2 | 11 | | 3 | | 16 |
| | 2 | 11 | 4 | 29 | 1 | 47 |

The dairy companies operated 11 trucks, or 23 per cent of the total number; the hauling contractors operated 20 trucks, or 43 per cent; and the individuals operated 16 trucks, or 34 per cent. It is significant that the trucks operated by the contractors are all 5-ton trucks with the exception of one which is of 7½-ton capacity.

### IMPROVED ROADS MADE POSSIBLE A CONSIDERABLE SAVING IN MILK TRANSPORTATION

One of the largest dairies in Philadelphia, which has an average daily run of 22,000 gallons, receives all but 300 gallons by motor truck. Up to four years ago all this milk was shipped in by railroad. The superintendent of this plant stated that in 1920 when they first began to haul milk by motor truck the roads were in very bad shape, which tended to hinder this kind of operation. Since the roads have been improved more trucks have been added, so that almost all the shipments are by motor truck. This dairy now owns 12 glass-lined tanks which it furnishes to hauling contractors who mount them upon chasses owned by them. The dairy agrees to keep the tanks painted, but the truckman takes all responsibility in the operation of the truck. The dairy pays the contractor a flat rate of 30 cents per 100 pounds or approximately 2.6 cents per gallon for the transportation of milk in these tank trucks operated from the various receiving stations. The nearest one is 47 miles and the most distant one is 60 miles away. The dairy estimated that the savings resulting from this method of transportation compared with rail shipments from the same points and the hauling from city railroad terminal to the dairy amounted to 5 cents per 100 pounds. On a daily run of 22,000 gallons this means a daily saving of slightly over $90.

The average rate paid to individuals operating milk trucks from the country and to contractors for transporting milk in 10-gallon cans is approximately 35 cents per 100 pounds. This rate covers distances from 15 to 60 miles. A 35 cents per 100 pounds rate is about the same as a rate of 3 cents per gallon. The one truck which operates in the 80–89-mile zone receives 6 cents per gallon.

Delivering milk to a receiving station where it is cooled and run into a tank truck for transportation to the city

### ALMOST ENTIRE CINCINNATI SUPPLY NOW DELIVERED BY MOTOR TRUCK

The year 1914 marked the beginning of the transportation of milk by motor truck to the Cincinnati market. By 1918 nearly 50 per cent of the daily shipments were by motor truck and the wagon shipments had practically ceased. The rest of the supply came in by railroad. In 1923 the year's shipments by motor truck were 12,430,000 gallons out of a total of 12,868,000 gallons received, or 97 per cent. In spite of the adverse road conditions and a decidedly hilly territory surrounding the city the motor truck shipments of milk increased in this 10-year period. Between the years 1915 and 1921 there was an increase of 36 per cent in the city's consumption of milk. It was mainly through the opening up of new producing territory through the use of the truck that the Cincinnati dealers and distributors were able to take care of the rapidly increasing consumption.

At the present time there is no "pick-up" milk brought in by the railroads; the only milk shipped by railroad is that brought from a receiving station at

Pierceville, Ind., a haul of 45 miles. It is predicted that the end of 1924 will see a complete motorization of Cincinnati's milk delivery when a new road will be completed leading from Pierceville to the Ohio State line joining a hard-surfaced road which will make it possible to ship the milk accumulated at the Pierceville station by truck to its destination. The extent to which Cincinnati receives its supply of milk by motor truck is significant when one takes into consideration the fact that there are four railroad lines running south from Cincinnati into Kentucky and nine steam railroad lines and seven traction lines radiating to the north, east, and west into Ohio and Indiana. The milk supply comes from approximately 3,200 producers; 60 per cent originates in Ohio, 30 per cent in Kentucky, and 10 per cent in Indiana. The area circumscribed by a radius of 30 miles supplies 80 per cent of the total amount of milk consumed and the remaining 20 per cent comes from the 30 to 60 mile zone.

#### LIGHT TRUCKS AND SHORT ROUTES NUMEROUS IN CINCINNATI AREA

The number of trucks operating in this area and the mileage zones in which they operate are shown in the following table.

*Number and per cent of trucks in the various mileage zones, Cincinnati area*

| Mileage zone | Number of trucks | Per cent | Mileage zone | Number of trucks | Per cent |
|---|---|---|---|---|---|
| 0–9 | 0 | 0 | 40–49 | 15 | 17 |
| 10–19 | 32 | 36 | 50–59 | 3 | 3 |
| 20–29 | 15 | 16 | | | |
| 30–39 | 25 | 28 | | 90 | 100 |

The fact that over a third of the trucks operate over routes of 20 miles and less is rather significant when compared with the situation in some of the other cities where data of this kind have been obtained.

The table below shows the number of trucks used in this territory classified according to capacity.

*Number of trucks by capacities, Cincinnati area*

| Capacity in tons | Number of trucks | Per cent | Capacity in tons | Number of trucks | Per cent |
|---|---|---|---|---|---|
| 1 | 16 | 18 | 3 | 2 | 3 |
| 1½ | 32 | 35 | 3½ | 12 | 13 |
| 2 | 18 | 20 | | | |
| 2½ | 10 | 11 | Total | 90 | 100 |

It is to be noted that over 50 per cent of the trucks are of 1-ton and 1½-ton capacities and that 3½-ton trucks are the largest operating in the territory. Small trucks are favored because the routes are not long and because the roads over which they have to operate contain a great many steep grades. All of the trucks are operated by one man to each truck.

The extent to which the trucks of smaller capacity are confined to the shorter routes is shown in the tabulation below.

*Number of trucks operating in the various mileage zones by capacities*

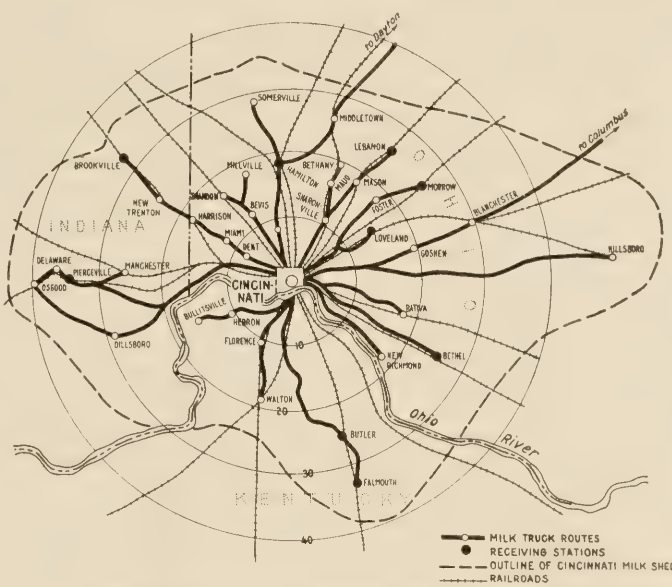
| Mileage zone | 1-ton | 1½-ton | 2-ton | 2½-ton | 3-ton | 3½-ton | Total |
|---|---|---|---|---|---|---|---|
| 0–9 | | | | | | | |
| 10–19 | 11 | 14 | 3 | 3 | | 1 | 32 |
| 20–29 | 2 | 5 | 3 | 1 | 1 | 3 | 15 |
| 30–39 | 1 | 8 | 6 | 2 | 1 | 7 | 25 |
| 40–49 | 1 | 5 | 5 | 4 | | | 15 |
| 50–59 | 1 | | 1 | | | 1 | 3 |
| Total | 16 | 32 | 18 | 10 | 2 | 12 | 90 |

While there are 48 trucks of 1-ton and 1½-ton capacity, 25 of these are operated in the 10–19 mile zone. Only four of the twelve 3½-ton trucks are in the 10–29 mile zone; the rest are operated over longer routes.

The type of body used very generally in this section is the ordinary rack body which can be used for both milk and stock hauling. Those trucks which are used exclusively for hauling milk are for the most part equipped with stake bodies. Livestock, particularly calves and hogs, are often transported along with a load of milk. The health department requires that where livestock is carried on the same truck with milk a light board partition of sufficient height be placed to separate entirely the livestock from the load of milk.

#### RETURN-LOAD BUSINESS NOT DEVELOPED

The glass-lined tank truck has never been tried. Most of the trucks are owned by individuals who live in the country and operate but one truck. The return-




Map of Cincinnati milk shed showing routes and mileage zones

load movement is not developed to any extent largely because no one has taken the initiative to organize and put in a central freight depot. One truck operator stated that he had tried to secure return loads but had to give it up because he found himself spending too much time driving from place to place in the city to gather his load. He felt that it paid him better to hurry home after delivering his load of milk and take a load of livestock back to the city in the afternoon. Such double trips could, of course, be made only where the route was of short distance. Several operators on routes from Kentucky have made arrangements to take back groceries and dry goods from wholesalers to country stores along their route. They felt they could give this kind of a return service because not much time was required of them to collect the return load but they refused to go into the general parcel and express business.

The number of operators and number of trucks operated by them is shown in the following table.

*Number of truck operators by classes and number of trucks operated by each, Cincinnati area*

| Class | Operators | | Trucks | |
|---|---|---|---|---|
| | Number | Per cent | Number | Per cent |
| Individuals | 64 | 98.5 | 78 | 87 |
| Dairies | 1 | 1.5 | 12 | 13 |
| Total | 65 | 100.0 | 90 | 100 |

According to this statement the 90 trucks engaged in this traffic were owned by 65 operators. Only a few of the individuals owned and operated more than one truck. Only one dairy company which operated 12 trucks was directly engaged in the transportation of milk. All the milk hauled by its trucks was obtained from 9 receiving stations most of which were beyond the 30-mile limit.

#### RATES CHARGED IN CINCINNATI AREA

An examination of the map of the Cincinnati milk shed and the information collected in making this survey indicates that the recent extension of the milk shed has been largely into Indiana and Kentucky. The new milk routes which have been established tend to follow the new and improved roads. Road construction has made possible to many farmers a new industry with a market ready to absorb the output.

While there are no definite uniform rates in effect for the transportation of milk by motor truck it is found that motor-truck operators grade their charges somewhat in accordance with the distances hauled. These rates may be stated as follows:

| Mileage zone | Rate in cents per 100 pounds | Approximate rate in cents per gallon | Mileage zone | Rate in cents per 100 pounds | Approximate rate in cents per gallon |
|---|---|---|---|---|---|
| 10–19 | 25 | 2.1 | 40–49 | 40 | 3.4–3.8 |
| 20–29 | 30 | 2.5 | 50–59 | 50 | 4.3 |
| 30–39 | 35 | 3.0–3.4 | | | |

These rates approximate 1 cent per 100 pounds per mile. Variations are found where poor and difficult roads are encountered. There is also a growing tendency among the truck men to add a differential of 5 cents per 100 pounds during the winter months when their operating costs are higher and their loads smaller on account of the seasonal fluctuations in the production of milk.

The Ohio Legislature passed an act in 1923 which requires all motor trucks engaged in the transportation of goods for others to register and obtain permits as common carriers. This change affects the operating expenses of all of those engaged in the business of transporting milk. The act provides that common-carrier motor trucks pay, in addition to the regular license fees, certain common-carrier fees and that the operators of such common-carrier trucks must take out cargo, liability, and property damage insurance. A 2-ton truck, for example, with a 35-horsepower rating paid as regular license fees about $32 a year. Under this new law it will have to pay in addition $80 as a common-carrier fee and insurance premiums amounting to about $105. This legislation adds approximately $185 a year to the costs of operating this kind of a truck. It will be interesting to see what effect these increased costs will have upon the motor-truck rates and the number of trucks operated.

#### MOTOR TRUCK HAS BEEN THE MEANS OF PROVIDING FOR GREATLY INCREASED CONSUMPTION IN DETROIT

In 14 years, from 1910 to 1924, the population of Detroit grew from 465,766 to 1,250,000, an increase of 168 per cent. With the ever increasing demand for milk the Detroit distributors had to look for new producing areas. It is significant that the areas developed did not lie along the railroads and electric lines which had been furnishing the greater part of the city's milk supply. The growth of Detroit has been coincident with motor-vehicle and highway development and these agencies not only furnished the means of transporting the new supply but also took over a considerable portion of the business handled by the older agencies.

In the following table there is shown a comparison of the amount of milk transported by these different agencies during July, 1915, and during February, 1924.

