SELECTION OF THE OPTIMUM SIZE STORAGE TANK FOR USE IN BULK MILK HANDLING

by

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INTRODUCTION

In recent years there has been an ever-increasing trend among grade-A milk producers throughout the United States toward the adoption of bulk milk handling facilities. This adoption of bulk facilities involves the transport and receiving of milk at processing plants as well as the production of this basic and vital food commodity. Experiments with bulk storage at the farm, pick-up, and transport in bulk to the processing plant were first conducted in California in 1939.1/ The practice of handling milk in bulk for cooling on the farm and for hauling to relay stations or processing plants has grown rapidly since about 1953. In that year there were approximately 6,000 bulk milk cooling tanks on farms throughout the United States. By December, 1956, there were approximately 57,000 bulk tanks in use on American dairy farms.2/ By June, 1958, surveys showed more than 80,000 bulk tanks in use throughout the country with more than 11,000 tanks in operation in the largest milk producing state, Wisconsin.3/

1/ The Heil Company, The Bulk Pick-up System of Marketing Milk, 1953, p. 11.

2/ U.S. Department of Agriculture, How Bulk Assembly Changes Milk Marketing Costs, 1957, p. 1.

3/ Dean, Myron P., "Pros and Cons on Bulk Milk Handling", Hoards Dairyman, June 10, 1958, p. 601.

The trend toward increased utilization of bulk milk facilities has also been pronounced in the State of Virginia. By late 1955 approximately 700 Virginia dairy farmers were reported to be using bulk storage tanks. These producers represented nearly seventeen percent of Virginia dairymen engaged in producing grade-A milk at that time.1/ By early 1959 there were approximately 2200 bulk storage tanks in use throughout the State. This number represented over seventy percent of the grade-A milk producers in Virginia at that date. The Washington, D. C., area, for example, received nearly one hundred percent of its milk from bulk tanks.2/ To collect and transport milk from these bulk storage tanks to processing plants or relay stations, there were 126 bulk tanker trucks in operation in Virginia in January, 1959.3/ The combined capacity of these trucks was over 280 thousand gallons.

The trend toward bulk milk handling indicates an ever-increasing investment in new equipment by producers, haulers, and milk precessors and distributors. Because of the investment involved in conversion to bulk handling, decisions to undertake such conversion are important ones. These decisions may be the result of any one of, or any combination of,

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1/ Agricultural Extension Service, "Dairy Outlook", Virginia Farm Economics, Virginia Polytechnic Institute, November, 1955, p. 7

2/ Virginia Department of Agriculture-Virginia Polytechnic Institute Agricultural Extension Service, The Grade-A Dairy Industry in Virginia, 1959, pp. 4, 47.

3/ Ibid. p. 19

several factors: (1) marketing regulations may force conversion from can to bulk handling; (2) the processor may institute the conversion for any one or more of a variety of reasons; (3) the producers themselves may favor and work toward conversion to the bulk handling of milk.

Having acknowledged the increasing trend toward the use of bulk handling facilities throughout the United States and in Virginia, attention is directed to the basic problem studied here.

Problem

From the standpoint of public welfare, a basic objective in marketing is that of making a given commodity available to the consumer at the least possible cost. To achieve this objective, resources must be used efficiently. Ordinarily, in the marketing process, management decisions involving resource use are made by several firms before the commodity reaches the consumer. Each step in the marketing process requires the commitment of resources and associated costs. In the marketing of grade-A milk, two significant costs are those of storage and transportation to processing plant or receiving station. In the current trend toward bulk handling of grade-A milk, the resources used (in the form of bulk storage tanks and bulk tankers for transportation) increase costs beyond that level associated with conventional can storage and hauling. These costs thus become even more significant in contributing to the price ultimately paid for milk on the consumer

market. Since, on a given milk route, there are many producers who must store milk, the cost of such storage becomes particularly important. The selection of storage tanks is usually made at or after the time at which the determination is made of hauling facilities and frequency of milk collection. Therefore, this study of the resources used by producers on a selected sample route and the selection of optimum tank size also includes the consideration of resources used by the hauler. Further, since resources used for storage and for hauling are interrelated, this study will examine the aggregate use of resources by producers and the hauler on the sample route selected for study.

In this study, optimum tank size will be assumed to be that size used by each producer which, when used in conjunction with existing hauling facilities under a given frequency of collection, will result in the least-cost storage and movement of milk to the receiving plant. Optimum size is, therefore, to be considered as that size for each producer (or combination of sizes for all route producers) which will produce the most efficient use of resources in the storage of milk and which, when combined with the most efficient use of resources by the hauler, will result in the least total cost of storing and transporting milk to the receiving plant.

This study will examine the aggregate resource use on a route where the decision has already been made to store and move milk in bulk. On such a route where the decision has been made to adopt the bulk system of storage and transport, the next logical and important decision involves

the selection of equipment to be used by both producers and hauler. The hauler must determine what kind of bulk tanker to use. His decision may be influenced by such factors as truck size, tank size, prices of competing lines of equipment, and a host of other factors.

The producers are also confronted with a variety of factors which will influence the selection of bulk tanks. Present herd size, plans to expand or not to expand herd size, ability to control seasonality of production, kinds and makes of storage tanks, prices of competing lines - - these factors should all be considered before milk producers on a given route select storage tanks. However, a decisive influence involved in the selection of both bulk storage tanks by producers and the selection of a transport tanker by the hauler is the frequency of milk pick-up to be practiced upon conversion to bulk handling. This factor is basic to the final determination of resource use and storage cost for producers as well as resource use and hauling costs for the hauler.

The size of storage tanks and associated costs, as well as size of bulk tanker and associated costs, will be a function of the frequency of milk pick-up. A number of surveys of dairy marketing indicate that every-other-day milk pick-up is employed in a large majority of the areas where bulk handling of milk is practiced. Findings contained in one study made by the United States Department of Agriculture indicate that in 1956 over half of the processing plants in the nation equipped to handle milk in bulk were receiving the individual producers' milk on

an every-other-day basis.1/ The majority of literature reviewed for this study indicated that this frequency of milk collection is the most commonly used where bulk handling is employed.

If every-other-day frequency of pick-up is being practiced without regard to the possible economies to be had from some alternative pick-up frequency, then such a practice arbitrarily establishes storage tank size for producers. In so doing, the producers on a given route may be forced to invest capital unnecessarily or may be denied savings resulting from some other frequency of pick-up. In addition to investment in storage tanks, operating costs associated with tanks selected for every-other-day pick-up would be just as arbitrarily determined. At the same time, it is logical to assume that economies for the hauler may be associated with some other frequency of collection. Less frequent collection would reduce truck operating costs under certain route conditions.2/

Finally, resources in the aggregate may not be used with maximum efficiency. There is some basis for reasoning that every-other-day frequency of milk pick-up practiced on the sample route selected for study does not permit the most efficient use of resources in the storage and transportation of milk to the processing plant. Since frequency of

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1/ U.S. Department of Agriculture, How Bulk Assembly Changes Milk Marketing Costs, 1957, p. 29.

2/ On a large route with many producers, for example, the hauler might arrange third-day pick-up to accommodate additional milk volume without undergoing the expense of acquiring an additional truck.

Milk pick-up affects resource use by both producers and the hauler on a given route, this study will examine the effects on aggregate resource use on a sample route when frequency of pick-up is projected to some other frequency. Particular attention will be directed to the selection of the optimum size of storage tanks resulting from the frequency of milk collection which permits the least-cost method of storing and transporting a given volume of milk to the processing plant.

In this study the costs of storing and collecting milk every day and every third day will be compared with those costs associated with every-other-day storage and collection on a selected route. This comparison will be made to determine the relative economies of the different frequencies of pick-up.

The hypothesis of this study is that, as frequency of milk storage and collection is extended from every day to every third day, dollars used by producers (for storage) substitute at a diminishing marginal rate for dollars used by the route hauler (for transportation).

Objectives of the Study

The objectives of this study are to determine for a sample bulk milk route: (1) total storage tank investment and operating costs of all route producers required for bulk storage of milk where pick-up is made every day, every other day, and every third day; (2) bulk tanker investment and costs of operation required for every-day, every-other-day, and every-third-day milk pick-up; (3) the rate at which all

resources used by route producers (for storage) substitute for resources used by the hauler (for transportation); (4) the resource use combination which will permit the lowest possible cost of milk storage and movement from farm to receiving station; and (5) the selection of optimum size storage tanks for storage of a given annual volume of milk.

Typicalness and Description of the Selected Case

The literature reviewed for this study consisted primarily of text material pertaining to the principle of substitution and research bulletins containing studies of bulk milk storage and collection.

Basic information pertaining to the principle of substitution was derived from economic texts.1/ Further explanations and illustrations of substitution and of resource use were obtained from agricultural periodicals.2/

The review of literature for this study revealed that the majority of previous studies of bulk milk handling were concerned with problems associated with conversion from conventional can storage and collection of milk. Only one study touched on the possibility of economies associated with the extension of storage and milk collection to every

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1/ Heady, E.O., Economics of Agricultural Production and Resource Use, Prentice-Hall, 1952, Chapter 5.

2/ Chambliss, R. Lee, Jr., "Reducing Costs Through Substitution", Virginia Farm Economics, Virginia Polytechnic Institute, Agricultural Extension Service, February, 1959, pp. 8-10.

third day which has been examined in this study.1/ No previous studies were found which examined, in detail, the variation of frequency of storage and pick-up to determine economies of resource use associated with each frequency. Research bulletins reviewed touched lightly on comparisons between every-day and every-other-day pick-up, but did not treat aggregate use of resources associated with each situation.

For the reasons mentioned above, the search of literature was concentrated on establishing that the sample route used in this study was a reasonably typical one and that procedures and resources used were representatives of those used throughout the grade-A dairy industry.