*Milk transported by different agencies, July, 1915, and February, 1924*

| | July, 1915 | | February, 1924 | |
|---|---|---|---|---|
| | *Pounds* | *Per cent* | *Pounds* | *Per cent* |
| Steam railroads | 5,363,415 | 41.8 | 775,710 | 2.1 |
| Electric railroads | 5,421,810 | 42.3 | 3,265,290 | 9.1 |
| Motor trucks and wagons | 2,038,130 | 15.9 | 31,743,690 | 88.8 |
| Total | 12,823,355 | 100.0 | 35,784,690 | 100.0 |

In 1924 when wagon shipments had ceased, 88.8 per cent of Detroit's milk supply was shipped by motor truck whereas only 15.9 per cent came in over the highways in 1915 by motor truck and by wagon. Steam and electric railroad shipments shrank from 84 per cent in 1915 to 11 per cent in 1924.

#### MOVEMENT OF MILK TO CITY LARGELY FROM RECEIVING STATIONS WITH LARGE TRUCKS PREDOMINATING AND LONG HAULS FREQUENT

With the constant increase in the mileage of improved roads the effective trucking radius has been correspondingly increased so that at present there are five trucks operating in the 70–79 mile zone. The numbers of motor trucks engaged in the transportation of milk according to mileage zones are shown in the table below.

*Number of trucks in the various mileage zones, Detroit area*

| Mileage zone | Number of trucks | Per cent | Mileage zone | Number of trucks | Per cent |
|---|---|---|---|---|---|
| 0–9 | | | 50–59 | 15 | 12.3 |
| 10–19 | 12 | 9.9 | 60–69 | 10 | 8.2 |
| 20–29 | 32 | 26.2 | 70–79 | 5 | 4.1 |
| 30–39 | 26 | 21.3 | | | |
| 40–49 | 22 | 18.0 | | 122 | 100.0 |

Almost 65 per cent of the motor trucks bringing milk into the city operate over routes 30 miles and over in length. The large number of trucks in the higher mileage zones is a significant fact. Approximately 25 per cent of the trucks go beyond the 50-mile radius for their loads.

The 122 motor trucks engaged in this milk traffic are classified as to capacity in the following table.

*Trucks classified by capacity, Detroit area*

| Capacity in tons | Number of trucks | Per cent | Capacity in tons | Number of trucks | Per cent |
|---|---|---|---|---|---|
| 1 | 2 | 1.6 | 4 | 4 | 3.3 |
| 1½ | 4 | 3.3 | 5 | 37 | 30.5 |
| 2 | 12 | 9.6 | 7½ | 1 | .8 |
| 2½ | 14 | 11.5 | | | |
| 3 | 27 | 22.2 | | 122 | 100.0 |
| 3½ | 21 | 17.2 | | | |

Trucks of large capacity predominate in number and 65 out of the 122 are tank trucks. Approximately 75 per cent of the trucks have a capacity of 3 tons and over; 30.5 per cent are in the 5-ton class. The 7½-ton truck is used in hauling crates of bottled milk from a farm 20 miles outside of the city over a hard-surfaced road. The run is made in a little over two hours.

Only 12 of these trucks are engaged in pick-up business, hauling directly from the farm to the city dealer or dairy plant. The others are all operated between country receiving stations and city dairies.

The 12 trucks picking up milk along the road do not go beyond the 30-mile limit and are all of the smaller capacities.

In the Detroit milk shed there are 120 receiving stations where the milk is collected from the producers, put through a cooling process in the summer months, and shipped to the city dairies either by tank trucks or by large can trucks. There are 110 trucks engaged in this kind of traffic, 65 of which are tank trucks. It is generally stated that there are more tank trucks engaged in the transportation of milk in the Detroit area than in any other section of the United States. The establishment of such a large number of receiving stations in this section and the transportation of cooled milk in cans and tank trucks was largely caused by the ruling of the city health department requiring the milk to arrive at a temperature not above 60° F. The enforcement of this rule hastened the establishment of receiving stations and also the bulk method of transportation.

The majority of these receiving stations are owned and operated by the city dairy companies. A few are owned by farmers' cooperative associations and by individuals. The typical receiving station consists of a small frame building equipped with a small boiler, can-washing machine, and cooler. The larger stations have additional equipment for separating, churns, cheese vats, condensing pans, and ice machines. The smaller stations use natural ice for cooling. The milk is hauled to the stations in small trucks and wagons by the farmers and by local individuals who may engage in that business. The price paid for this hauling usually averages from 15 cents to 20 cents per 100 pounds depending on the roads and distances.

#### TANK TRUCKS USED FOR LARGE VOLUME MOVEMENT PARTICULARLY FROM DISTANT STATIONS

In cases where shipment to the city is made by tank truck the truck is run alongside the receiving station where it is filled either by gravity or by a small compressed air pump. The tanks are filled to capacity to prevent churning en route. Where receiving stations are located near to one another the tank trailer has been found very useful. The tank truck and the tank trailer proceed to the first station where the trailer is left to be filled while the tank truck goes on to the station beyond to get its load. On the return trip the tank trailer is picked up by the tank truck and both are taken to the city dairy.

Of the 65 tank trucks 35 are owned and operated by one concern which has a contract for this kind of hauling with one of the largest dairies in Detroit. The average daily hauling of these 35 tank trucks and the number of receiving stations they serve, and the various mileage zones are shown in the following statement.

*Average amount of milk hauled daily with 35 tank trucks, mileage zones and number of receiving stations, Detroit area*

| Mileage zones | Number of stations | Average amount of milk hauled daily [1] | Average amount per station | Mileage zones | Number of stations | Average amount of milk hauled daily [1] | Average amount per station |
|---|---|---|---|---|---|---|---|
| | | *Pounds* | *Pounds* | | | *Pounds* | *Pounds* |
| 10–19 | 5 | 17,433 | 3,487 | 50–59 | 5 | 113,180 | 22,636 |
| 20–29 | 6 | 38,861 | 6,477 | 60–69 | 1 | 18,934 | 18,934 |
| 30–39 | 7 | 84,591 | 12,084 | 70–79 | 2 | 41,480 | 20,740 |
| 40–49 | 4 | 33,158 | 8,289 | | | | |

[1] In some areas the gallon is the standard unit, while in others the pound or hundredweight is used. For purposes of comparison it may be remembered that 100 pounds of milk represents 11.7 gallons.

The average amount of milk hauled from these receiving stations daily ranges from 3,487 pounds for the stations in the 10–19 mile zone to 22,636 pounds per station in the 50–59 mile zone. It is observed that the daily amount moved from stations increases with the distance to the stations, with one exception.

Where trucks take over business formerly handled by railroads, the railroad rate is adopted as the trucking charge. The following are samples of motor-truck rates in effect for various distances:

*Typical motor truck rates, Detroit area*

| Station | Distance in miles | Rate in cents per 100 pounds | Station | Distance in miles | Rate in cents per 100 pounds |
|---|---|---|---|---|---|
| Washington | 30.0 | 27 | Peters | 38.0 | 30 |
| Memphis | 53.5 | 50 | New Boston | 27.3 | 45 |
| Macomb | 30.0 | 27 | Waltz | 25.5 | 45 |
| Utica | 21.0 | 24 | Scofield | 34.0 | 45 |

The hauling from the last three stations is performed by one concern, which charges a flat rate of 45 cents. In general, the rates are graded in such a manner as to approximate a charge of 1 cent per 100 pounds per mile,

Tank trucks are used principally for transporting milk from receiving stations to the city plant. A large fleet of such trucks is used in the Detroit area

though there are obvious exceptions. The survey did not show that any differentials were made as between tank trucks and other types of trucks used in the transportation of milk.

Practically every milk truck in the Detroit area employs the services of a driver only, which is to be expected where the entire load is secured at one point. Few trucks entering the city pick up milk along the road, and in no case is cooperative hauling done. There has also been no development of the return-load feature, with the exception of small shipments of ice cream taken back from the city dairies to points in the country. The use of tank trucks naturally eliminates the opportunity of developing city-to-country shipments of merchandise and other kinds of freight.

#### CITY OF MILWAUKEE LOCATED IN HEAVY MILK PRODUCING SECTION

The greater part of the milk supply of Milwaukee is received from the territory within 30 miles of the city. This takes in the whole of Milwaukee County, the northern part of Racine County, the eastern part of Waukesha County, and the southern parts of Washington and Ozaukee Counties. Lake Michigan on the east prevents any milk coming from that direction.

This half-circular territory is probably the heaviest milk-producing section in close proximity to any large city in the United States. Along the outskirts of the city's milk shed are found a string of condenseries and a number of receiving plants operated by Chicago milk distributors.

As late as 1916 half of the milk consumed came to the city by wagon and the other half was shipped by railroad. At the present time, as is shown by the table below, almost 90 per cent of the milk is transported into the city by motor truck and the wagon has been wholly displaced.

*Number and per cent of cans transported daily by rail and motor truck, Milwaukee area*

| | Number of cans | Per cent |
|---|---|---|
| Motor truck | 7,352 | 87.5 |
| Electric railroad | 1,055 | 12.0 |
| Steam railroad | 50 | .5 |
| | 8,457 | 100.0 |

A type of body especially built for milk hauling. Note side opening, tight sides for protection against freezing, and canvas cover. Cans must be of uniform size for maximum load

The containers are all 8-gallon cans. These were the average daily receipts in the month of February, 1924, at a time when several of the outlying routes were closed to motor traffic so that the rail lines were at this time carrying slightly more than their normal share. It is noteworthy that the steam railroads which penetrate and serve this whole area carried only 50 cans of milk a day. The electric railroad has been able to hold its milk shipments largely because it has worked out a coordination of its rail service with motor trucks which act as feeders. It has made an arrangement with an operator of two motor trucks which collect on an average of 300 cans each and deliver at the milk platforms on the interurban line where they are picked up by a special train and hauled into the city.

That Milwaukee's milk trucks operate in a territory not far distant from the city is shown in the following table:

*Number and per cent of trucks operating in various mileage zones, Milwaukee area*

| Mileage zone | Number of trucks | Per cent |
|---|---|---|
| 0–9 | 5 | 4.0 |
| 10–19 | 71 | 56.8 |
| 20–29 | 45 | 36.0 |
| 30–39 | 4 | 3.2 |
| Total | 125 | 100.0 |

There are 125 motor trucks engaged in hauling milk directly to the city dairy plants; 76 trucks, or 60.8 per cent operate within the 0–19 mile zone; 45 trucks, or 36 per cent, operate in the 20–29 mile zone; only 4 trucks, or 3.2 per cent, operated over routes between 30 and 39 miles in length.

In the following table the motor trucks are divided both as to capacity and to mileage zones.

*Number of trucks classified by capacity in the various mileage zones, Milwaukee area*

| Mileage zone | 1-ton | 1½ ton | 2-ton | 2½ ton | 3-ton | 3½ ton | 5-ton | Total |
|---|---|---|---|---|---|---|---|---|
| 0–9 | 4 | 1 | | | | | | 5 |
| 10–19 | 8 | 10 | 21 | 20 | 3 | 6 | 3 | 71 |
| 20–29 | 11 | 8 | 5 | 10 | 9 | | 2 | 45 |
| 30–39 | 2 | 1 | | | | | 1 | 4 |
| Total | 25 | 20 | 26 | 30 | 12 | 6 | 6 | 125 |
| Per cent | 20.0 | 16.0 | 20.8 | 24.0 | 9.6 | 4.8 | 4.8 | 100.0 |

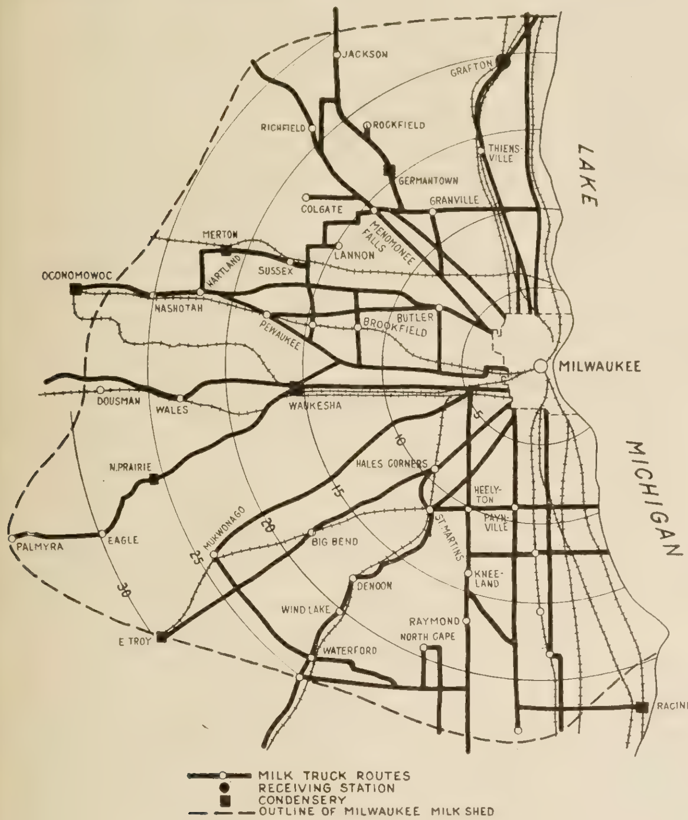
Out of a total of 125 trucks only 6 or 4.8 per cent are of the 5-ton class. Over 56 per cent of the trucks are in the 1 to 2 ton class. On account of the small area over which they operate it can not be said that the small-capacity trucks are found only in the low-mileage zones and the larger trucks in the higher-mileage zones. The tabulation shows that one of the 5-ton trucks operates in the 30–39 mile zone and there are two 1-ton trucks operating over the same length of route.

Most of the trucks are equipped with bodies of light board construction to prevent the freezing of milk. Where the ordinary stake bodies are used there is much trouble on this account in winter. Bodies of sufficient height to allow plenty of room for double-decking a load of standard 8-gallon cans are used. All the cans being of the same size, the hauler is enabled to load his truck to maximum capacity. The bodies have side gates so that the trucks can readily load from milk platforms on both sides of the road.

#### RECEIVING STATIONS NOT NECESSARY IN MILWAUKEE AREA

The large volume of milk which can be gathered in the territory close to the city makes the establishment of receiving stations unnecessary. The rates of the small trucks delivering milk to receiving stations are practically as high as those charged for shipment to the city milk plants. An experiment was made with the operation of a tank truck from a receiving station 12 miles from the city but the operation was finally discontinued when the station haulers demanded nearly as much per 100 pounds as direct city haulers were getting f. o. b. city plants. With the excellent system of hard-surfaced highways possessed by the Milwaukee milk shed it is doubtful whether receiving stations can be successfully operated within the present confines of the milk-producing territory.

The milk trucks in this territory are owned mainly by individuals who live in the country at or near the point of origin of their respective routes and who farm a few acres after the daily milk hauling is completed. These farmer-truck operators, who compose about 90 per cent of the total number, usually own but one truck, sometimes two. There are no large fleet organizations such as operate in the Detroit milk shed. The trucks are usually operated by the owner and there is seldom a helper employed. The owner and operator of the truck acts in the capacity of the farmer's agent rather than the dealer's. The hauling contract is made between the hauler and the producer and not between the truck owner and the dealer. The dealer, however, deducts the hauling charges from each producer's monthly milk check and remits these to the truck operator thus saving the hauler the trouble of collecting a number of small accounts.




Map of Milwaukee milk shed showing routes and mileage zones

Twelve of the trucks engaged in milk traffic are owned and operated by one of the largest dairy companies. This company employs several of its smaller trucks as feeders to the larger trucks operating over longer routes.

Milk hauling is an everyday business. The milk must move in the winter as well as in the summer, on stormy days as well as fair. Consequently steps have been taken to assure the regularity of truck movements despite heavy snowfalls. Milwaukee is fortunate in having practically all of its incoming main country highways constructed with a hard surface, and the efficient snow removal by the counties from which the milk comes has permitted trucks to reach the city in all kinds of weather. Snow removal in Wisconsin is left to the county authorities. Drift fences have been a big aid at several points and snow plows are placed in operation as soon as the snow commences to fall. These are kept operating without stopping until the snow ceases. During extremely heavy snow conditions and when the frost is coming out of the ground the milk is brought by the producers over the dirt roads to the main hard-surfaced roads where the regular trucks pick it up from platforms.

The return-load traffic has not been developed to any extent in the Milwaukee area. Most of those operating the milk trucks have a good paying load of milk and do not seem to care to develop this additional business. Because of the relatively short routes many of the trucks make two trips with milk and others haul produce to market in the afternoon after they have returned the empty milk cans from the morning trip.

#### HIGH RATES CHARGED BY TRUCKS TRAVERSING BAD ROADS

The rates charged for hauling vary for trucks covering the same length of route. In order to give a complete picture of the rate schedules there are shown in the following tabulation the exact rates charged by each of the trucks and the length of the routes and also the average rates for each of these instances.

| Miles | Rates in cents per 100 pounds charged by each truck | Average rate, cents per 100 pounds |
|---|---|---|
| 7 | 15 | 15 |
| 8 | 16, 20 | 19.6 |
| 10 | 15, 15 | 15 |
| 11 | 18 | 18 |
| 12 | 15, 23 | 19 |
| 13 | 22, 20, 16, 23, 23, 25 | 21.5 |
| 14 | 21, 23, 15, 20, 20, 20, 23, 23, 15, 24, 23, 23, 21, 20 | 21 |
| 15 | 23, 23, 22, 20, 23, 23 | 22.3 |
| 16 | 23, 23, 23, 23, 23, 22, 23, 21, 23 | 22.6 |
| 17 | 23, 23 | 23 |
| 18 | 20, 25, 24, 25, 22, 23, 25 | 24 |
| 19 | 24 | 24 |
| 20 | 27, 23, 20, 25, 23, 22 | 23.3 |
| 21 | 30 | 30 |
| 22 | 23, 25, 30, 23, 25, 30, 23 | 25.5 |
| 23 | 23, 23, 25 | 23.6 |
| 24 | 25, 23, 21, 23 | 23 |
| 25 | 30, 30 | 30 |
| 26 | 28 | 28 |
| 27 | 28, 26 | 27 |
| 28 | 30, 25, 30 | 28.3 |
| 30 | 30, 30 | 30 |
| 34 | 35 | 35 |
| 39 | 40 | 40 |

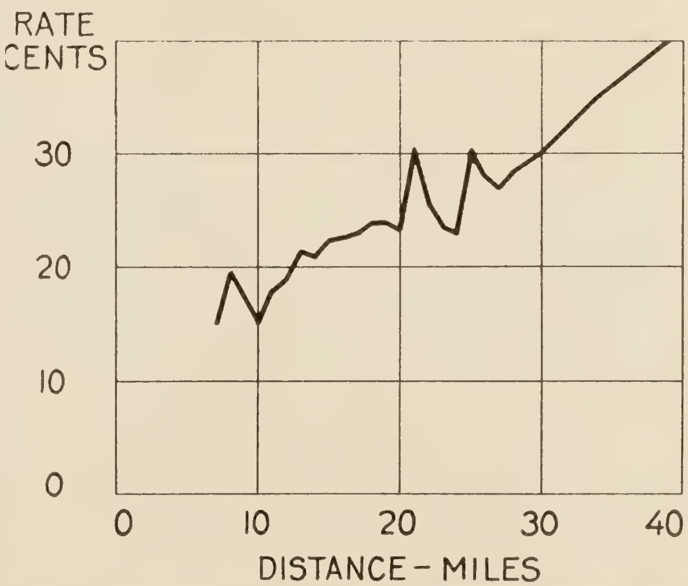



Diagram showing average rates per 100 pounds for hauling milk by truck for varying distances in Milwaukee area

The rates average from 15 cents per 100 pounds for a short haul of 7 miles to 40 cents for a 39-mile haul. For distances of 27 miles and over the rate approximates 1 cent per 100 pounds per mile. For the shorter distances it is generally higher. Up to 10 miles the rate is practically 2 cents per 100 pounds per mile and for distances above that it is in the neighborhood of 1½ cents. There are, however, glaring inconsistencies in some of the rates charged for specific distances. It is usually found that where there are higher rates than others for similar distances the trucks charging the higher rates collect their loads in sections which are not provided with hard-surfaced roads and then have some distance to go before they strike the main improved highway leading into the city. As an illustration, there are two trucks operating a distance of 12 miles; one charges 15 cents, starts at a point on a hard-surfaced road and continues over it until it reaches the city; the other truck, which charges 23 cents going the same distance, proceeds for about 4 miles before it reaches a concrete road. Similarly the two trucks which charge a rate of 15 cents for a distance of 14 miles operate over a hard-surfaced road the entire route; the other trucks operating over a like distance charge higher rates and in most cases follow routes which are not confined solely to the higher types of roads. There are undoubtedly other reasons which may account for these differentials in charges for the same distances, but the condition of the highway appears to be the important factor and accounts for most of the variations.

#### CHEAP TRANSPORTATION BENEFITS BOTH PRODUCER AND CONSUMER

In the following table is shown a comparison of net prices received at the farm in a number of milk markets of the country in 1923:

*Average milk prices, 1923*

| City | Average net price per 100 pounds at the farm | City | Average net price per 100 pounds at the farm |
|---|---|---|---|
| Philadelphia | $2.46 | Columbus | $2.08 |
| Cincinnati | 2.02 | Pittsburgh | 2.34 |
| Detroit | 2.232 | Cleveland | 2.50 |
| St. Paul and Minneapolis | 2.21 | | |
| Chicago (estimated) | 1.60 | Average | 2.152 |
| Louisville | 1.87 | Milwaukee | 2.39 |

The average retail selling price in these cities, excluding Milwaukee, was 12.9 cents per quart; in Milwaukee the average retail selling price for 1923 was 10.41 cents per quart. This indicates that the producers in the Milwaukee shed received 11.5 per cent more than the producers supplying these other markets and the consumers paid only 81 per cent of what the consumers paid in these other cities. The higher price received by the producers is to a large extent accounted for by the production of such a large quantity of milk in an area close to the market, thereby reducing the amount which has to be paid out for transportation. The high-type roads in this area are factors in holding haulage charges down to a low level. Extensive use of motor trucks in the transportation of milk has eliminated the necessity of city hauling from railroad terminals to dairy plants. This was an expense which the distributors had to bear and its elimination is one of the factors which enables them to sell at a lower price than that charged in other cities.

#### PRACTICALLY ALL MILK NOW SHIPPED BY MOTOR TRUCK IN ST. PAUL AND MINNEAPOLIS

From the standpoint of the transportation and marketing of milk St. Paul and Minneapolis, commonly called the Twin Cities, are generally considered as one market. The producers who supply these cities are organized and are known as the Twin City Milk Producers' Association, composed of over 6,000 members. The association controls about 80 per cent of all the milk produced and sold within the milk shed of these two cities which lies within a radius of 40 miles. On account of large quantities of surplus milk at various seasons of the year the association has found it necessary to operate 15 receiving stations which are equipped to manufacture one or several milk products, such as butter, cheese, casein, and condensed milk. During the late summer and the fall months, when the production of milk is lower than at any other time of the year, these stations may be shipping their entire supply into the Twin Cities to meet the demands of the distributors. During March, 1924, the association handled 23,186,496 pounds of milk. Only half of this was sold as fluid milk to the city distributors, the rest being converted into milk products at these country stations. Consequently only 50 per cent of the milk bought by the association was transported to the Twin Cities, thereby saving that part of the hauling cost.

Of the total amount of milk handled by the association only about 1 per cent is shipped by railroad; the remainder is hauled direct by motor truck to the plants of the city distributors or to the nearest receiving stations of the association. There are now only four rail shipping points, located from 30 to 47 miles distant, and these are not on any of the State highways. There are still a small number of farmers who haul their milk directly by wagon or truck to city dealers or in some cases they do their own distributing from door to door. The milk brought in by this method is only a small portion of the consumption of these two large cities.

At the present there are 122 motor trucks engaged in hauling milk directly to the city dairies or to the two central plants maintained in the Twin Cities by the association. These plants are operated by the association as pooling plants to which various city dealers come for the milk which they distribute. The number and per cent of trucks in the various mileage zones is shown in the following table.

*Number and per cent of trucks in various mileage zones, Twin Cities area*

| Mileage zones | Number of trucks | Per cent |
|---|---|---|
| 0–9 | 11 | 9.0 |
| 10–19 | 45 | 36.9 |
| 20–29 | 54 | 44.2 |
| 30–39 | 12 | 9.9 |
| Total | 122 | 100.0 |

Practically 90 per cent of the trucks are operated within the 0–30-mile zone and the remaining 10 per cent are in the 30–39-mile zone. In addition to these trucks there are nearly 60 station haulers who gather milk within a radius of 10 to 15 miles from the various receiving stations. The milk produced within 25 miles of the Twin Cities is usually taken directly to the city dairy plants or to the association's two central plants. Milk produced in the territory beyond is diverted to the country receiving stations where it is cooled and reshipped to the Twin Cities or manufactured into milk products. There are only two tank trucks operating in this territory. These are used by one of the distributors in transporting his supply of milk from country receiving stations to his city plant.