On the sample route studied, the twenty-two producers involved used storage tanks ranging in size from 200 to 1000 gallons capacity.2/ These sizes seemed representative of tanks mentioned in other studies of bulk milk handling. One study of fifty-nine farms selling milk in the Washington, D. C., milk shed showed tank sizes ranging from 200 to 600 gallons capacity.3/ A study of the bulk system in the state of Oregon

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1/ Baum, E.L. and Pauls, D.E., A Comparative Analysis of Costs of Farm Collection of Milk by Can and Tank in Western Washington, 1952, State College of Washington, Technical Bulletin 10, May, 1953, pp. 26-27.

2/ Appendix B, Table 1.

3/ Beal, G.M. and Twining, C.R., Bulk Handling of Milk in the Washington, D. C. Milk Shed, University of Maryland Agricultural Experiment Station, Misc. Publication 176, June, 1953, p. 9.

showed a size range of from 100 to 1000 gallons capacity.1/ A study of one New England area reported tank sizes ranging from 300 to 1000 gallons capacity.2/ By late 1957, tanks used in the area served by the Maryland and Virginia Milk Producers' Association for the metropolitan Washington, D. C., market ranged from 100 to 1500 gallons capacity with an average tank size of 300 gallons.3/

With respect to tank size, this study revealed excessive tank investment by producers.4/ The producers on the Farris Brothers route have their milk picked up every other day. Recommendations for the purchase of the correct size tank (based on each producers' output) are available from a number of sources, and it is surprising that there was seemingly little correlation between recommended tank size and actual size of tanks on the route studied.

For every-other-day pick-up, a Vermont study recommends tank capacity for four milkings plus allowance for herd expansion.5/ A study made at the University of Maryland also recommends tank capacity for

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1/ Nelson, Glen T., Economic Aspects of Farm Tank Handling of Milk in Oregon, Agricultural Experiment Station, Oregon State College, Circular of Information 520, February, 1953, p. 2.
2/ Vermont Agricultural Experiment Station, Economic Effects of Bulk Milk Handling in Vermont, Bulletin 581, June, 1955, p. 13.
3/ Smathers, James B., "Before Shifting from Cans to Bulk ...", Hoard's Dairyman, November 25, 1957, pp. 1126-1127.
4/ Appendix B, Table 4.
5/ Vermont Agricultural Experiment Station, Economic Effects of Bulk Milk Handling in Vermont, Bulletin 581, June, 1955, p. 18.

four milkings with every-other-day pick-up.1/ However, the Maryland study showed that, of fifty-nine farms studied, less than forty percent of the tanks used were large enough to hold milk for every-other-day pick-up during the flush production season. This situation is in sharp contrast to the excessive tank sizes found on the farms included in this study. The major reason given by producers on the route studied for excessive tank size was a desire to have ample storage capacity for future herd expansion. This reason for larger-than-necessary tank size is supported by a study made of a sample area within the Washington, D. C., milk shed. In that study, of fifty-nine farms surveyed and where tank utilization was low on a number of farms, twenty-five producers had increased herd size since tank installation or were planning to do so.2/

Of the twenty-two tanks used on the sample route, twenty were ice-bank types and two were the direct-expansion type.3/ This pattern of tank types is contrary to the general trend toward adoption of bulk storage tanks in Virginia. By early 1959 sixty-seven percent of the bulk tanks used in Virginia were direct expansion tanks and only thirty-three percent were ice-bank.4/

Initial storage tank cost on the route studied ranged from $2,161

1/ Beal and Twining, Op. cit., p. 10.
2/ Beal and Twining, Op. cit., p. 13.
3/ Appendix B, Table 1.
4/ Figures obtained from Dr. G. C. Graf, Head, Department of Dairy Science, Virginia Polytechnic Institute.

for the smallest tank of 200 gallons capacity to $4,783 for the largest tank of 1000 gallons capacity.1/ These were suggested retail selling prices.2/ These prices seemed reasonable in light of tank prices in other areas. For example, Glen T. Nelson of Oregon State College has reported tank costs of as low as $1,750 for a 100 gallon tank to as high as $5,574 for a 1000 gallon tank.3/ In the Vermont study, average prices of tanks ranging in size from 200 gallons to 500 gallons were as follows:

Tank size-gallons	Average price
200	$2,021
300	$2,389
400	$2,693
500	$3,188 4/

Prices paid for equivalent size tanks used on the route studied here were as follows:

Tank size-gallons	Price paid
200	$2,161
300	$2,628
400	$2,571
500	$3,628

It should be noted that prices in the Vermont study are five years old.

Several studies indicate that costs of operating the ice-bank tanks were somewhat higher than costs of operating the direct-expansion tanks. Electrical costs constitute a major part of cost of operation. A study

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1/ Appendix B, Table 2.
2/ Prices were taken from price lists obtained from manufacturers of tanks used on the route studied.
3/ Nelson, Op. cit., p. 2.
4/ Vermont Agricultural Experiment Station, Economic Effects of Bulk Milk Handling in Vermont, Bulletin 581, June, 1955, p. 13.

by Michigan State University states that the cost of electricity is higher for the ice-bank type tank than for the direct-expansion tank.1/ The Vermont study reports that, in a field test using electrical meters on both direct-expansion and ice-bank type tanks, electrical consumption was somewhat higher for the ice-bank tanks.2/ Somewhat higher electrical consumption by ice-bank tanks, as compared to direct-expansion tanks, was also reported by one U.S.D.A. bulletin reviewed.3/ Cost of operation of tanks used on the sample route studied is discussed later.

With respect to the hauler, the equipment and procedures used on the sample route studied were found to be reasonably typical of equipment and procedures used elsewhere in the grade-A dairy industry.

The hauler on the route studied used an 1800 gallons capacity bulk tanker equipped with a positive-action pump capable of pumping at the rate of fifty gallons per minute. One study of the transition to bulk handling of milk in northern New England showed thirty percent of the bulk tankers in use to have a capacity of 1800 gallons.4/ These trucks

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1/ Michigan State University, Handling Milk in Bulk on the Farm, Cooperative Extension Service, Extension Bulletin 342, p. 16.

2/ Vermont Agricultural Experiment Station, Economic Effects of Bulk Milk Handling in Vermont, Bulletin 581, June, 1955, p. 14.

3/ United States Department of Agriculture, How Bulk Assembly Changes Marketing Costs, Agricultual Marketing Service, Marketing Research Division, Report 190, July, 1957, pp. 40-41.

4/ Bowring, J. R. and Taylor, K.A., Transition to the Bulk Assembly of Milk in Northern New England, University of New Hampshire, Agricultural Experiment Station, Station Bulletin 453, October, 1958, p. 30.

were equipped with two types of pumps - - centrifugal and positive-action. While the centrifugal pumps normally have a faster pumping capacity, they have the disadvantage of using gravity flow so that the storage tank must be higher than the bulk tanker pump. The positive-action pump has a smaller pumping capacity but can pump milk from below the tanker level. This is a positive advantage since, on the route studied, all but one of the storage tanks were below the level of the bulk tanker when milk was pumped from storage tank to truck. The bulk tanker used on the Farris route is equipped with this positive-action type pump.

With respect to farm-stop procedure employed by the tanker operator, the procedure followed at each farm on the sample route was found to be similar to procedures reported in other studies. This procedure is discussed later.

Farm-stop time under every-other-day milk collection ranged from 10.4 minutes to 20.4 minutes with an average time of 13.5 minutes per farm.1/ This average farm-stop time compared favorably with an average stop time of 14.6 minutes reported in a study of bulk milk handling by Glen T. Nelson of Oregon State College.2/ The major portion of this total stop time was consumed by fixed time operations of approximately

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1/ Appendix C, Table 4.
2/ Nelson, Op. cit., p. 4.

9.0 minutes. This time was about the same as that reported by Baum and Pauls who found fixed time operations to average 8.5 minutes at each farm using bulk storage facilities.1/ In a study for The Heil Company these fixed operations were reported to range from 5.8 to 12.9 minutes per farm stop.2/ One U.S.D.A. Marketing Research report shows a fixed time variance per farm of from 6.0 to 15.0 minutes.3/

Variable time operations on the route studies ranged from 1.4 to 11.4 minutes per stop. This time element is a function of milk volume, pump capacity, season, frequency of collection, and a number of other factors. Variable time operations for the sample route are presented in Appendix C, Table 4.