The classification of the motor trucks engaged in the milk traffic by capacity is set forth in the following tabulation.

*Number and per cent of trucks by capacity, Twin Cities area*

| Capacity in tons | Number of trucks | Per cent | Capacity in tons | Number of trucks | Per cent |
|---|---|---|---|---|---|
| 1 | 76 | 62.3 | 3 | 5 | 4.1 |
| 1½ | 12 | 9.9 | 3½ | 4 | 3.2 |
| 2 | 20 | 16.4 | | | |
| 2½ | 5 | 4.1 | | 122 | 100.0 |

The large number of trucks of 1-ton capacity is striking; 62.3 per cent of the total number are in this group. Almost 90 per cent of the trucks are of 1 to 2 ton capacity. Practically all of the trucks are fully equipped with pneumatic tires.

### TRUCK RATES HIGHER THAN FOR OTHER AREAS

The average rates charged for hauling milk by motor truck are set forth in the table following.

*Transportation rates charged by trucks, Twin Cities area*

| Distance in miles | Average rate in cents per 100 pounds | Distance in miles | Average rate in cents per 100 pounds |
|---|---|---|---|
| 0–9 | 22.5 | 20–29 | 33.0 |
| 10–19 | 28.0 | 30–39 | 37.5 |

These rates are higher than those in several other milk sheds. Higher rates are partly due to road conditions but can not be entirely ascribed to this cause. The general use of pneumatic tires results in higher operating expenses. It is claimed by those engaged in this business that they are necessary in order to operate successfully over the snow-covered roads during the winter months. Many haulers quote a winter and a summer rate. Others maintain a uniform rate which they feel is high enough on the average to cover their added costs during the winter months.

The milk trucks in this territory are owned and operated by individuals living in the country where their routes originate, 81 operate 1 truck each, 16 operate 2 trucks, and 3 operate 3 trucks each. This indicates that there is no developed fleet operation. Several milk trucks are operated by country storekeepers who use their trucks in bringing back return loads of merchandise and the return load movement is confined to this class.

Under a statute recently passed these milk trucks operating over regular routes and on fixed schedules are classed as common carrier vehicles and have to pay as a tax and license fee 10 per cent of the value of the truck. The "base price for taxation" is obtained from a statement filed by truck manufacturers, "less 10 per cent for the second year, less 20 per cent for the third," and so on until the eighth year when it is 70 per cent for that year and for each subsequent year. The old rate was based on an assessment of 2¾ per cent of the value.

### MOTOR TRUCK HAS GROWN TO PRINCIPAL AGENCY FOR MILK TRANSPORTATION IN INDIANAPOLIS

Although Indianapolis is located in the heart of a rich agricultural district, the production of market milk in the counties tributary to the city has always been limited in quantity until recently. City distributors in order to meet the demands of the market were forced to reach out distances of 40 to 50 miles which meant the establishment of receiving stations. The milk, after it was cooled, was shipped in cans from these stations to the city by steam and electric railroads.

Highway transportation has caused a great change in the last five years, developing a producing area which is much closer to the city. Receiving stations are gradually being closed. One large dairy company has closed 8 out of 12 stations and expects to close 1 or 2 more this year. The producing area or milk shed has in this case grown smaller rather than larger. For both the producer and the city distributor the use of the motor truck in hauling milk has greatly simplified operations.

The average amount of milk transported into Indianapolis daily during the month of March, 1924, is shown in the following statement:

*Amount of milk transported into Indianapolis, daily average, March, 1924*

| | Amount of milk in pounds | Per cent |
|---|---|---|
| Motor truck | 224,458 | 94 |
| Electric railroad | 14,450 | 6 |
| Total | 238,908 | 100 |

A receiving station equipped to convert surplus milk into other products

Five years ago the electric railroads carried 50 per cent of the milk supply, wagons 30 per cent, steam railroads 10 per cent, and motor trucks 10 per cent. At the present time no milk is received by steam railroad and the traction lines bring in only 6 per cent of the total supply. The traction lines lost this kind of traffic largely because the motor truck furnished a complete service from the point of production in the country to the city dairy plants.

The number of trucks engaged in this service and the mileage zones are shown in the following statement:

*Number of motor trucks operating in the various mileage zones*

| Mileage zones | Number of trucks | Per cent | Mileage zones | Number of trucks | Per cent |
|---|---|---|---|---|---|
| 0–9 | 4 | 4.7 | 30–39 | 17 | 19.8 |
| 10–19 | 26 | 30.2 | 40–49 | 10 | 11.5 |
| 20–29 | 29 | 33.8 | | | |
| | | | Total | 86 | 100.0 |

This table shows that over a third of the trucks operate in the 0–19 mile zone and another third in the 20–29 mile zone. Two-thirds of the number of trucks engaged in this traffic operate in the area within 30 miles of the city.

In the following table is shown the number of trucks by capacities operating in the various mileage zones:

*Number of trucks by capacities in various mileage zones*

| Mileage zones | 1-ton | 1½-ton | 2-ton | 2½-ton | 3-ton | Total |
|---|---|---|---|---|---|---|
| 0–9 | 4 | | | | | 4 |
| 10–19 | 11 | 10 | 4 | 1 | | 26 |
| 20–29 | 17 | 8 | 4 | | | 29 |
| 30–39 | 14 | 1 | 2 | | | 17 |
| 40–49 | 7 | 2 | | | 1 | 10 |
| Total | 53 | 21 | 10 | 1 | 1 | 86 |
| Per cent | 61.6 | 24.4 | 11.6 | 1.2 | 1.2 | 100.0 |

The large number of small trucks operating in this territory is significant; 86 per cent are 1 to 1½-ton capacity; 97 per cent are 2-ton or less. All the trucks are of the open-body type except one 3-ton truck which is of the closed-van type and operates from a receiving station over a 48-mile route.

In the following table are set forth the average rates charged by the trucks and by one of the electric lines.

*Rates charged per 100 pounds by trucks and by electric railroads, Indianapolis area*

| Distance | Truck rates per 100 pounds | Electric railroad rates per 100 pounds | Distance | Truck rates per 100 pounds | Electric railroad rates per 100 pounds |
|---|---|---|---|---|---|
| *Miles* | *Cents* | *Cents* | *Miles* | *Cents* | *Cents* |
| 5–10 | 30 | 19.84 | 30–35 | 45 | 25.73 |
| 10–15 | 33 | 21.32 | 35–40 | 48 | 26.46 |
| 15–20 | 36 | 22.78 | 40–45 | 50 | 27.20 |
| 20–25 | 39 | 23.52 | 45–50 | 50 | 28.67 |
| 25–30 | 42 | 24.26 | | | |

The truck rates for the shorter distances average considerably higher than the rates charged in other territories for short hauls. For the longer distances the rates are slightly more than a cent per 100 pounds per mile which seems to be a normal scale in other cities. Although the truck rates are maintained on a higher level than the traction-line rates still shipments by motor truck have been increasing.

Return loads are seldom carried by the milk trucks in this territory. The trucks are practically all owned by individuals living in the country who may be farming on a small scale. The license fees paid are the same as are paid by other trucks not engaged in regular service.

# CHARLES M. UPHAM APPOINTED DIRECTOR OF ADVISORY BOARD ON HIGHWAY RESEARCH

CHAS. M. UPHAM, State Highway Engineer of North Carolina, has been recently appointed director of the Advisory Board on Highway Research of the National Research Council, to succeed Dr. W. K. Hatt who resigned in order to resume his work at Purdue University.

Charles M. Upham

The present board intends to continue the excellent plans already effected and to extend its activities so that the results of highway research may be practically applied by the States and counties carrying on programs of highway construction and maintenance and by others interested in highways. The organization has been extended so that each State highway department may have a representative on the board who will serve as a point of contact between it and the State. It is also planned to have similar representation from universities engaged in highway research.

Mr. Upham, the new director, has had extensive experience in highway work. He received his early training with the Massachusetts highway department and later became chief engineer of the Coleman du Pont Road in Delaware. Following this he was for four years chief engineer of the Delaware State Highway Department, when he was called to take charge of the extensive highway construction program in North Carolina. Mr. Upham holds a B. S. degree from Tufts College and an honorary C. E. degree from the University of North Carolina. He is an associate member of the American Society of Civil Engineers and holds active membership in many other technical societies. For the past two years he has been business director of the American Road Builders' Association, and has been reelected several times to his present position as secretary of the American Association of State Highway Officials.

It is expected that Mr. Upham's wide acquaintance and broad experience in the highway field will make his connection as director of the Advisory Board on Highway Research especially valuable to those agencies which can utilize the information being made available by this organization.

The offices of the board are now located in the new and imposing building of the National Research Council at B and Twenty-first Streets, Washington, D. C.

# FRICTION TESTS OF CONCRETE ON VARIOUS SUB-BASES

BY A. T. GOLDBECK, CHIEF, DIVISION OF TESTS, UNITED STATES BUREAU OF PUBLIC ROADS

THE rational design of any structure, whether it be a bridge or a pavement, necessitates a knowledge of the stresses to which it will be subjected. In a framed structure, stress analysis is comparatively simple, and may be made with practical surety. When one attempts, however, to analyze a concrete road slab, a bewildering maze of uncertain forces is found. The uncertainty lies not so much in not knowing what forces exist as in an almost total lack of knowledge regarding their magnitude. We know that a concrete road slab is acted upon by forces which tend to slide it along its supporting base, which bend it, warp it, subject it to direct compression or tension, or to a combination of direct stresses and bending, forces of shear which tend to abrade its surface, and disrupting forces which weaken it locally. The series of tests discussed in this article was made to throw light on at least one of the forces acting on concrete roads, namely, the force of friction at the base.

It has been shown by several investigators that concrete elongates and shortens due to two principal phenomena; change in temperature and change in moisture content. A coefficient of 0.0000055 per degree Fahrenheit seems to accurately express the effect of temperature change. Tests [1] made on a number of large specimens of concrete demonstrate that moisture also plays an important part in influencing the length of concrete structures. Measurements made on new concrete after hardening and repeated at a later date indicate that drying out may cause a shrinkage of as much as 0.06 per cent while specimens kept in a moist condition may expand 0.01 per cent. Both old and new concrete if subjected to alternately wet and dry conditions must inevitably expand and contract. Carefully conducted field measurements [2] made with a specially designed instrument corroborate laboratory measurements and show that concrete pavements are subjected to considerable motion over their subbase.

#### DETERMINATION OF FRICTIONAL RESISTANCE A STEP TOWARD RATIONAL DESIGN OF CONCRETE PAVEMENTS

Heavy masses of concrete can not be slid over the ground without considerable frictional resistance which will vary with the kind and conditions of subbases. In order to study the effect of the movement of pavements on the internal stresses developed, let a hypothetical case be considered in which the pavement after being laid is subjected to a rise in temperature and in addition, due to weather and subbase conditions, is not allowed to dry out. Such a pavement will necessarily expand and the ends of the slab will move away from the center. Friction will act to resist this movement and in this way becomes an external force producing almost direct compression in the concrete. Should the frictional resistance exceed the compressive strength of the concrete, a compression failure will result.

Assume another case in which the temperature decreases considerably after the laying of the pavement, and let the concrete dry out due to dry weather and a well-drained subbase. This concrete will shrink and the ends of the slab will approach its center. Friction will act against the movement and tension will be produced in the concrete. Concrete is weak in tensile resistance and not much shrinkage is required to crack the pavement if the subbase is very rough. From these considerations it will be recognized that as a step toward the rational design of concrete pavements the determination of frictional resistance at the base is necessary, and the following investigation was made with this in view.