Since the variance of milk collection frequency was used in this study to examine the use of resources under each frequency of pick-up, other studies which examined savings associated with different collection frequencies were of particular interest. Of the material examined, those studies which discussed hauling costs suggested that lower costs were associated with every-other-day bulk collection of milk, (as compared with every-day collection). Although the studies examined referred only to savings accruing to the hauler, a number of comments were made in

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1/ Baum and Pauls, Op. cit., p. 15.
2/ The Heil Company, The Bulk Pick-up System of Marketing Milk, Milwaukee, 1953, p. 5.
3/ United States Department of Agriculture, How Bulk Assembly Changes Milk Marketing Costs, Agricultural Marketing Service, Marketing Research Division, Report 190, July, 1957, p. 29.

reference to cost changes when frequency of pick-up was altered. In a study for the Farmer Cooperative Service, Joseph M. Cowden made the following remarks concerning every-other-day versus every-day pick-up of milk:

> Every-other-day bulk service on the other hand can reduce both mileage and time requirements on a per hundredweight of milk basis. Total hauling costs on efficiently organized every-other-day bulk routes are not only much lower than on daily bulk routes but in practically all cases substantially lower than on can routes serving comparable groups of producers..... Every-other-day bulk service can save up to 50 percent on the mileage of the pickup section of the route as compared to daily service by either bulk or can trucks.... Every-other-day service also provides a practicable solution to the high farm stop time problem. The every-other-day hauler, by picking up 2 days' milk at each stop, cuts the farm stop time per 100 pounds of milk to about the time it takes to load the same amount of milk in cans.... As the volume of milk collected per farm increases, the time spent by the bulk hauler at the farm is more efficiently utilized. As previously indicated this time does not increase in proportion to the quantity of milk loaded. To a considerable extent the same costs are spread over a greater volume of milk. This fact is primarily responsible for improvement in the relative cost position of bulk hauling as the volume of milk loaded per stop increases.1/

Bowring and Taylor state that the fixed time operations which represent overhead costs for the hauler can be reduced through change from daily collection to every-other-day collection. They further suggest that savings resulting from every-other-day or every-third-day

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1/ Cowden, Joseph M., Comparing Bulk and Can Milk Hauling Costs, Farmer Cooperative Service, United States Department of Agriculture, FCS Circular 14, June, 1956, pp. 4-6.

pick-up can be passed on to producers in the form of lower hauling rates.1/ One study for The Heil Company suggests that, by making pick-ups every other day or even every third day, the hauler can serve two or three routes with the same pick-up tanker and thus more fully utilize his equipment.2/

Only one study reviewed contained information pertaining to costs associated with every-third-day collection. This study, conducted by Baum and Pauls, reported third-day pick-up to be cheaper than other frequencies of pick-up in the area studied. Their study contains the following comments regarding collection frequency:

> An increase in the time interval between collections necessitates greater investments in farm storage and refrigeration equipment. This policy would result in higher fixed costs on the farm. Since the total amount of milk handled each day at the receiving point would not be affected, receiving room costs per hundredweight of milk ought to remain the same. The distance traveled to collect a given amount of milk decreases with each day increase in the collection time interval; hence, truck operation costs per hundredweight of milk would decrease. The shorter route length associated with a given volume of milk and the decrease in the total fixed time required to service fewer stops result in lower route labor costs.
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> The analysis comparing daily can pick-up of milk and alternate day, every third day, and every fourth day, indicates the lowest cost of collection and receiving per hundredweight of milk is secured when the alternate day pick-up of milk in cans is used. A similar comparison made for tank pick-up systems indicates every third day pick-up to have the lowest cost per hundredweight of milk.

1/ Bowring and Taylor, Op. cit., p. 37.
2/ The Heil Company, The Bulk Pick-up System of Marketing Milk, Milwaukee, 1953, p. 8.

> Beyond these points, the increase in farm storage and refrigeration costs offsets any savings gained by the other factors.1/

The material quoted above would indicate that positive economies are to be found with every-third-day storage and collection of milk.

1/ Baum and Pauls, Op. cit., pp. 26-27.

DESIGN OF THE STUDY

This study was designed to make use of the case study method to determine whether a more efficient system than that presently used in bulk milk handling on a small milk collection route is feasible. Estimates for alternative systems are projected by the use of available data in the construction of budgets for systems involving variations in the frequency of milk pick-up. Resultant estimated costs of the several systems, indicating the differential incidence of these costs on both the producers and the hauler, permit determination of the least-cost method of storing and moving a given volume of milk from farm to processor.

Analytical Setting

The analytical tool used here is that of the principle of substitution.1/ This is explained adequately in the literature, but since its use will be modified somewhat, some clarification seems necessary. In production situations where the output can be held constant and two input factors substituted for each other at varying rates, the least-cost combination can be determined by comparing the substitution ratio with the inverse of the price ratio. Usually, inputs are continous and measured in physical quantities. In the present problem inputs are

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1/ Heady, E.O., Economics of Agricultural Production and Resource Use, Prentice-Hall, 1952, Chapter 5.

discrete in that only three combinations are possible and the unit of measurement is dollars (on an annual basis).

With a given production function, where substitution between two or more factors is possible, input factors may substitute for each other at increasing, constant, or decreasing rates.1/ In the present problem, it was anticipated that inputs (in dollars) used by producers for storage would substitute for inputs (in dollars) used by the hauler for transportation at a diminishing marginal rate as frequency of collection was extended from every-day to every-third-day pick-up.

Normally, decisions involving substitution between two factors are made by a single firm. However, in the present problem, substitution is between producers' dollars and hauler's dollars - - therefore, in theory, decisions regarding substitution between these two factors would have to be made by separate firms, producers and the hauler. This does not alter the validity of the principle of substitution nor its application here in attempting to establish the least-cost method of storing and moving a given volume of milk to the processing plant.

Selection of Milk Route

The primary considerations in selecting a route for use in this study were: (1) adequate volume of milk hauled, (2) typical pick-up

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1/ Heady, E.O., and Jensen, H.R., Farm Management Economics, Prentice-Hall, 1955, pp. 69-77.

procedure, (3) typical operating procedure by hauler, and (4) adequate route length.

The bulk milk route chosen was the route operated by Farris Brothers Dairy, Inc., of Newbern, Virginia. This firm operates the bulk route under contract to Southern Dairies, Inc., Winston-Salem, North Carolina. The Farris bulk route serves a three-county area embracing twenty-two producers.1/

Milk is hauled from farms to a Farris operated relay station in Newbern, Virginia. From this point it is transported to Winston-Salem in a 2500 gallons semi-trailer every other day. With regard to volume, in 1959 this route picked up from farms and delivered to the Newbern relay station a total of 771,169 gallons of milk (6,632,054 pounds). The route is arranged to provide for every-other-day farm pick-up.2/ The milk collection tanker used is a two-and-one-half-ton stake type truck equipped with an 1800 gallons stainless steel tank capable of holding 15,480 pounds of milk. The route requires approximately 168 miles of travel to pick up and deliver the milk of twenty-two producers to the Newbern relay station on an EOD pick-up basis.

Scope of the Study

The case study method was used with a relatively typical bulk milk

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1/ See route map in Appendix A.
2/ Every-other-day will hereafter be expressed as EOD.

route serving as the basis for study. The study covers a time period of one year. The most recent year for which the necessary data were available --1959-- was used.

Although conversion to bulk milk handling may, in certain cases, involve three separate firms (producer, hauler, and processor), data involving only the producer and hauler were included in this study. This was done deliberately because frequency of milk pick-up primarily affects the producer who must store his milk until pick-up and the hauler who must have the equipment to accommodate a given route volume under a given frequency of pick-up.

The problem would have been extended beyond its intended scope if the bulk tanker had been considered as a part of the operating equipment of the processor. If the study had assumed the bulk tanker to be processor equipment, savings on hauling which might result from altering frequency of pick-up would have had to be considered in the light of altered costs of receiving milk at the processing plant. Such considerations would be outside the scope of this study which was designed to determine the least-cost method of storing and moving a given volume of milk from farm to processing plant and to provide a basis for selection of the optimum size of storage tank as a result of such determination. Therefore, the hauler was considered a separate firm rather than a unit of operating equipment of the milk processor.

Collection of Data

To collect necessary data, dairy supply companies were contacted for

studies pertaining to bulk milk handling and for data on storage tanks. Research bulletins were obtained from a variety of sources including colleges, manufacturers, and dairy service organizations. Finally, the author obtained data on the sample route under study through conferences with the President of Farris Brothers Dairy and by personal observations of route and producer operations. Timed observations were obtained by visiting representative producers and by traveling the milk route with the bulk tank operator.

Procedure of Analysis

The estimates and findings developed in this study are based upon a budgetary analysis of a selected bulk pick-up route under alternative pick-up schedules. Computations involved in this study were standard arithmetic computations. Total dollar input (resource use) was determined for both producers and the hauler under existing route conditions involving EOD milk pick-up. This information was then used to project dollar requirements for producers and the hauler under systems of every-day and every-third-day pick-up. After establishing dollar input requirements associated with each of the three different frequencies of storage and pick-up, the data were used to establish an iso-product contour reflecting the rate of substitution of dollars (resources) used by producers for storage for dollars (resources) used by the hauler for transportation as frequency of pick-up was extended from every day to every third day.

Every-fourth-day pick-up was initially considered in the problem and preliminary data were assembled for use. However, fourth-day pick-up was rejected as being impractical for two basic reasons: (1) it would have necessitated the purchase of at least one additional bulk tanker by the hauler and would have incurred costs attendant to the operation of the tanker (both purchase price and additional operational cost would increase substantially the hauling costs of milk); and (2) substantially larger storage tanks would be required on the farms for storage for fourth-day pick-up would entail modification and enlargement of the milk house, requiring additional investment for storage beyond that of the tank itself.

CHARACTERISTICS OF EXISTING STORAGE AND HAULING FACILITIES

Producers

Producers on this route were located in a three-county area requiring approximately 168 miles of travel by the hauler for each complete collection of milk on an EOD basis. Mileage traveled varied slightly by season because of variation in milk production.1/ The majority of the producers used the ice-bank type cooler, with sizes ranging from 200 to 1000 gallons capacity.2/ Although most producers are advised to install tanks to accommodate four milkings plus twenty percent reserve capacity at peak month output for EOD pick-up, producers on this route had not followed such advice consistantly. Tank sizes ranged from sixty-three gallons less than, to 216 gallons more than, this recommended size (based on individual producer output).3/ Interviews with representative farmers produced a variety of reasons for the wide variance in this production-storage relationship. The principal reason given for installing storage tanks larger than the recommended size was that the producer wanted ample storage capacity to accommodate future additional output if and when he increased herd size. Where the tank size was smaller than that recommended, herd size had increased since

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1/ Appendix C, Table 1.
2/ Appendix B, Table 1.
3/ Appendix B, Table 1.

installation of bulk tanks. However, no one of the four producers in this latter situation was experiencing acute shortage of storage space.