#### DESCRIPTION OF SPECIMENS AND METHOD OF TESTS

The bases of concrete roads have been of varying character. Loam, clay, old macadam, gravel, sand, and many other kinds of material support the concrete, and some offer more frictional resistance than others. In planning the series of tests, therefore, a number of different bases were used. Shallow ditches 6 inches deep, 3 feet wide, and 7 feet long were first dug in clay soil at the Arlington Experimental Station of the Bureau of Public Roads. Filling material forming the subbases was then deposited, tamped solidly, and smoothed or otherwise treated in readiness for placing the concrete. Upon the subbases slabs were cast 2 feet wide, 6 feet long, and 6 inches thick of 1:1½:3 concrete, machine mixed, of medium-wet consistency. The various subbases prepared were as follows:

A. Clay, smooth top surface.

B. Clay with cobblestones partly rolled in surface.

C. Broken stone, three-fourths inch to dust, flat top surface.

D. Concrete base, top surface troweled smooth.

E. Loam, smooth top surface.

F. Sand, top surface smoothed and oiled with heavy flux oil.

G. Clay, surface scored to make it uneven.

H. Gravel, three-fourths inch to one-fourth inch, flat surface.

I. Broken stone, 3-inch

J. Concrete base, troweled surface, oiled with heavy flux oil.

K. Sand, surface smooth.

L. Clay, oiled with heavy flux oil.

The first set of tests was made when the specimens were one month old. A frame made of a piece of one-half-inch round steel bent to surround the specimen was fastened to the pulling chain, which in turn was linked to a spring dynamometer. Force was applied by means of a light steel rail used as a long lever. Two men at the end of the lever were able to apply a constantly increasing force with great steadiness. The movements of the slab were read by means of a Berry strain gauge, and in this way the movements corresponding to the force applied as indicated by the dynamometer were obtained.

The forces required to slide the specimens, together with their corresponding movements are shown in the diagram. Each specimen weighed approximately 870 pounds. The ground during these tests was damp but very firm. It will be noted that movement takes place almost as soon as the load is applied in all cases except

[1] The Expansion and Contraction of Concrete while Hardening, by A. T. Goldbeck, 1911 Proceedings of American Society for Testing Materials.

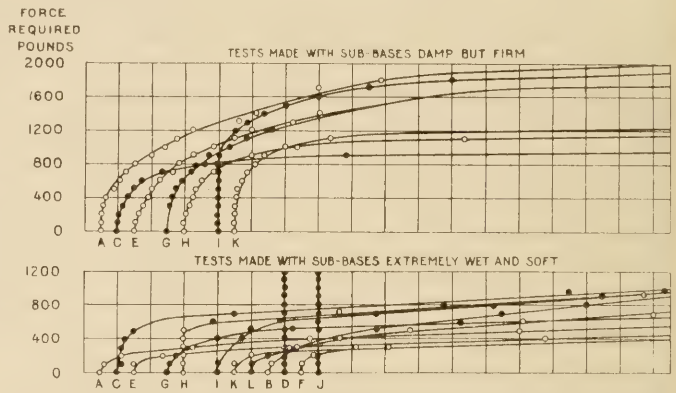
[2] See United States Department of Agriculture Bulletin No. 532, The Expansion and Contraction of Concrete and Concrete Roads.

that in which large broken stone was used in the base. Here there is great friction from the start until finally when a load of 1,000 pounds is reached slipping begins to take place. Great force was required to start the slab, after which no more was necessary than in some of the other bases. Apparently the coefficient of friction is not constant but varies with the displacement. When the slab on the loam base had been slid 0.035 inch, the load was gradually released, and the return movement noted on the strain gauge. The subbase seemed to behave in a somewhat elastic manner as the slab actually recovered considerable of its forward movement. This can be accounted for only by the partial springing back of the subbase toward its original position, carrying the slab along with it. The values of the frictional resistance offered at various displacements are given in Table 1.

#### FRICTIONAL RESISTANCE LOWERED BY WET SUBBASE

The same specimens and a few more that had been completed in the meantime were again tested after a period of about a month and a half. During this interval the ground was frozen solid almost all of the time, but the day before the tests a thaw set in, and combined with rain served to make the ground exceedingly muddy. The bases of most of the specimens were thoroughly saturated with water which stood on the surface in small puddles. The results obtained under such conditions are shown in the diagram, and it will be noted that the frictional resistance is considerably lower than it was in the previous tests. The water acted as a lubricant and permitted the slabs to slip easily. The values of the frictional resistance offered at various displacements are given in Table 2.

The results in the latter table, when compared with those given in the previous table, show very clearly that much depends upon the moisture condition of the subbase. A wet subbase permits the concrete to slide very much more easily than does a dry subbase. This apparently applies also to the specimens placed on broken stone and gravel bases, particularly when the movements are small.




Movement of concrete slabs on various subbases due to application of horizonta forces. Horizontal divisions represent movements of two one-thousandths of an inch. All slabs were 2 feet wide, 6 inches thick, and weighed 870 pounds

In order to try the effectiveness of a heavy oil coating for decreasing the friction at the subbase, several specimens were made having sand, clay, and concrete subbases treated with a heavy flux oil. The oil was applied while hot and was spread over the surfaces with a broom in a layer of sufficient thickness to completely cover the subbase. The concrete was deposited on these oiled bases immediately. So far as can be noticed, the oil is not effective in decreasing the friction in any of the bases, even when applied to the concrete base that had been carefully troweled smooth. It was impossible to slide the concrete specimen on the concrete base, even when a load of 2,500 pounds was applied. No attempt was made to apply a greater load than this, because 2,500 pounds was the limit of the dynamometer. When the maximum load had

(Continued on page 23)

TABLE 1.—*Frictional resistance of concrete on various subbases in damp but firm condition*

| Kind of base | Movement | Force | Coefficient | Movement | Force | Coefficient | Movement | Force | Coefficient |
|---|---|---|---|---|---|---|---|---|---|
| | *Inches* | *Pounds* | | *Inches* | *Pounds* | | *Inches* | *Pounds* | |
| Level clay | 0.001 | 480 | 0.55 | 0.01 | 1,130 | 1.3 | 0.05 | 1,800 | 2.07 |
| Uneven clay | 0.001 | 500 | 0.57 | 0.01 | 1,120 | 1.29 | 0.05 | 1,800 | 2.07 |
| Loam | 0.001 | 300 | 0.34 | 0.01 | 1,030 | 1.18 | 0.05 | 1,800 | 2.07 |
| Level sand | 0.001 | 600 | 0.69 | 0.01 | 1,080 | 1.24 | 0.05 | 1,200 | 1.38 |
| $\frac{3}{4}$-inch gravel | 0.001 | 450 | 0.52 | 0.01 | 960 | 1.10 | 0.05 | 1,100 | 1.26 |
| $\frac{3}{4}$-inch broken stone | 0.001 | 380 | 0.44 | 0.01 | 800 | 0.92 | 0.05 | 950 | 1.09 |
| 3-inch broken stone | 0.001 | 1,060 | 1.84 | 0.01 | 1,550 | 1.78 | 0.05 | 1,900 | 2.18 |

TABLE 2.—*Frictional resistance of concrete on various subbases in thoroughly saturated condition with water and surrounding ground exceedingly soft*

| Kind of base | Movement | Force | Coefficient | Movement | Force | Coefficient | Movement | Force | Coefficient | Movement | Force | Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Inches* | *Pounds* | | *Inches* | *Pounds* | | *Inches* | *Pounds* | | *Inches* | *Pounds* | |
| Level clay | 0.001 | 120 | 0.14 | 0.01 | 300 | 0.35 | 0.05 | 500 | 0.58 | 1.5 | 950 | 1.09 |
| Uneven clay | 0.001 | 200 | 0.23 | 0.01 | 460 | 0.53 | 0.05 | 620 | 0.71 | 1.4 | 925 | 1.06 |
| Loam | 0.001 | 150 | 0.17 | 0.01 | 260 | 0.3 | 0.05 | 410 | 0.47 | 0.75 | 925 | 1.06 |
| Level sand | 0.001 | 140 | 0.16 | 0.01 | 280 | 0.32 | 0.05 | 400 | 0.46 | 0.75 | 875 | 1.00 |
| $\frac{3}{4}$-inch gravel | 0.001 | 510 | 0.58 | 0.01 | 640 | 0.73 | 0.05 | 950 | 1.01 | 0.5 | 1,050 | 1.2 |
| $\frac{3}{4}$-inch broken stone | 0.001 | 400 | 0.46 | 0.01 | 660 | 0.76 | 0.05 | 940 | 1.08 | 2.0 | 1,160 | 1.33 |
| 3-inch broken stone | 0.001 | 240 | 0.28 | 0.01 | 630 | 0.73 | 0.05 | 900 | 1.04 | 0.875 | 1,625 | 1.87 |
| Oiled clay | 0.001 | 150 | 0.17 | 0.01 | 410 | 0.47 | 0.05 | 850 | 0.98 | 1.25 | 1,425 | 1.64 |
| Clay and cobble stones | 0.001 | 140 | 0.16 | 0.01 | 410 | 0.47 | 0.05 | 710 | 0.82 | 1.75 | 1,260 | 1.45 |
| Concrete base | 0.001 | 2,500+ | 2.9+ | 0.00 | 2,500+ | 2.9 + | 0.00 | 2,500+ | 2.9 + | 0.00 | 2,500+ | 2.9 + |
| Sand, oiled | 0.001 | 180 | 0.21 | 0.01 | 280 | 0.32 | 0.05 | 480 | 0.55 | 0.375 | 800 | 0.92 |
| Concrete, oiled | 0.000 | 2,500+ | 2.9+ | 0.00 | 2,500+ | 2.9 + | 0.00 | 2,500+ | 2.9 + | 0.00 | 2,500+ | 2.9 + |

# THE BULKING OF MOIST SANDS

## EFFECT OF PHENOMENON ON STRENGTH AND YIELD OF CONCRETE

By Arthur A. Levison, Highway Engineer, United States Bureau of Public Roads

When dry sand is moistened by mixing with a moderate amount of water, the volume of the sand is increased out of all proportion to the amount of water added. Stated otherwise, dry sand weighs more per cubic foot than moist sand. While this bulking or swelling phenomenon was recognized and investigated more than 30 years ago, the direct effect of it on the measurement of fine aggregates for concrete has attracted attention only recently. The Iowa State Highway Commission, for example, experimented in 1923 with the weighing of aggregates for concrete road construction and, as a result of the experiment, has adopted the practice of weighing as standard procedure. One of the advantages claimed for the weighing method is that the effect of moisture on the volume of fine aggregates can be disregarded, the only correction necessary being that for the weight of contained water. The inundation of sands has also been advocated as a means of measuring accurately under almost constant conditions the amount of sand and water for each batch of concrete.

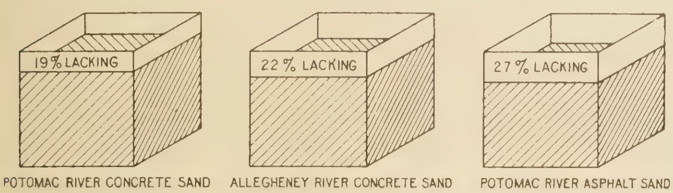



FIG. 1.—Volume of sand obtained by drying out 1 cubic foot of moist sand

Experiments made recently by the United States Bureau of Public Roads show that the extent to which a given sand will bulk is dependent principally upon its nature and gradation, the manipulation, and the amount of moisture present. In general, fine sands bulk more than coarse sands. Figure 1 shows the shrinkage of three widely different sands, the volume of which, measured in a condition of maximum bulking, was 1 cubic foot. It is apparent that volumetric measurements of concrete sands under certain moisture conditions will give approximately 20 per cent less of actual sand than the same volumes of the sand when measured in a dry condition.

| PERCENTAGES RETAINED ON STANDARD SIEVES | SAND "C" POTOMAC RIVER CONCRETE SAND | SAND "M" ALLEGHENY RIVER CONCRETE SAND | SAND "F" POTOMAC RIVER ASPHALT SAND |
|---|---|---|---|
| ¼ INCH | 1 | 0 | 0 |
| NO 10 | 48 | 13 | 1 |
| NO. 20 | 70 | 24 | 7 |
| NO 30 | 79 | 48 | 19 |
| NO. 40 | 83 | 68 | 31 |
| NO. 50 | 88 | 89 | 49 |
| NO 80 | 93 | 97 | 70 |
| NO. 100 | 95 | 98 | 82 |
| NO. 200 | 97 | 99 | 92 |
| PASSING NO 200 | 3 | 0.8 | 8 |

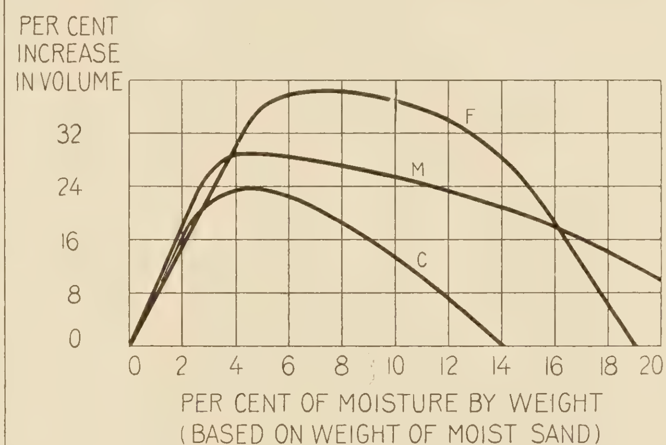



FIG. 2.—Curves showing the bulking of three different sands due to various percentages of moisture

### BULKING AMOUNTING TO MORE THAN 25 PER CENT POSSIBLE WITH ORDINARY MOIST SAND

The relation between increase in volume and percentage of moisture is shown by the curves in Figure 2, from which it is evident that the rate of change of bulking is most rapid for moisture contents up to 3 or 4 per cent. Sands used for concrete construction are almost never dry and 3 per cent of moisture constitutes a barely damp condition. Even with 6 per cent of moisture there is no visible evidence of free water. On a 20-mile concrete paving job in Iowa where the aggregates were weighed, moisture determinations made several times each day showed that the moisture content of the sand ranged from 3 to 6 per cent with by far the majority of the determinations lying between 4 and 5 per cent. If the conditions on the Iowa job are at all representative, it will be apparent that for sands C and M, laboratory bulking factors of 22 and 28 per cent, respectively, will be sufficiently accurate for moisture contents between 3 and 6 per cent. Another interesting fact evidenced by the bulking curves is that it was possible with sands C and F to incorporate sufficient water to bring the sands back to an equivalent of the dry bulk. In the case of sand M this could not be done by the methods adopted.