With respect to resource efficiency, many producers possessed storage capacity considerably in excess of that presently required.1/ There were two principal reasons for this situation: (1) as mentioned above, deliberate purchase of large tanks to accommodate future herd expansion, and (2) a high degree of seasonality of production.2/ This latter factor was not vital to the problem and thus was not investigated. However, the fact that a high degree of seasonality of production existed indicates failure to plan production for the entire year.

Hauler

As previously stated, the hauler involved in this study traveled portions of a three-county area to collect milk on an EOD basis. He utilized a two-and-one-half-ton stake type truck with a gross load rating equivalent to the maximum permitted on Virginia highways. The chasis was equipped with a stainless steel tank capable of holding 1800 gallons (15,480 pounds). The route was approximately 168 miles in length with some slight variation in mileage due to seasonality of milk output. This distance was the average distance traveled for a complete EOD collection of milk.

1/ Appendix B, Table 1.
2/ Appendix A, Table 2.

Three trips to the Newbern relay station were required to transport all milk from farms to the station during a complete collection of milk. The driver operated on a split shift, with the first load being collected in the evening between 6:00 P.M. and 2:00 A.M. After a few hours of sleep, the driver returned to the route at 6:00 A.M. and collected the second and third loads by 4:00 P.M., approximately twenty-two hours after the milk collection was begun. After the last load was transferred to the semi-trailer in Newbern, the tanker was cleaned and made ready for the next collection beginning at 6:00 on the evening of the next day.

PRODUCER AND HAULER INVESTMENT AND COSTS - - EVERY-OTHER-DAY PICK-UP

General

The monthly milk deliveries on the route studied for the year 1959 served as a starting point for computing producers and hauler investment and costs for EOD frequency of storage and collection.1/ This delivery (production) schedule also served as the basis for projections of investment and costs for every-day and every-third-day storage and pick-up. These figures were obtained from the offices of the hauler, Farris Brothers Dairy, Inc., Newbern, Virginia. From these figures, Table 3, Appendix A, was constructed showing average individual producer deliveries for every-day, EOD, and every-third-day frequencies of pick-up. These average production figures were, in turn, used to compute and project the ultimate investment and costs for all route producers and the hauler under each frequency of collection. The time period used to forecast investment and costs was the twelve-month period from January 1 through December 31, 1959.

Total Producer Investment and Costs

A major investment item for the producers involved in this study was

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1/ Appendix A, Table 1.

the initial cost of bulk storage tanks. To achieve price uniformity for this study, the manufacturers' suggested retail price was used to determine tank investment. Individual producer investment in storage tanks is shown in Table 2, Appendix B. Total investment by all producers is presented in Table 1. Annual costs of storage for all route producers is also presented in Table 1. These annual storage costs consisted of depreciation, interest, insurance and taxes, cleaning, and tank operating costs. Explanations of cost computations are contained in table footnotes.

Tank operating costs were difficult to determine. Data reflecting operating costs in other sections of the dairy industry presented a wide variation in cost of operation. The principle elements in cost of tank operation are repair costs and cost of electricity. If tanks receive reasonable care, repair costs should be insignificant. Determination of electrical cost is difficult because of the variety of factors which may affect the running time of tank compressors; such factors are: (1) quantity of warm milk added per milking, (2) rate of milk addition, (3) original volume of cold milk in the tank, (4) size of tank and compressor, and (5) ambient temperature of the milk house. Other influencing factors are seasonality of production and efficiency of the particular tank cooling system.

The method of estimating cost of operation for this study is shown in Table 3, Appendix B. The data in this table are based on material

contained in a U.S.D.A. bulletin which was reviewed.1/ The available cost figures were for every-day storage and pick-up. Projections of cost were made by multiplying the established daily cost by factors of two and three to obtain storage cost for EOD and every-third-day pick-up.

It is important to note that these operational storage costs do not include initial tank investment. The total annual cost of operation for all route producers was obtained by multiplying the total in column (4) of Table 3 2/ by a factor of 365 (number of days during which storage cost was incurred). The resultant total cost is presented in Table 1.

Labor cost for tank cleaning was also difficult to determine. None of the material reviewed provided figures for this cost, and interviews with representative producers failed to provide a basis for determining the average hourly wage paid to those persons responsible for tank cleaning. Many producers performed their own dairy chores and could not accurately furnish hourly wage rates. Those farmers who paid a dairyman to milk had a variety of agreements with this farm help. Certain farmers gave a percentage of the monthly milk receipts to the dairyman while others paid the dairyman by the hour or by the month. Where the hourly and monthly wage was paid, there was no uniformity of wage payment.

1/ Cowden, Joseph M., Comparing Bulk and Can Milk Hauling Costs, Farmer Cooperative Service, United States Department of Agriculture, FCS Circular 14, June, 1956, pp. 4-6.

2/ Appendix B, Table 3.

Average wage rates for the State were not used because the sample area studied was not considered large enough to be representative of averages for the entire State. For these reasons a rate of $1.00 per hour was arbitrarily chosen as the basis for determining labor cost for cleaning for all producers.

Observations of the time required to clean storage tanks produced two major conclusions: (1) there was an insignificant variation in time required to clean large and small tanks, and (2) the average time required to clean tanks and to clean utensils after use was twenty minutes. Initial cleaning is performed by the driver of the bulk tanker who, upon emptying the storage tank, is required to rinse the tank before leaving the farm. The producer is required to brush-clean all utensil surfaces with hot dairy detergent water after which he rinses the tank with hot water.1/ Later, before depositing fresh milk, the producer must sanitize the tank with an effective approved bactericidal agent. With an average cleaning time of twenty minutes per tank, twenty-two producers would expend labor worth $7.26 for each complete route collection. This figure was multiplied by a factor of 183 (number of cleanings required under EOD pick-up for one year) to obtain the total expenditure for labor for cleaning shown in Table 1.

Total cost to all route producers for the one-year period under EOD

1/ Virginia Department of Agriculture and Immigration, Regulations Pertaining to Farm Bulk Milk Holding, 1956, p. 3.

storage and pick-up was $11,313.15.

Hauler Investment and Costs

As for producers, a major cost item for the hauler was the purchase of equipment. Retail cost of the bulk tanker is shown in Table 1.

Cost of operation for the hauler embraces all items included in footnote (f) of Table 1. This operational cost was computed by Farris Brothers Dairy to be $0.25 per mile. To establish that this system of presenting operational cost was fairly common and to establish further that the rate of $0.25 per mile was reasonable, two other sizeable firms engaged in operating similar equipment were contacted.1/ Both the procedure for presenting cost of operation, as in Table 1, and the rate of $0.25 per mile were confirmed by the companies contacted. Cost of operation for the hauler thus became solely a function of mileage traveled by the bulk tanker. Table 1, Appendix C, shows the mileage presently traveled for EOD milk collection. With an average distance traveled per complete collection of 168 miles and with 183 collections per year under EOD pick-up, the total yearly mileage was 30,744. At $0.25 per mile, the total annual cost of operation was computed to be $7,686.00. This figure is shown in Table 1.

1/ Highway Equipment Leasing Corporation, Christiansburg, Virginia; Southern Dairies, Inc., Christiansburg, Virginia.

Table 1. - Investment and Annual Operating Costs for all Route Producers and Hauler on a Selected Bulk Milk Route - - Every-Other-Day Pick-up, Virginia, 1959[a]

Producers	
Initial investment in tanks, all producers	$63,278.00
Costs of operation:	
depreciation[b]	$ 4,218.53
interest[c]	$ 1,581.95
insurance and taxes[d]	$ 316.39
estimated operating costs (electricity and repair)	$ 3,869.00
cleaning[e]	$ 1,328.58
Total annual cost - all route producers	$11,313.15
Hauler	
Initial investment in bulk tanker	$13,710.00
Cost of operation @ $0.25 per mile[f]	$ 7,686.00
Total annual cost for hauling	$ 7,686.00
Total annual cost of operation - storage and hauling	$18,999.15

a For a period from January 1 through December 31, 1959.
b Depreciation was calculated on the straight line method with fifteen years estimated life with no salvage value.
c Interest was calculated at the rate of 2.5 percent on initial investment.
d Insurance and taxes were calculated at the rate of 0.5 percent on initial investment.
e Labor for cleaning was calculated at the rate of $1.00 per hour.
f Includes all items of cost as follows: interest on investment, insurance, depreciation, taxes, licenses, fuel, lubricants, repairs, tires, labor.

In addition to cost determinations made above, estimations of average truck speed were made in order to arrive at some approximation of the time required to collect milk under every-third-day pick-up. Ability to cover the route was not in question with EOD pick-up, for it was being done. Nor was there any question that one truck could do the job on every-day pick-up where only one full load and a fraction of a second load would be hauled. However, third-day pick-up would require more trips by the present tanker for each complete collection because of the additional accumulation of milk. Therefore, a determination was made of the approximate time required for route operations under every-third-day milk collection.

The starting point for these determinations was the measured route time of eighteen hours under existing EOD milk pick-up. Three adjustments had to be made, however, before actual average travel time could be determined.

The first adjustment involved time spent at each producer's farm. Average farm-stop time for each frequency of pick-up was computed and is shown in Table 4.1/ With respect to farm-stop time, variable time operations were a function of producer output. Computation of these times is explained in table footnotes. Fixed-time operations were timed and these times, presented in Table 4, Appendix C, reflect an average of

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1/ Appendix C, Table 4.

the time spent at all farms. Fixed-time operations remain the same regardless of output, and include the following standard procedures at each collection point: (1) measure milk and record its weight, (2) start farm tank agitator, (3) attach tanker hose to bulk tank outlet, (4) read and record milk temperature, (5) take butterfat sample and place in bottle in tanker's ice chest, (6) start tanker pump and pump milk to tanker, (7) disconnect tanker hose and electric cord and return them to tanker, and (8) flush out farm tank with clean water.1/

The second adjustment involved a determination of the average time spent unloading milk at the relay station. In this connection, as frequency of pick-up was extended from every day to every third day, the number of trips to the relay station increased for each complete collection of milk, as did the unloading time involved.2/ Information pertinent to unloading time is presented in Table 5.3/

The third adjustment involved the time required to clean the tanker at the end of each collection for the entire route. This operation was timed and found to require ninety minutes.

With the three adjustments just described, computation of operational

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1/ The Heil Company, The Bulk Pick-up System of Marketing Milk, Milwaukee, 1953, p. 11.

2/ Although the number of trips per complete collection would increase, the total number made during the year under third-day pick-up would decrease.

3/ Appendix C, Table 5.

time for the route was made as follows:

Total measured operational time . . .	18 hours, 0 mins.	(1080 mins.)
minus total average stop time of .	4 hours, 46 mins.	(286 mins.)
minus total unload time of . . .	1 hour , 25 mins.	(85 mins.)
minus tanker cleaning time of . .	1 hour , 30 mins.	(90 mins.)
Actual running time	10.3 hours	(619 mins.)

$$\frac{\text{Route length - - - - - - 168 miles}}{\text{Actual running time of 10.3 hours}} = \text{16.6 miles per hour average running speed}$$

The actual average running speed of the bulk tanker seems unrealistically slow. However, this includes time spent in off-the-road farm lanes, starts and stops, and slow running due to full milk load.

The average running speed is used later in the projections of operations associated with every-third-day pick-up.

ADJUSTMENT OF EXISTING EVERY-OTHER-DAY STORAGE FACILITIES, INVESTMENT, AND COSTS OF OPERATION

Existing producer storage facilities and associated investment and attendant costs of operation on the route studied were found to be considerably in excess of actual requirements.1/ Existing storage capacity was found to be as high as 216 gallons in excess of the actual storage requirements during the peak production month.2/ This situation produced an annual average rate of tank utilization as low as twenty-nine percent for one producer and an annual average rate of utilization for the entire route of fifty-two percent.3/ From the evidence collected, it appeared that this over-investment resulted from two major factors: (1) a general failure to observe industry recommendations for tank purchase based on peak-month storage requirements plus provision for twenty percent reserve capacity, and (2) a general desire to provide for future herd expansion. As a result of these factors, existing cost of storage tanks associated with EOD milk collection was quite high and was considered unsuitable for a realistic projection of the substitution of producers' dollars (for storage) for hauler dollars (for transportation). Therefore, Table 2 was constructed to reflect actual investment requirements for storage under present EOD milk collection.

1/ Appendix B, Table 2.
2/ Appendix B, Table 1.
3/ Appendix B, Table 4.

Table 2. Adjusted Producer Storage Facilities and Associated Investment of all Route Producers - - Every-Day, Every-Other-Day, and Every-Third-Day Frequencies of Pick-up

	Existing EOD		Required EVDD[a]		Required EOD		Required 3RDD[b]	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Producer	Pres tank size	Pres tank inv	Req tank size	Req tank inv	Req tank size	Req tank inv	Req tank size	Req tank inv
500	425	$3102	300	$2497	500	$3514	800	$4224
501	425	$3102	150	$1761	240	$2217	425	$3102
502	300	$2594	100	$1417	200	$2037	300	$2594
503	425	$3102	200	$2161	350	$2741	500	$3514
504	500	$3628	200	$2161	350	$2741	475	$3358
505	330	$2716	150	$1761	240	$2217	330	$2716
506	200	$2161	100	$1417	150	$1729	200	$2161
508	425	$2462	250	$2022	425	$3005	545	$2824
509	400	$2571	160	$1608	350	$2741	500	$2924
510	300	$2270	150	$1907	240	$2217	400	$3182
511	300	$2770	200	$2247	425	$3005	650	$4015
514	300	$2594	200	$2161	350	$2741	500	$3514
515	330	$2716	150	$1761	300	$2497	425	$3102
517	425	$3102	200	$2161	425	$3005	650	$3980
523	1000	$4783	475	$3472	1000	$4783	1-1000	$4783
							1-300	$2497
524	350	$2741	200	$2161	350	$2741	500	$3514
507	250	$2451	100	$1550	200	$2037	250	$2451
513	300	$2770	150	$1907	300	$2497	400	$3182
518	250	$2451	150	$1907	240	$2217	400	$3182
519	250	$2451	100	$1550	200	$1729	300	$2745
520	475	$3472	150	$1761	300	$2497	475	$3472
521	300	$2770	200	$2247	350	$2741	500	$3615
		$63278		$43597		$57649[c]		$74651

a Denotes every day.
b Denotes every third day.
c Adjusted figures in column (7) are based on suggested retail price of prevalent type tank used.

The adjusted total investment figure of $57,649 in column (7) of Table 2 was used to compute adjusted costs for all route producers in Table 3 below.

Table 3. - Adjusted Investment and Annual Operating Costs for all Route Producers on a Selected Bulk Milk Route - - Every-Other-Day Pick-up, Virginia, 1959 .....

Adjusted initial investment in all route tanks	$57,649.00
Adjusted costs of operation:	
depreciation[a]	$ 3,843.27
interest[b]	$ 1,441.23
insurance and taxes[c]	$ 288.25
estimated operating costs (electricity and repair)[d]	$ 3,869.00
cleaning[e]	$ 1,328.58
Adjusted total annual cost - all route producers	$10,770.33

a Depreciation was calculated on the straight line method with fifteen years estimated life with no salvage value.
b Interest was calculated at the rate of 2.5 percent on initial investment.
c Insurance and taxes were calculated at the rate of 0.5 percent of initial investment.
d This figure remains the same as presented in Table 1, p. 36.
e This figure remains the same as presented in Table 1, p. 36.

PRODUCER AND HAULER INVESTMENT AND COSTS - - EVERY-DAY PICK-UP

Total Producer Investment and Costs

With daily storage and pick-up, a major cost to all route producers was again the initial investment in bulk storage tanks. Projected tank cost for individual producers is shown in Table 2.1/ Total investment in storage tanks by all route producers, as shown in Table 4, was $43,597.00.

Projected annual storage costs (costs of operation) are shown in Table 4. As was the case for EOD storage and pick-up, cost of operation includes depreciation, interest, insurance and taxes, estimated operating costs, and cleaning. With respect to estimated operating costs (electricity and repair), the figure in Table 4 was obtained by multiplying the total in column (4) of Table 3 2/ by a factor of 365 (number of days during which storage cost would be incurred). Labor costs were determined by using the previously mentioned average cleaning time of twenty minutes per tank and wage rate of $1.00 per hour.

Total cost of operation for all route producers for every-day storage and pick-up was computed to be $10,733.28 as shown in Table 4.

1/ Appendix B, Table 2.
2/ Appendix B, Table 3.

Hauler Investment and Costs

Again, a major cost for the hauler was that of the purchase of the bulk tanker. This cost figure is contained in Table 4.

Table 4. - Investment and Annual Operating Costs for all Route Producers and Hauler on a Selected Bulk Milk Route - - Every-Day Pick-up, Virginia, 1959[a].....

Producers	
Initial investment in tanks, all producers	$43,597.00
Costs of operation:	
depreciation[b]	$ 2,906.47
interest[c]	$ 1,089.93
insurance and taxes[d]	$ 217.98
estimated operating costs (electricity and repair)	$ 3,869.00
cleaning[e]	$ 2,649.90
Total annual cost - all route producers	$10,733.28
Hauler	
Initial investment in bulk tanker	$13,710.00
Cost of operation @ $0.25 per mile[f]	$12,045.00
Total annual cost for hauling	$12,045.00
Total annual cost of operation - storage and hauling	$22,778.28

a For a period from January 1 through December 31, 1959.
b Depreciation was calculated on the straight line method with fifteen years estimated life with no salvage value.
c Interest was calculated at the rate of 2.5 percent on initial investment.
d Insurance and taxes were calculated at the rate of 0.5 percent on initial investment.
e Labor for cleaning was calculated at the rate of $1.00 per hour.
f Includes all items of cost as follows: interest on investment, insurance, depreciation, taxes, licenses, fuel, lubricants, repairs, tires, labor.

Cost of operation, computed on the basis of $0.25 per mile and on an average route distance of 132 miles per complete collection, was $12,045.00, as shown in Table 4. (The average distance of 132 miles for each collection was based on distances shown in Appendix C, Table 2).

PRODUCER AND HAULER INVESTMENT AND COSTS - - EVERY-THIRD-DAY PICK-UP

Total Producer Investment and Costs

As with the two previous storage situations, projected investment in storage tanks represents a major cost to producers with third-day storage and pick-up. Projected tank cost for individual producers is shown in Table 2.1/ Total investment in storage tanks by all route producers, as shown in Table 5, was $74,651.00.

Projected annual storage costs (costs of operation) are shown in Table 5. As for the two previous storage and collection situations, cost of operation includes depreciation, interest, insurance and taxes, estimated operating costs, and cleaning. With respect to estimated operating costs (electricity and repair), the figure in Table 5 was obtained by multiplying the total in column (4) of Table 3 2/ by a factor of 365 (number of days during which storage cost would be incurred). Labor costs were again obtained by using an average cleaning time of twenty minutes per tank and an hourly wage rate of $1.00 per hour.

Total cost of operation for all route producers for every-third-day storage and pick-up was determined to be $11,970.99 as shown in Table 5.

Hauler Investment and Costs

As with the two previous situations, a major cost to the hauler was

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1/ Appendix B, Table 2.
2/ Appendix B, Table 3.

the cost of the bulk tanker. This cost figure is contained in Table 5.