The arrangement of apparatus for the laboratory test is shown in Figure 3. A standard slump cone was supported in an inverted position so that its bottom was 12 inches above the top of a one-half cubic foot metal container. A weighing scale, shovels, scoops, and an oven or some convenient means of drying small samples of wet sand completed the necessary equipment. The first step in a test was to determine the weight of one-half cubic foot of the dry sand when poured through the slump cone into the container without tamping. About 2 cubic feet of dry sand was spread on a con-

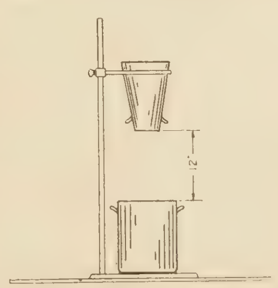



FIG. 3.—Arrangement of apparatus for bulking test

FIG. 4.—Steel bins and batchers used to determine field bulking of sand

crete floor and, beginning with a small amount of water, successive increments were added so as to raise the moisture content of the sand by steps of approximately 1 per cent. After each increment of water, the sand was thoroughly mixed and agitated with shovels until the moisture was uniformly distributed throughout the pile. When each increment of moisture has been thoroughly incorporated, a representative sample of moist sand was taken to be weighed and dried for determination of the percentage of moisture based on the weight of the moist sand, and two or more determinations of the weight per one-half cubic foot were made. This latter operation was performed after dropping the moist sand through the cone until the container overflowed, the excess being struck off with a straightedge. The entire process was repeated until the sand became saturated and water began to drain off the pile. The computation for bulking was made on a weight basis by deducting the weight of water from the weight of one-half cubic foot of moist sand and finding the difference between this weight and that of one-half cubic foot of the dry sand. Dividing this difference by the weight of dry sand in one-half cubic foot of moist sand, the percentage of bulking was obtained.

### LABORATORY TESTS CLOSELY CHECKED BY FIELD EXPERIMENTS

The effect of moisture on the volume of sand having been determined in the laboratory, the question arose as to what amount of bulking actually took place in the field on a construction job. For the purpose of obtaining this information, experiments were conducted with a modern concrete proportioning plant consisting of steel bins and adjustable measuring batchers with the constant strike-off feature.[1]

The measuring batcher was first calibrated for capacity at various settings of the adjustable feature with dry sand, the capacities being based on the weights of dry sand contained in the batcher. Normal stock pile sand was then loaded into the bin and, with the batcher set for a known cubical capacity as determined by the calibration test, it was loaded with the moist sand and the contents were then dumped and weighed. Deducting the weight of the water, the resultant amount of dry sand in a known volume was found. From this the bulking of the sand under plant conditions was computed. Incidentally, it was also found possible to compute the required setting of the adjustable batcher which would give a capacity of moist sand equivalent in weight to the original capacity in dry sand. The above-described work was done with Allegheny River sand, designated as M in Figure 2, and the bulking under field conditions was found to be 3 per cent less than that in the laboratory. The normal condition of the stock pile sand was 5.5 per cent moisture content. Owing to the fact that the experimental work was done during February and March and that the plant was out of doors it was not found practical to reduce the moisture content below this percentage. Field experiments were made with moisture contents greater than 5.5 per cent up to a maximum of 9 per cent and for this range the amount of bulking did not vary any more than is shown by the bulking curves in Figure 2. A photograph of the plant used in the field tests is shown in Figure 4.

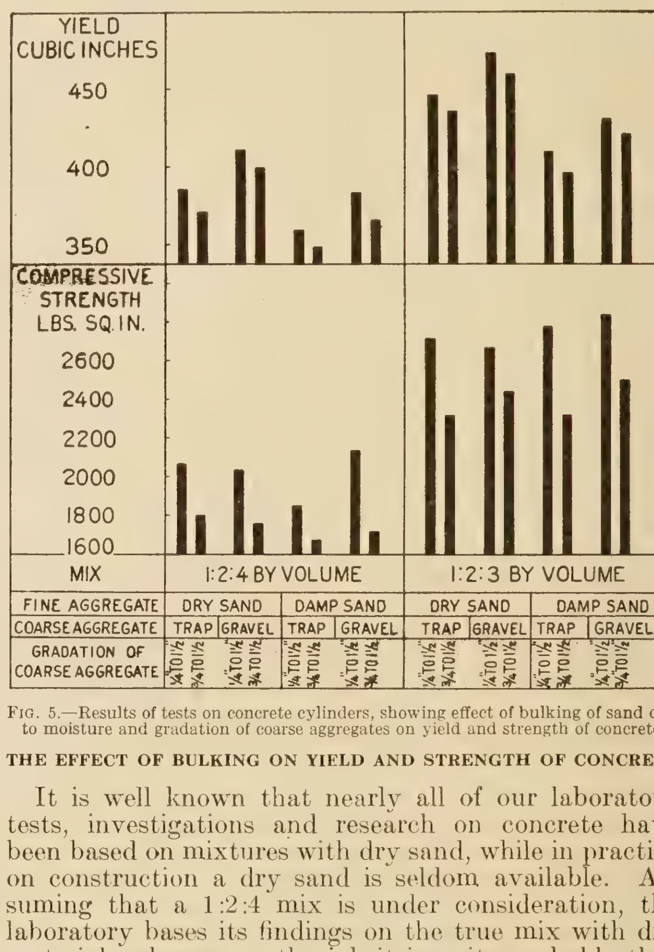



FIG. 5.—Results of tests on concrete cylinders, showing effect of bulking of sand due to moisture and gradation of coarse aggregates on yield and strength of concrete

### THE EFFECT OF BULKING ON YIELD AND STRENGTH OF CONCRETE

It is well known that nearly all of our laboratory tests, investigations and research on concrete have been based on mixtures with dry sand, while in practice on construction a dry sand is seldom available. Assuming that a 1:2:4 mix is under consideration, the laboratory bases its findings on the true mix with dry materials whereas on the job it is quite probable that the mix approximates more nearly 1:1.6:4. As a result of this the field concrete will have a richer mortar than intended, but there may be a deficiency of mortar which will affect both the workability and density of the concrete. If the workability is impaired, the tendency is to use more mixing water and thus the greater richness of the mortar may be offset to some extent at least. It follows, therefore, that a deficiency of mortar may have a direct effect on the strength and yield of concrete.

For the purpose of studying the effect on yield and strength 96 6 by 12 inch concrete cylinders were made and tested. The gradation of coarse aggregates was introduced as an additional variable in order to learn its effect also. The fine aggregate was Potomac

[1] This work was made possible through the courtesy and cooperation of the Blaw-Knox Co. of Pittsburgh, Pa.

River sand and where damp sand was used it contained 6 per cent of water by weight. The materials were proportioned by volume under uniform conditions. The consistency was kept as constant as possible by the use of flow table measurements for each cylinder, in addition to measuring the amount of mixing water beforehand.

The cylinders were made in sets of 16 on six different days, a complete series being cast each day. The operators doing the mixing and molding were changed from day to day so as not to carry any one personal equation throughout the work. It was found that the measurements for yield and the results of the compressive strength tests showed substantially the same trend for each set of 16 cylinders. The average results of the tests on the 96 cylinders are shown in Figure 5.

### CONCLUSIONS

The test results recorded in Figure 5 form the basis for the following definite conclusions:

1. With gravel concrete the yield per unit volume of coarse aggregate exceeds that with trap rock by about 6 per cent.
2. The decrease in yield due to the omission of coarse aggregate between one-fourth and three-fourths inches in size is from 3 to 4 per cent.
3. The decrease in yield due to using the nominal volume of damp sand without a correction for bulking is 7 per cent for a 1:2:4 mix and $8\frac{1}{2}$ per cent for a 1:2:3 mix.
4. The decrease in yield due to using damp sand without a bulking correction and omitting the smaller sizes of coarse aggregate is 12 per cent.
5. For a 1:2:4 mix, the mixes made with dry sand averaged 14 per cent stronger than those made with the same volumes of damp sand. For a 1:2:3 mix, the mixes made with dry sand averaged 3 per cent weaker than those made with the same volumes of damp sand.
6. The omission of the smaller sizes of coarse aggregate resulted in a decrease in strength of from 12 to 14 per cent.
7. With a 1:2:4 mix, the cylinders made with dry sand and well-graded coarse aggregate averaged 17 per cent stronger than those made with damp sand and poorly graded coarse aggregate. With a 1:2:3 mix, this difference in strength was 12 per cent in the same direction.

It should be borne in mind that the above conclusions are based on laboratory specimens only and can not as yet be interpreted to apply directly to field conditions. In fact, it is not the intention of this article to advocate the practice of making a volumetric correction for the bulking of sand on the job until it has been demonstrated that the scheme for making the correction is practicable, also that as a result the concrete is more economical and at least as strong as under present practice. It is thought, however, that the additional sand introduced into the mix, where an adjustment is made for bulking, may tend to improve the workability of the concrete and thus assist in maintaining a uniform consistency and securing a more economical and uniform concrete. All of these possibilities are yet to be demonstrated under actual construction conditions.

(Continued from page 20.)

been reached for some of the specimens it was slowly released, and the recovery of the specimen noted. In some instances this amounted to almost one fourth inch. It thus becomes evident that when the concrete slides over the subbase there is a considerable amount of yielding of the base material, and it is therefore to be expected that if the material is fairly homogeneous, and the movement of the concrete takes place slowly the material of the subbase will gradually yield under this movement, and will thereby offer less resistance than these tests seem to indicate.

### LOWERING FRICTIONAL RESISTANCE SHOULD REDUCE FREQUENCY OF TRANSVERSE CRACKS

In considering friction results, the maximum resistances are naturally of greatest importance, since these create the greatest stresses. Those given in the first table are therefore of more interest than those in the second, and these results very clearly show that the friction varies considerably, depending upon the character of the subbase. The indications are that friction can be greatly decreased if proper care is given to the preparation of the subbase. Every ridge or depression that is in the subbase surface before concrete is deposited furnishes an additional grip for the concrete, thereby tending to elastically deform a larger amount of base material, and thus offering greater resistance to the sliding of the concrete.

The formation of transverse cracks in the concrete bases can readily be ascribed to direct tension due to frictional resistance at a time when the concrete is contracting, whether this is caused by decrease in temperature, or by drying out of the moisture. The test results show that the coefficient of friction can readily vary from almost 0 to something over 2 or more depending upon the movement of the concrete and the character of the subbase. The distance between transverse cracks is dependent upon the coefficient of friction, and the total force of friction must extend over this distance. Calling the coefficient of friction f, the distance between cracks D, the weight of the pavement per square foot w, we may write the equation: $f \times w \times D =$ tensile strength of concrete per foot of width. Assuming the tensile strength of concrete to equal 100 pounds per square inch, the pavement to be 6 inches in thickness, the weight of a cubic foot of concrete to be 150 pounds, and the coefficient of friction to equal 0.5, the equation s stated as follows:

$$0.5 \times 75 \times D = 72 \times 100, \text{ or } D = 185 \text{ feet.}$$

If the coefficient of friction equals 2, the distance between cracks becomes 46 feet. It is conceivable that conditions may exist in which the frictional resistance may mount much higher than this, and may be excessive in spots.