The annual cost of operation for the hauler, computed on the basis of $0.25 per mile and an average route distance of 177 miles per collection, was $5,398.50, as shown in Table 5. (The average distance of 177 miles for each complete collection was based on distances shown in Appendix C, Table 3.)

With respect to time demands and running time for every-third-day pick-up, it was determined that the single bulk tanker could easily collect the additional accumulation of milk associated with this frequency of storage. Projected data showing the collection requirements for third-day pick-up are shown in Appendix C, Table 3. This table shows that the maximum distance demand occured in September when the tanker would have to make five trips and travel an average distance of 211 miles per complete collection of milk. Dividing this figure by the previously determined average running speed of 16.6 miles per hour produced an average time requirement of twelve hours and forty-one minutes for over-the-road movement. Added to this was the average unload time of two hours and twenty-three minutes associated with third-day pick-up.1/ Finally, average total farm-stop time of five hours and twenty-six minutes associated with third-day pick-up was added to produce the total time of operation.2/ These figures produced a total average time of twenty hours and thirty minutes required for operating the existing tanker on an every-

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1/ Appendix C, Table 5.
2/ Appendix C, Table 4.

third-day pick-up basis during the peak production period of September. Therefore, the existing tanker could easily accommodate milk output during the fall peak production period.

Although somewhat greater demands would be made on the driver, it is probable that, by splitting the route, the one man could drive the route under every-third-day pick-up. Further, the distance of 211 miles is the peak distance traveled while the average distance for this frequency of pick-up is only 177 miles. This distance (based on an average running speed of 16.6 m.p.h.) could be covered in eighteen hours and thirty minutes. This is only thirty minutes more than the time presently required for operating the tanker on an EOD basis.

Table 5. - Investment and Annual Operating Costs for all Route Producers and Hauler on a Selected Bulk Milk Route - - Every-Third-Day Pick-up, Virginia, 1959[a]

Producers	
Initial investment in tanks, all producers	$74,651.00
Costs of operation:	
depreciation[b]	$ 4,976.73
interest[c]	$ 1,866.28
insurance and taxes[d]	$ 373.26
estimated operating costs (electricity and repair)	$ 3,869.00
cleaning[e]	$ 885.72
Total annual cost - all route producers	$11,970.99
Hauler	
Initial investment in bulk tanker	$13,710.00
Cost of operation @ $0.25 per mile[f]	$ 5,398.50
Total annual cost for hauling	$ 5,398.50
Total annual cost of operation - storage and hauling	$17,369.49

a For a period from January 1 through December 31, 1959.
b Depreciation was calculated on the straight line method with fifteen years estimated life with no salvage value.
c Interest was calculated at the rate of 2.5 percent on initial investment.
d Insurance and taxes were calculated at the rate of 0.5 percent on initial investment.
e Labor for cleaning was calculated at the rate of $1.00 per hour.
f Includes all items of cost as follows: interest on investment, insurance, depreciation, taxes, licenses, fuel, lubricants, repairs, tires, labor.

PRODUCER VERSUS HAULER COSTS

With adjustments in investment and cost of operation for producers established and presented in Table 3, Table 6 was constructed to indicate the total dollar inputs by all route producers and the route hauler for the three frequencies of storage and pick-up examined in the problem.

Table 6. - Projected Total Dollar Inputs under Three Collection Frequencies - - All Producers and Hauler on a Selected Bulk Milk Route, Virginia, 1959[a]

	Every-day pick-up[b]	Every-other-day pick-up	Every-third-day pick-up[c]
Producers	$10,733.28	$10,770.33[d]	$11,970.99
Hauler	$12,045.00	$ 7,686.00[e]	$ 5,398.50
Total dollar input	$22,778.28	$18,456.33	$17,369.49

a Based on actual production from January 1 through December 31, 1959.
b Figures taken from Table 4.
c Figures taken from Table 5.
d Figure taken from Table 3.
e Figure taken from Table 1.

The figures in Table 6 indicate the changes in resource use which occur when frequency of milk storage and pick-up is extended from every day to every third day. Dollar inputs of increasing amounts are required for producer storage as the collection of milk is extended to every third day. The storage facilities needed to hold milk for third-day pick-up involve a substantially greater dollar cost than that cost associated

with either every-day or EOD storage. The input schedule reflected in Table 6 indicates a requirement for dollar input increments (resource use) of increasing amounts for producer storage. As frequency of collection is extended to every third day, additional dollars used for storage substitute for fewer dollars used for hauling. Table 6 indicates that, since the size of each increment of dollar input increases as frequency of storage and collection is extended, those dollars used for storage substitute at a diminishing marginal rate for dollars used for hauling.

It seems probable that the rate of substitution just discussed is partially due to the substantially larger investment and costs associated with tanks for third-day storage. Many small tanks vary in size by only a small amount, in some lines by only fifty gallons. Therefore, dairy farmers may purchase tanks from a selection in which the price differential is not too great. However, the large tanks produced by most manufacturers generally differ in size by at least 100 gallons and in some lines by an even greater amount. Therefore, dairymen faced with the problem of purchasing large tanks to accommodate third-day storage of milk might be forced to buy tanks much larger than actually required and would have to commit dollars for storage capacity which would not be used for some time if at all. For these reasons, as storage is extended and tanks for storage become larger, each successive increase in tank size brings forth investment increments of greater amounts.

From the figures presented in Table 6, the iso-product contour in

Figure 1 was constructed, reflecting a diminishing marginal rate of substitution of producers' dollars for hauler dollars as frequency of milk collection is moved from every day to every third day. This substitution ratio results from the necessity of applying increasingly larger quantities of dollars to purchase additional tank storage space as frequency of pick-up is extended, while, at the same time, inputs of dollars by the hauler diminish because of decreased cost of operation associated with reduced travel.

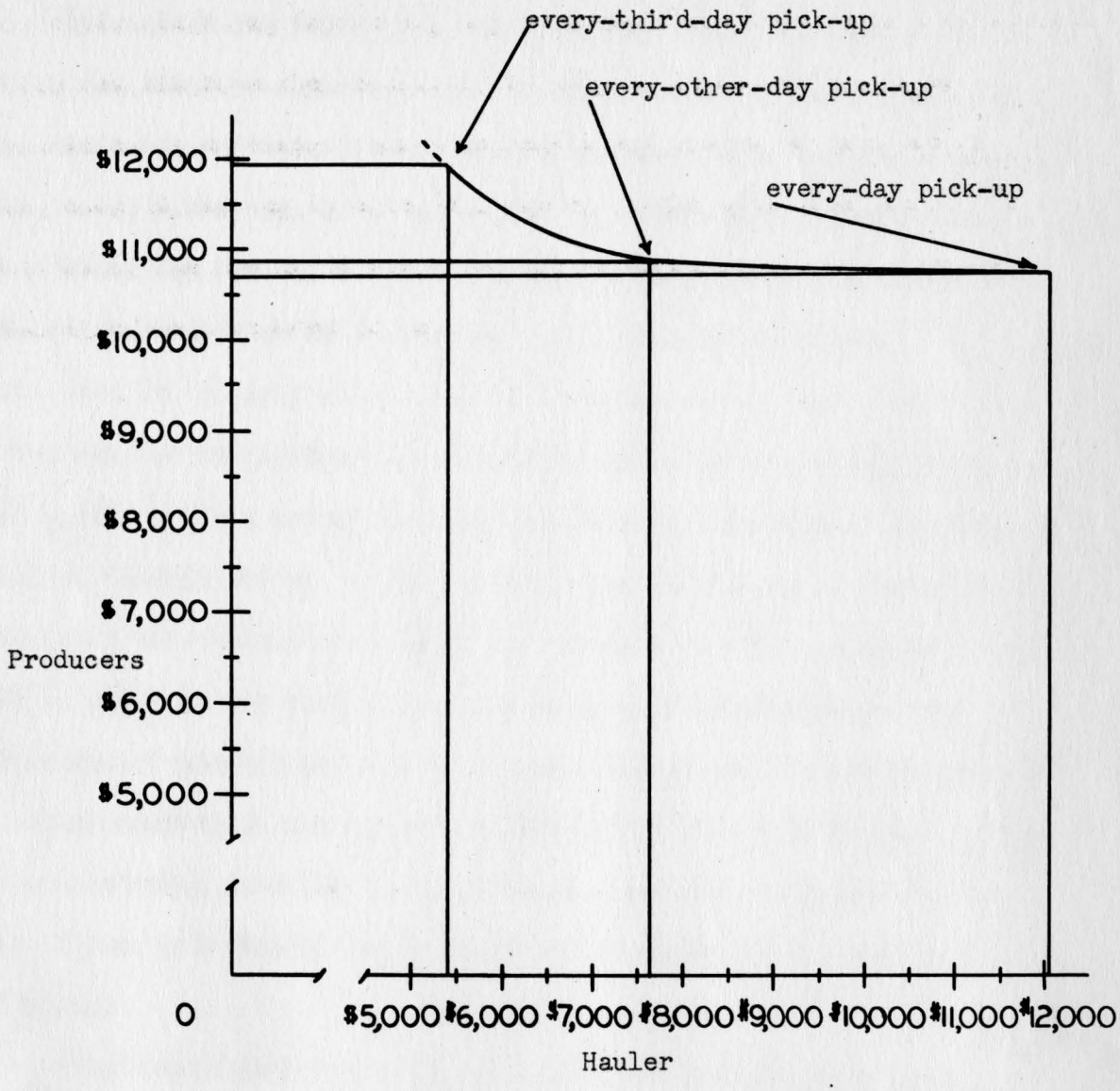

Figure 1 - Iso-Product Contour Reflecting Rate of Substitution Between Dollar Inputs by Producers and Dollar Inputs by Hauler on a Selected Bulk Milk Route - - Every-Day, Every-Other-Day, and Every-Third-Day Storage and Collection, Virginia, 1959.