It is quite apparent from the above formula that in order to reduce the frequency of transverse cracks, the subgrade must be made as smooth as possible and the concrete must be kept moist as long as practicable in order to prevent tensile stress from being set up in the concrete before it has acquired high resistance to tension.

# ROAD MATERIAL TESTS AND INSPECTION NEWS

## BUREAU OF STANDARDS SCREEN SCALE FOR TESTING SIEVES

In the April issue attention was called to efforts being made by the American Society for Testing Materials to adopt a practical standard screen scale for testing sieves. Although progress is being made along this line by the society, the work of standardization is of necessity very slow. Until such standardization can be effected, the bureau believes that the United States standard sieve series, adopted by the United States Bureau of Standards, should be used wherever possible.

In a circular letter dated April 15, 1924, the Bureau of Standards calls attention to certain revisions in tolerances on wire diameter and average opening in its screen scale which make it possible easily to obtain sieves commercially which will conform to this standard. The Bureau of Standards also offers to test any sieve for the purpose of determining whether it conforms to the standard screen scale. The schedule of fees for this work is as follows:

| | |
|---|---|
| Test and certification or report on any testing sieve | $2. 00 |
| Extra charge for placing a preliminary identification number on sieves not otherwise identified | . 10 |
| Test and report on a piece of sieve cloth, per square foot | 3. 00 |

Tests for the Federal Government and for State governments are conducted without charge.

*Bureau of Standards screen scale for testing sieves*

| Sieve number | Sieve opening | | Wire diameter | | Tolerance in average opening | Tolerance in wire diameter | Tolerance in maximum opening |
|---|---|---|---|---|---|---|---|
| | *Millimeters* | *Inches* | *Millimeters* | *Inches* | *Per cent* | *Per cent* | *Per cent* |
| 4 | 4. 76 | 0. 187 | 1. 27 | 0. 050 | ±3 | −15 to +30 | 10 |
| 5 | 4. 00 | . 157 | 1. 12 | . 044 | ±3 | −15 to +30 | 10 |
| 6 | 3. 36 | . 132 | 1. 02 | . 040 | ±3 | −15 to +30 | 10 |
| 7 | 2. 83 | . 111 | . 92 | . 036 | ±3 | −15 to +30 | 10 |
| 8 | 2. 38 | . 0937 | . 84 | . 0331 | ±3 | −15 to +30 | 10 |
| 10 | 2. 00 | . 0787 | . 76 | . 0299 | ±3 | −15 to +30 | 10 |
| 12 | 1. 68 | . 0661 | . 69 | . 0272 | ±3 | −15 to +30 | 10 |
| 14 | 1. 41 | . 0555 | . 61 | . 0240 | ±3 | −15 to +30 | 10 |
| 16 | 1. 19 | . 0469 | . 54 | . 0213 | ±3 | −15 to +30 | 10 |
| 18 | 1. 00 | . 0394 | . 48 | . 0189 | ±3 | −15 to +30 | 10 |
| 20 | . 84 | . 0331 | . 42 | . 0165 | ±5 | −15 to +30 | 25 |
| 25 | . 71 | . 0280 | . 37 | . 0146 | ±5 | −15 to +30 | 25 |
| 30 | . 59 | . 0232 | . 33 | . 0130 | ±5 | −15 to +30 | 25 |
| 35 | . 50 | . 0197 | . 29 | . 0114 | ±5 | −15 to +30 | 25 |
| 40 | . 42 | . 0165 | . 25 | . 0098 | ±5 | −15 to +30 | 25 |
| 45 | . 35 | . 0138 | . 22 | . 0087 | ±5 | −15 to +30 | 25 |
| 50 | . 297 | . 0117 | . 188 | . 0074 | ±6 | −15 to +35 | 40 |
| 60 | . 250 | . 0098 | . 162 | . 0064 | ±6 | −15 to +35 | 40 |
| 70 | . 210 | . 0083 | . 140 | . 0055 | ±6 | −15 to +35 | 40 |
| 80 | . 177 | . 0070 | . 119 | . 0047 | ±6 | −15 to +35 | 40 |
| 100 | . 149 | . 0059 | . 102 | . 0040 | ±6 | −15 to +35 | 40 |
| 120 | . 125 | . 0049 | . 086 | . 0034 | ±6 | −15 to +35 | 40 |
| 140 | . 105 | . 0041 | . 074 | . 0029 | ±8 | −15 to +35 | 60 |
| 170 | . 088 | . 0035 | . 063 | . 0025 | ±8 | −15 to +35 | 60 |
| 200 | . 074 | . 0029 | . 053 | . 0021 | ±8 | −15 to +35 | 60 |
| 230 | . 062 | . 0024 | . 046 | . 0018 | ±8 | −15 to +35 | 90 |
| 270 | . 053 | . 0021 | . 041 | . 0016 | ±8 | −15 to +35 | 90 |
| 325 | . 044 | . 0017 | . 036 | . 0014 | ±8 | −15 to +35 | 90 |

The preceding table gives the standard sizes of screen wire and openings with allowable tolerances as recommended by the Bureau of Standards. A detailed explanation of this table is contained in Bureau of Standards Circular LC–74, copies of which may be obtained by addressing the United States Bureau of Standards, Washington, D. C.

## BUREAU OF PUBLIC ROADS DISCONTINUES TESTING OF ROAD MATERIALS FOR GENERAL PUBLIC

On July 1, 1924, the bureau discontinued the general practice of testing samples of road materials for any citizen of the United States. Samples will be tested only when submitted by or at the request of a representative of the United States Government, or of a State, county, or municipality, and then only when accompanied by a statement to the effect that the sampling was done by a disinterested party. This statement should be made on United States Bureau of Public Roads Form T–206, and should include the name and title of the sampler.

## INVESTIGATION OF STABILITY OF BITUMINOUS MIXTURES

Study of the factors which influence the stability of bituminous paving mixtures is being continued by the Bureau of Public Roads. Late in 1922 27 coarse-graded asphaltic concrete mixtures of widely different proportions were laid upon a circular track at the out-of-door laboratory of the bureau at Arlington, Va. These were subjected to truck traffic until their relative stability was shown by various degrees of displacement. Plans are now completed for the replacement of these first mixtures with a second series, 28 of which will be sheet asphalt and five will be coarse-graded asphaltic concrete. Certain indications developed by the original series have been utilized in the design of these mixtures and further information regarding the behavior of fine sand and coarse sand in comparison with the so-called sheet asphalt sand grading is expected to be brought out. Some of the sections will carry varying percentages of filler and in others asphalts of low susceptibility to temperature changes will be used.

It is manifestly impossible to subject to service tests all materials in the infinite variety of combinations to which they are susceptible. The ultimate objects of this investigation, therefore, are the development of the laws which influence stability and the evolution of a laboratory test, or series of tests, by which it will be possible to predetermine the service behavior and relative merits of bituminous mixtures. Consequently, in this scheme the service tests of a comparatively few mixtures of widely different composition and of known traffic-resisting characteristics are expected to play the role of a correlating agency between laboratory and field behavior.

GOVERNMENT PRINTING OFFICE

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

# STATUS OF FEDERAL AID HIGHWAY CONSTRUCTION

AS OF

JUNE 30, 1924

| STATES | FISCAL YEARS 1917-1923 | | | FISCAL YEAR 1924 | | | | | | | | | BALANCE OF FEDERAL AID FUND AVAILABLE FOR NEW PROJECTS | STATES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PROJECTS COMPLETED PRIOR TO JULY 1, 1923 | | | PROJECTS COMPLETED SINCE JUNE 30, 1923 | | | * 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 | $ 3,789,011.74 | $ 1,794,703.21 | 367.9 | $ 809,709.89 | $ 391,544.33 | 96.2 | $ 15,132,450.48 | $ 7,400,051.40 | 866.4 | $ | $ | | $ 1,666,664.06 | Alabama |
| Arizona | 6,518,025.52 | 3,195,689.68 | 372.1 | 1,820,339.89 | 1,091,994.20 | 155.7 | 2,419,995.90 | 1,439,148.62 | 164.7 | 282,404.40 | 172,577.32 | 32.8 | 1,596,291.18 | Arizona |
| Arkansas | 6,623,205.72 | 3,306,572.12 | 736.2 | 2,471,545.59 | 1,115,773.51 | 208.2 | 6,247,120.36 | 1,986,982.36 | 342.9 | 1,618,539.55 | 654,010.77 | 81.1 | 1,997,061.24 | Arkansas |
| California | 6,495,547.60 | 3,538,967.90 | 340.5 | 4,503,527.43 | 2,108,180.27 | 193.2 | 11,871,819.13 | 6,395,695.08 | 434.1 | 1,092,308.63 | 499,050.87 | 25.2 | 4,551,411.88 | California |
| Colorado | 6,470,695.56 | 3,136,238.67 | 426.6 | 1,637,374.75 | 893,660.30 | 76.0 | 4,833,066.27 | 2,595,855.07 | 173.5 | 672,176.76 | 375,620.34 | 21.9 | 2,558,506.62 | Colorado |
| Connecticut | 2,568,643.95 | 1,026,148.85 | 60.7 | 494,226.07 | 243,409.75 | 12.9 | 3,041,169.37 | 1,029,509.90 | 52.3 | | | | 1,082,126.50 | Connecticut |
| Delaware | 2,196,610.22 | 621,154.83 | 45.2 | 860,222.00 | 386,560.00 | 27.3 | 1,096,672.50 | 420,933.60 | 27.6 | 303,864.00 | 107,700.00 | 7.2 | 203,181.57 | Delaware |
| Florida | 69,466.31 | 29,700.63 | 15.6 | 891,667.76 | 431,770.29 | 33.2 | 9,190,175.12 | 4,506,550.50 | 259.4 | 398,642.71 | 171,123.94 | 10.3 | 1,147,741.64 | Florida |
| Georgia | 13,960,499.47 | 6,363,703.60 | 925.5 | 3,206,873.85 | 1,592,101.60 | 288.7 | 8,925,089.27 | 4,268,001.56 | 736.2 | 509,604.61 | 198,168.78 | 50.2 | 2,027,921.46 | Georgia |
| Idaho | 6,880,673.73 | 3,272,111.01 | 426.1 | 1,301,024.19 | 820,284.51 | 80.7 | 1,498,933.13 | 868,722.94 | 97.8 | 934,329.98 | 606,550.13 | 57.4 | 1,110,043.41 | Idaho |
| Illinois | 25,211,526.23 | 11,414,291.96 | 743.5 | 1,753,179.83 | 865,254.37 | 61.2 | 16,485,446.19 | 8,192,130.42 | 557.0 | 608,902.19 | 304,451.08 | 22.1 | 2,660,364.17 | Illinois |
| Indiana | 5,513,487.76 | 2,668,277.55 | 167.0 | 2,063,956.40 | 987,263.42 | 68.7 | 15,956,388.75 | 7,798,552.57 | 523.4 | 829,586.07 | 395,284.89 | 25.6 | 2,463,013.57 | Indiana |
| Iowa | 16,040,079.62 | 6,056,136.48 | 1059.4 | 7,155,698.57 | 3,180,895.38 | 623.5 | 8,689,469.34 | 4,026,657.08 | 622.9 | 289,642.44 | 144,342.39 | 42.5 | 1,928,105.67 | Iowa |
| Kansas | 12,216,428.90 | 4,248,438.34 | 349.7 | 4,867,707.58 | 1,734,738.46 | 153.0 | 16,689,331.36 | 6,248,427.04 | 598.0 | 2,874,528.15 | 1,196,608.53 | 121.6 | 1,811,076.63 | Kansas |
| Kentucky | 6,620,288.80 | 2,789,991.15 | 285.0 | 4,202,690.51 | 1,823,956.13 | 144.4 | 7,573,552.00 | 3,663,928.55 | 329.2 | 101,082.14 | 50,541.07 | 4.0 | 2,043,322.10 | Kentucky |
| Louisiana | 7,131,394.90 | 3,157,128.03 | 590.4 | 1,357,068.28 | 479,015.33 | 70.8 | 5,683,581.53 | 2,815,058.90 | 372.3 | | | | 814,239.74 | Louisiana |
| Maine | 4,662,854.19 | 2,242,963.03 | 159.8 | 2,248,204.59 | 1,056,972.35 | 70.9 | 1,437,207.97 | 714,171.72 | 54.6 | 735,510.48 | 359,684.85 | 30.2 | 716,180.05 | Maine |
| Maryland | 5,309,394.94 | 2,524,843.54 | 185.0 | 1,450,649.48 | 688,478.24 | 58.2 | 2,225,748.35 | 894,685.95 | 71.0 | 435,565.02 | 138,232.09 | 12.6 | 402,710.18 | Maryland |
| Massachusetts | 6,841,975.16 | 2,802,957.88 | 163.7 | 3,349,226.86 | 1,302,769.34 | 69.1 | 5,173,074.47 | 1,800,430.47 | 90.4 | 475,458.32 | 142,847.12 | 7.1 | 1,870,775.19 | Massachusetts |
| Michigan | 9,526,041.53 | 4,343,817.14 | 363.4 | 3,906,093.54 | 1,716,795.09 | 131.1 | 13,609,397.79 | 6,587,382.19 | 484.5 | 169,111.25 | 80,185.50 | 5.2 | 3,151,592.08 | Michigan |
| Minnesota | 19,628,671.37 | 8,004,277.87 | 1893.4 | 4,208,889.87 | 1,881,565.20 | 398.6 | 8,600,577.00 | 3,623,184.40 | 676.4 | 671,124.09 | 290,100.00 | 113.7 | 1,519,291.53 | Minnesota |
| Mississippi | 4,746,771.31 | 2,284,557.86 | 462.4 | 3,141,422.58 | 1,544,383.53 | 192.6 | 7,695,258.21 | 3,839,698.61 | 489.8 | 313,302.99 | 133,316.80 | 10.0 | 1,729,316.20 | Mississippi |
| Missouri | 5,272,757.08 | 2,358,848.60 | 365.6 | 6,079,270.62 | 2,887,050.58 | 437.9 | 14,814,141.06 | 7,070,575.64 | 601.9 | 2,962,047.64 | 1,440,646.30 | 181.2 | 4,163,066.88 | Missouri |
| Montana | 7,935,165.30 | 3,896,053.50 | 711.5 | 932,093.86 | 488,281.62 | 79.9 | 2,537,536.91 | 1,922,348.47 | 265.6 | 1,396,549.47 | 780,776.09 | 119.5 | 3,878,957.32 | Montana |
| Nebraska | 3,159,614.47 | 1,449,675.04 | 475.6 | 4,716,522.69 | 2,265,016.55 | 964.8 | 6,675,996.20 | 3,244,725.73 | 687.2 | 1,133,884.44 | 561,762.35 | 100.2 | 3,929,766.33 | Nebraska |
| Nevada | 3,049,109.29 | 1,562,111.35 | 203.6 | 411,136.23 | 291,513.63 | 22.0 | 4,755,024.78 | 4,063,643.23 | 394.1 | 67,255.43 | 56,086.90 | 3.5 | 916,963.89 | Nevada |
| New Hampshire | 2,336,997.00 | 1,129,004.69 | 140.5 | 739,753.19 | 358,862.89 | 30.8 | 886,516.84 | 414,374.33 | 29.8 | 275,923.34 | 130,442.38 | 9.4 | 402,279.71 | New Hampshire |
| New Jersey | 5,423,362.96 | 1,975,783.52 | 112.1 | 2,200,432.16 | 665,747.97 | 36.6 | 10,226,184.47 | 2,728,243.65 | 70.1 | 417,573.68 | 107,667.49 | 4.1 | 1,091,804.37 | New Jersey |
| New Mexico | 4,706,909.12 | 2,433,663.68 | 617.1 | 599,377.33 | 325,186.00 | 97.2 | 6,165,553.69 | 4,041,486.28 | 657.7 | 825,138.02 | 507,459.84 | 54.7 | 1,281,536.20 | New Mexico |
| New York | 9,826,633.82 | 4,358,659.70 | 290.6 | 9,036,108.67 | 3,899,184.74 | 282.1 | 24,663,366.96 | 9,526,032.97 | 563.2 | 7,272,400.00 | 2,430,398.75 | 147.6 | 6,493,871.84 | New York |
| North Carolina | 11,770,363.76 | 5,325,763.37 | 826.8 | 797,369.21 | 350,994.29 | 57.9 | 9,623,594.36 | 3,484,417.74 | 266.6 | 2,354,959.10 | 1,060,134.58 | 55.2 | 2,072,941.02 | North Carolina |
| North Dakota | 5,142,167.55 | 2,492,599.09 | 792.5 | 3,946,815.56 | 1,925,906.33 | 795.4 | 3,159,113.69 | 1,554,191.41 | 504.0 | 518,237.30 | 259,119.11 | 80.8 | 2,131,840.06 | North Dakota |
| Ohio | 22,840,050.09 | 7,966,325.17 | 662.8 | 10,282,701.34 | 3,913,592.82 | 299.7 | 12,789,365.01 | 4,853,124.66 | 351.1 | 1,674,801.96 | 529,493.47 | 42.4 | 2,877,627.88 | Ohio |
| Oklahoma | 9,795,634.54 | 4,417,788.46 | 371.5 | 3,191,230.72 | 1,471,063.57 | 125.8 | 8,689,043.76 | 4,194,467.46 | 389.8 | 2,008,286.36 | 826,077.47 | 82.4 | 1,628,306.04 | Oklahoma |
| Oregon | 10,391,362.48 | 4,782,736.38 | 534.1 | 1,691,510.69 | 1,036,357.41 | 121.5 | 2,927,450.56 | 1,708,203.60 | 175.6 | 488,601.30 | 298,714.84 | 29.5 | 680,146.77 | Oregon |
| Pennsylvania | 33,090,029.45 | 12,615,056.79 | 652.8 | 3,735,219.53 | 1,499,636.00 | 76.9 | 15,325,653.77 | 4,613,831.25 | 268.5 | 7,246,308.80 | 1,820,951.25 | 118.7 | 4,052,138.71 | Pennsylvania |
| Rhode Island | 1,484,075.35 | 647,634.96 | 38.6 | 290,321.90 | 131,593.00 | 7.4 | 1,087,787.06 | 411,759.49 | 22.7 | 334,265.25 | 89,147.31 | 5.6 | 652,906.24 | Rhode Island |
| South Carolina | 6,161,485.41 | 2,885,754.37 | 655.1 | 2,834,991.32 | 1,238,290.85 | 269.3 | 5,998,020.81 | 2,360,714.93 | 517.6 | 547,844.28 | 162,127.61 | 28.1 | 1,040,658.24 | South Carolina |
| South Dakota | 4,756,907.24 | 2,320,007.33 | 534.5 | 3,915,690.62 | 1,924,628.94 | 455.3 | 6,268,470.80 | 3,166,316.97 | 793.1 | 674,713.27 | 306,887.96 | 38.4 | 980,838.80 | South Dakota |
| Tennessee | 3,210,970.94 | 1,535,762.18 | 112.5 | 3,594,712.41 | 1,778,173.89 | 147.1 | 13,761,114.87 | 6,501,844.69 | 433.3 | 1,333,366.80 | 580,307.44 | 52.6 | 1,628,548.80 | Tennessee |
| Texas | 29,172,501.06 | 11,094,069.77 | 2259.6 | 13,169,497.50 | 5,096,555.14 | 863.2 | 25,874,603.79 | 10,200,655.43 | 1624.5 | 2,875,326.43 | 1,039,200.03 | 165.7 | 4,293,732.63 | Texas |
| Utah | 2,175,007.41 | 1,196,437.68 | 116.6 | 1,129,416.34 | 699,368.24 | 102.4 | 4,382,736.86 | 2,833,446.15 | 304.2 | 351,526.03 | 250,895.55 | 28.6 | 1,136,325.38 | Utah |
| Vermont | 1,370,715.63 | 669,433.75 | 53.1 | 551,398.53 | 273,335.37 | 21.3 | 1,527,160.47 | 731,432.50 | 42.6 | 357,120.31 | 176,795.65 | 7.9 | 682,981.73 | Vermont |
| Virginia | 6,823,978.36 | 3,279,029.56 | 402.5 | 3,211,323.12 | 1,522,752.87 | 160.0 | 8,859,252.85 | 3,975,621.01 | 302.7 | 1,110,531.09 | 183,718.10 | 35.1 | 1,631,831.46 | Virginia |
| Washington | 10,356,960.82 | 4,812,105.70 | 419.8 | 1,027,634.85 | 471,789.75 | 37.2 | 2,851,003.81 | 1,306,000.00 | 121.6 | 325,457.31 | 140,000.00 | 9.2 | 1,149,782.55 | Washington |
| West Virginia | 4,100,225.73 | 1,800,932.41 | 206.3 | 1,369,522.22 | 564,109.12 | 49.3 | 4,823,818.81 | 2,158,539.55 | 163.8 | 822,524.01 | 371,845.22 | 28.2 | 858,705.70 | West Virginia |
| Wisconsin | 15,504,691.39 | 5,996,389.24 | 1077.6 | 3,249,211.76 | 1,444,044.33 | 247.7 | 3,546,039.10 | 1,763,705.92 | 150.4 | 237,619.47 | 106,939.26 | 10.4 | 4,366,772.25 | Wisconsin |
| Wyoming | 4,601,439.36 | 2,210,774.20 | 534.8 | 1,526,186.25 | 867,324.50 | 152.8 | 4,355,513.36 | 2,647,849.95 | 327.4 | | | | 961,402.35 | Wyoming |
| Hawaii | | | | | | | | | | | | | $ 365,625.00 | Hawaii |
| TOTALS | $ 407,704,641.14 | $ 174,044,673.82 | 23297.2 | $ 141,950,750.13 | $ 63,807,726.00 | 9155.7 | $ 380,649,591.14 | $ 172,613,311.94 | 18053.5 | $ 50,927,944.87 | $ 20,236,993.42 | 2119.7 | 94,422,294.82 | TOTALS |

* Includes projects reported completed (final vouchers not yet paid) totaling: Estimated cost $ 55,507,667.40 Federal aid $ 25,385,774.44 Miles 2704.0

# APPORTIONMENT OF THE FEDERAL AID FUND

FISCAL YEAR 1925

| States | Amount | States | Amount |
|---|---|---|---|
| Alabama | $1, 542, 052. 56 | Nebraska | $1, 577, 155. 34 |
| Arizona | 1, 053, 003. 56 | Nevada | 947, 623. 25 |
| Arkansas | 1, 258, 857. 07 | New Hampshire | 365, 625. 01 |
| California | 2, 464, 990. 78 | New Jersey | 936, 413. 03 |
| Colorado | 1, 361, 482. 06 | New Mexico | 1, 185, 528. 88 |
| Connecticut | 475, 513. 91 | New York | 3, 663, 105. 86 |
| Delaware | 365, 625. 17 | North Carolina | 1, 697, 246. 16 |
| Florida | 887, 336. 52 | North Dakota | 1, 178, 708. 13 |
| Georgia | 1, 983, 022. 99 | Ohio | 2, 795, 804. 69 |
| Hawaii | 365, 625. 00 | Oklahoma | 1, 753, 189. 71 |
| Idaho | 936, 698. 01 | Oregon | 1, 176, 830. 15 |
| Illinois | 3, 203, 867. 99 | Pennsylvania | 3, 365, 956. 21 |
| Indiana | 1, 939, 903. 32 | Rhode Island | 365, 624. 87 |
| Iowa | 2, 078, 248. 33 | South Carolina | 1, 054, 028. 17 |
| Kansas | 2, 081, 230. 04 | South Dakota | 1, 209, 144. 18 |
| Kentucky | 1, 411, 584. 45 | Tennessee | 1, 628, 740. 97 |
| Louisiana | 995, 301. 59 | Texas | 4, 410, 169. 76 |
| Maine | 686, 453. 36 | Utah | 847, 741. 90 |
| Maryland | 635, 945. 01 | Vermont | 365, 625. 27 |
| Massachusetts | 1, 089, 806. 22 | Virginia | 1, 448, 562. 55 |
| Michigan | 2, 226, 824. 73 | Washington | 1, 113, 308. 17 |
| Minnesota | 2, 120, 906. 56 | West Virginia | 798, 275. 47 |
| Mississippi | 1, 294, 371. 65 | Wisconsin | 1, 877, 600. 32 |
| Missouri | 2, 423, 485. 75 | Wyoming | 936, 372. 13 |
| Montana | 1, 544, 483. 19 | Total | 73, 125, 000. 00 |