SUMMARY

This study was designed to determine the total investment and operating costs on a selected sample route for all producers and for the route hauler where storage and collection of milk occured every day, every other day, and every third day. The study was also designed to examine the rate at which resources (measured in dollars) used by grade-A producers on the route studied substitute for resources (measured in dollars) used by the milk hauler on the same route. The study was further designed to determine the least-cost method of storing and moving a given volume of milk from farm to processor or receiving station through the use of bulk storage and hauling facilities. Finally, the study was designed to examine the effects on total producers' cost and on total hauler cost on the sample route by alteration of the frequency of storage and pick-up. (This information is used to predict the most economical storage and movement of milk and is used as a guide in recommending selection of tanks which, when used with other bulk facilities, will result in the least-cost handling of a given volume of milk.)

A bulk milk route embracing portions of a three-country area and involving twenty-two producers was used in this case study. The hauler operated independently rather than as an employee of the milk processor. The production and hauling period was a twelve-month period from January 1 through December 31, 1959.

With respect to producer costs, storage costs were lowest with every-day storage and pick-up of milk and increased as frequency of pick-up was extended to every third day. The greatest increase in storage costs occurred when collection frequency moved from every other day to every third day. Conversely, hauling costs were least with every-third-day milk pick and increased consistently as milk was picked up more frequently. The greatest increase in hauling costs occurred when frequency of collection was shifted from every other day to every day.

With respect to resource use by producers, it was determined that considerable over-investment in storage tanks existed. This was due to plans for herd expansion, failure to adhere to industry recommendations in the purchase of tanks, and a high degree of seasonality of production. Average tank utilization for the entire period ranged from as low as twenty-nine percent to as high as ninety-nine percent, with an annual average utilization rate of fifty-two percent.

Investment in and utilization of equipment by the hauler was found to be reasonable and satisfactory in view of the annual volume of milk moved.

Initial investment in equipment was determined to be a major cost item for both producers and the hauler. A general over-investment in producer storage facilities indicated a lack of advance planning for, and estimation of, actual storage requirements. This over-investment of dollars increased the farm-to-market cost of storing and moving a given

volume of milk.

The least-cost combination for storing and moving the annual output of milk in the sample area studied was that combination resulting from every-third-day storage and pick-up. When frequency of collection was moved to this point, the cost to all route producers was greatest. However, the reduction in hauling costs more than offset the increased cost for combined route producers so that the least-cost handling of milk occurred with third-day collection. Therefore, the study indicated that the greatest possible economies are associated with third-day storage and collection of milk.

This study determined that dollars used by the combined producers on the sample route substituted for dollars used by the hauler at a diminishing marginal rate when collection frequency was moved to every third day. This indicated a requirement of increasingly larger increments of producers' capital as frequency of pick-up was extended to every third day.

In the statement of the problem, optimum tank size was defined as that size used by each producer which, when used in conjunction with existing hauling facilities under a given frequency of collection, would result in the least-cost storage and movement of milk from farms to receiving plant or relay station. Since the study determined that the least-cost combination in bulk milk handling occurred with every-third-day pick-up, it is concluded that, from the standpoint of reducing cost

and using resources efficiently, the tank sizes used for third-day storage would be considered more nearly optimum for the sample route used in this study.

CONCLUSIONS

Based on the findings of this study, it is concluded that, on the sample route studied, the size of bulk storage tanks purchased for and used in conjunction with every-third-day collection of milk would be optimum as the term is used here. Storage tanks used on this route for every-third-day pick-up would require a smaller aggregate cost for all route operations than that required with any other frequency of storage and collection. From the standpoint of using dollars (and the resources which they purchase) as efficiently as possible, and from the standpoint of performing a complete, or some phase of, a production function with a minimum of cost, it is concluded that selection of storage tanks to be used for three-day storage would be best.

A shift to third-day storage and pick-up on the route studied could not take place without additional cost to producers. Greater investment in larger storage tanks would be necessary in some cases. The lower aggregate cost for third-day pick-up is largely the result of considerable savings for the hauler under third-day collection of milk. It seems logical that, should such a shift in collection frequency occur and if savings such as those indicated in this study accrue to the hauler, the hauler should be willing to pass some part of these savings along to route producers in the form of lower hauling costs. While this would be desirable, particularly from the standpoint of the route producers, there is no assurance that the hauler would pass such savings on to the

producer.

From the findings of this study, it is concluded that resources are not now being used as efficiently as might be possible on the route studied. This conclusion is based on cost figures which indicate that the present system of EOD storage and pick-up requires a greater dollar input than would be necessary under third-day pick-up of milk. The present method of using dollars under EOD pick-up may be the result of state health regulations which prohibit the storage of grade-A milk for more than fifty-two hours. Other reasons may also exist for the practice of alternate day collection used on this route.

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APPENDIX A

Production Figures for a Selected Bulk Milk Route, Virginia, 1959

Appendix Table 1. - Monthly Milk Deliveries of all Producers on a Selected Bulk Milk Route, Virginia, 1959[a]

Producer	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
500	33843	32508	39225	37072	37909	30307	35215	40122	51026	53542	44599	42143
501	16762	12757	12253	11090	14972	22905	23406	23908	24027	21181	19537	21793
502	13929	14063	16347	17238	15562	13937	16313	18688	20661	18458	13995	12299
503	21690	20601	27718	35558	33946	30804	29577	28350	33634	32777	26117	25957
504	21458	18079	19029	22462	21339	21426	24277	27128	33243	30412	22791	20578
505	14361	11356	11303	12908	17732	17469	20478	22486	22331	20804	18257	17828
506	7784	6664	5862	6560	7547	8199	10701	13202	13418	13676	11798	10329
508	26423	26259	27516	32330	30169	22731	21908	21085	29941	39059	35199	34664
509	23853	22687	25162	31185	32699	28480	23286	18092	24466	31970	27834	25871
510	20421	16398	18412	22841	22104	22989	20281	17573	15577	23555	23637	22832
511	33401	28659	29206	35438	33804	28960	29166	29373	32133	37893	33954	35179
514	28801	27281	28312	31578	33265	31514	30283	29052	34137	32412	27965	29753
515	22538	20480	18689	22586	24627	21467	22623	23779	28687	28380	23253	24364
517	29785	21669	21818	24380	28157	25657	29737	33817	38652	35573	34694	32770
523	72129	60367	65608	62024	66926	52813	66204	79595	90788	92030	81964	76459
524	20191	16007	17705	22972	23040	18972	23067	27165	33913	35123	29153	28175
507	10097	9781	11314	13064	14917	16967	15112	15505	16206	15900	14316	11916
513	21895	18481	23560	16700	21996	20474	18135	22194	25974	25117	20076	24932
518	23208	11961	11984	17320	21588	15929	19914	11318	11127	19140	22181	23672
519	17901	15972	16957	17740	16195	14340	9529	8141	12608	18634	17063	19576
520	14791	13150	14889	15150	18197	15274	12255	18387	23970	27382	22554	17386
521	26194	23550	20494	20550	23201	23729	21158	25226	33159	34832	32156	27172
Totals:	521455	458730	493363	528746	559892	505343	522625	554186	649678	687850	603093	585648

a Expressed in pounds.

Appendix Table 2. - Seasonality of Production of Producers on a Selected Bulk Milk Route, Virginia, 1959[a]

Producer	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	High	Low	Differential
500						L[b]				H[c]			53542	30307	23235
501				L					H				32757	11090	21667
502									H			L	20661	12299	8352
503		L		H									35558	20601	14957
504		L							H				33243	18079	15164
505			L					H					22486	11303	11183
506			L							H			13676	5762	7914
508								L		H			39059	21085	17974
509					H			L					32699	18092	14607
510									L		H		23637	15577	8060
511		L								H			37893	28659	9234
514		L							H				34137	27281	6856
515			L						H				28687	18689	9998
517		L							H				38652	21669	16983
523						L				H			92030	52813	39217
524		L								H			35123	16007	19116
507		L				H							16967	9781	7186
513				L					H				25974	16700	9274
518									L			H	23672	11127	12545
519								L				H	19576	8141	11435
520							L			H			27382	12255	15127
521		L								H			34832	20494	14338
											Totals:		722243	407811	314422

a Amounts expressed in pounds.
b Represents low production month.
c Represents high production month.

Appendix Table 3. - Average Daily Individual Producer Deliveries of all Producers on a Selected Bulk Milk Route, Virginia, 1959[a]

Producer	Jan			Feb			Mar			Apr		
	EVD[b]	EOD[c]	3RDD[d]	EVD	EOD	3RDD	EVD	EOD	3RDD	EVD	EOD	3RDD
500	1128	2256	3384	1083	2166	3249	1308	2616	3924	1236	2472	3708
501	558	1116	1674	426	852	1278	408	816	1224	370	740	1110
502	464	928	1392	468	936	1404	544	1088	1632	574	1148	1722
503	724	1448	2172	686	1372	2058	924	1848	2772	1186	2372	3558
504	718	1436	2154	602	1204	1806	634	1268	1902	748	1496	2244
505	478	956	1434	378	756	1134	376	752	1128	430	860	1290
506	260	520	780	222	444	666	196	392	588	218	436	654
508	880	1760	2640	876	1752	2628	918	1836	2754	1078	2156	3234
509	796	1592	2388	756	1512	2268	838	1676	2514	1040	2080	3120
510	680	1360	2040	546	1092	1638	614	1228	1842	762	1524	2286
511	1114	2228	3342	956	1912	2868	974	1948	2922	1182	2364	3546
514	960	1920	2880	910	1820	2730	944	1888	2832	1052	2104	3156
515	752	1504	2256	682	1364	2046	622	1244	1866	752	1504	2256
517	992	1984	2976	722	1444	2166	734	1468	2202	812	1624	2436
523	2404	4808	7212	2012	4024	6036	2186	4372	6558	2068	4136	6204
524	674	1342	2022	534	1068	1602	590	1180	1770	766	1532	2298
507	336	672	1008	326	652	978	378	756	1134	436	872	1308
513	730	1460	2190	616	1232	1848	786	1572	2358	556	1112	1668
518	774	1548	2322	398	796	1194	400	800	1200	578	1156	1734
519	596	1192	1788	532	1062	1596	566	1132	1698	592	1184	1776
520	492	984	1476	438	876	1314	490	980	1470	506	1012	1518
521	874	1748	2622	786	1572	2358	684	1368	1952	686	1372	2058
Totals:	17384	34762	52152	14955	29908	44865	16114	32128	48242	17628	35256	52884

Appendix Table 3. - (Continued)

Producer	May			Jun			Jul			Aug		
	EVD	EOD	3RDD	EVD	EOD	3RDD	EVD	EOD	3RDD	EVD	EOD	3RDD
500	1264	2528	3792	1010	2020	3030	1174	2348	3522	1338	2676	4014
501	500	1000	1500	764	1528	2292	780	1560	2340	796	1592	2388
502	518	1036	1554	464	928	1392	544	1088	1632	622	1244	1866
503	1132	2264	3396	1026	2052	3078	986	1972	2958	946	1892	2838
504	712	1424	3126	714	1428	2142	810	1620	2430	904	1808	2712
505	592	1184	1776	582	1164	1746	682	1364	2046	750	1500	2250
506	252	504	756	274	548	822	360	720	1086	440	880	1320
508	1006	2012	3018	758	1516	2274	730	1460	2190	702	1404	2106
509	1090	2180	3270	950	1900	2850	776	1552	2328	604	1208	1812
510	736	1472	2208	766	1532	2298	676	1352	2028	586	1172	1758
511	1126	2252	3378	966	1932	2898	972	1944	2916	992	1984	2976
514	1108	2216	3324	1050	2100	3150	1010	2020	3030	972	1944	2916
515	820	1640	2460	716	1432	2148	754	1508	2262	792	1584	2376
517	938	1876	2814	856	1712	2568	992	1984	2976	1128	2256	3384
523	2230	4460	6690	1760	3520	5280	2206	4412	6618	2654	5308	7962
524	768	1536	2304	632	1264	1896	768	1536	2304	906	1812	2718
507	498	992	1488	566	1132	1698	504	1008	1512	516	1032	1548
513	734	1468	2202	682	1364	2046	604	1208	1812	740	1480	2220
518	718	1436	2154	530	1060	1590	664	1328	1992	378	756	1134
519	538	1076	1614	444	888	1332	318	636	954	272	544	816
520	606	1212	1818	510	1020	1530	408	816	1224	612	1224	1836
521	774	1548	2322	790	1580	2370	706	1412	2118	840	1680	2520
Totals:	18660	36206	55974	16810	33620	50430	17424	33848	52278	18490	36980	55470

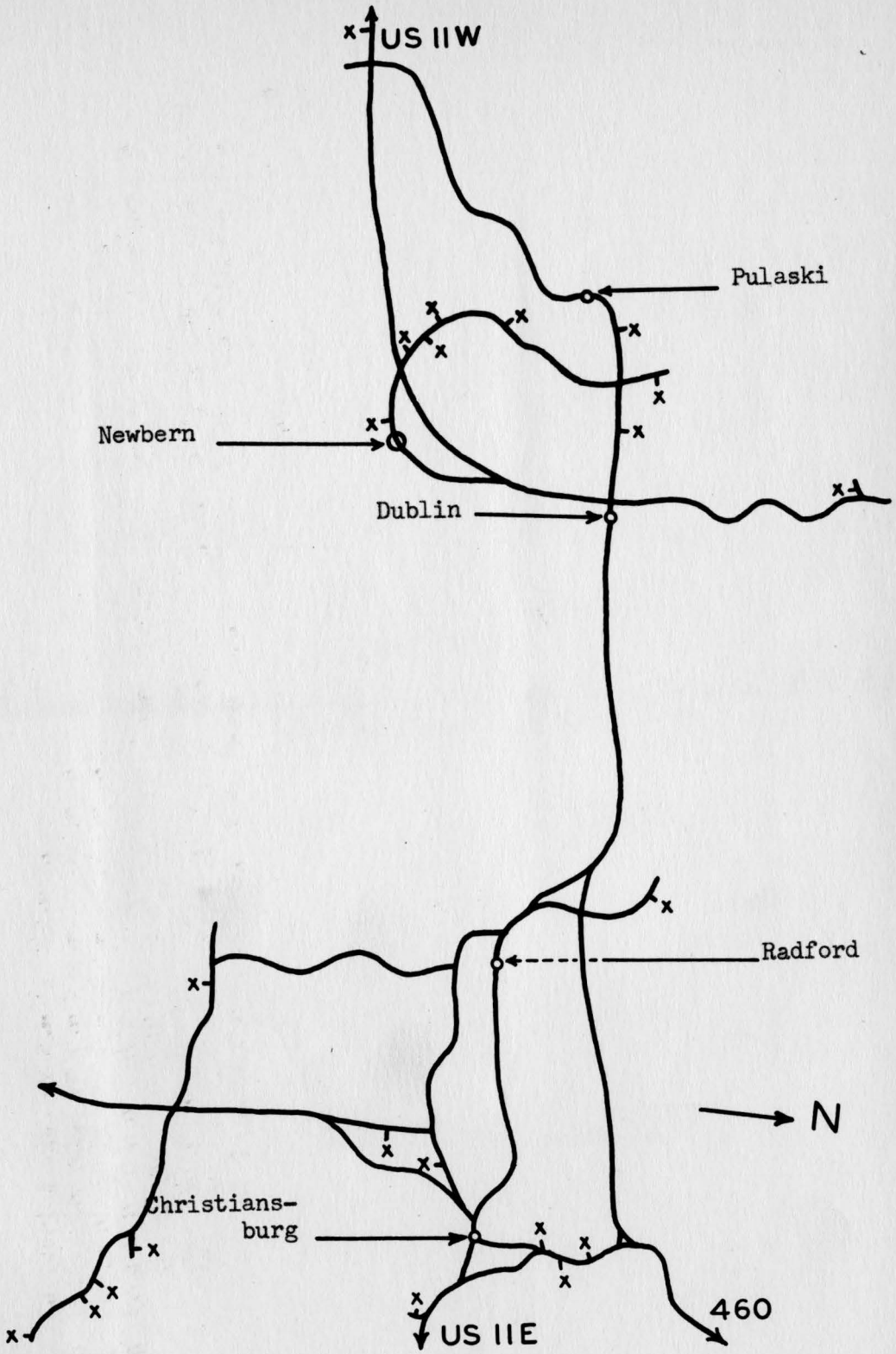
Appendix Table 3. - (Continued)

Producer	Sep			Oct			Nov			Dec		
	EVD	EOD	3RDD	EVD	EOD	3RDD	EVD	EOD	3RDD	EVD	EOD	3RDD
500	1300	2600	3900	1784	3768	5352	1486	2972	4458	1404	2808	4212
501	800	1600	2400	706	1412	2118	644	1288	1932	726	1452	2178
502	688	1376	2064	616	1232	1848	466	932	1398	410	820	1230
503	1122	2244	3366	1092	2184	3276	870	1740	2610	866	1742	2598
504	1108	2216	3324	1014	2028	3042	760	1520	2280	686	1372	2058
505	744	1488	2232	694	1388	2082	608	1216	1824	594	1188	1782
506	448	896	1344	456	912	1368	394	788	1182	344	688	1032
508	998	1996	2994	1302	2604	3906	1174	2348	3522	1156	2312	3468
509	816	1632	2448	1066	2132	3198	928	1856	2784	862	1724	2586
510	520	1040	1560	786	1572	2358	788	1576	2364	762	1524	2286
511	1072	2144	3216	1264	2528	3792	1132	2264	3396	1172	2344	3516
514	1138	2276	3414	1080	2160	3246	932	1864	2796	992	1984	2976
515	956	1912	2868	946	1892	2838	776	1552	2328	812	1624	2436
517	1286	2572	3858	1186	2372	3558	1156	2312	3468	1092	2184	3276
523	3026	6052	9078	3068	6163	9204	2732	5464	8196	2548	5096	7644
524	1130	2260	3390	1170	2324	3510	572	1144	2916	940	1880	2820
507	540	1080	1620	530	1060	1540	444	888	1332	398	796	1194
513	866	1732	2598	838	1676	2514	670	1340	2010	832	1664	2496
518	370	740	1110	638	1276	1914	740	1480	2220	790	1580	2370
519	420	840	1260	622	1244	1860	568	1136	1704	652	1304	1956
520	800	1600	2400	912	1824	2736	752	1504	2256	580	1160	1740
521	1106	2212	3318	1162	2324	3486	1072	2144	3216	906	1812	2718
Totals:	21254	42508	63762	22932	46075	68746	19664	39328	60192	19524	39058	58572

a Expressed in pounds.

Appendix Table 3. - (Continued)

b Deliveries with every-day pick-up.
c Deliveries with every-other-day pick-up.
d Deliveries with every-third-day pick-up.
e Procedure for computing:
    (1) Each producer's monthly production was divided by 60 to obtain average pounds per milking.
    (2) Resultant in (1) was multiplied by factors of 2, 4, and 6, to obtain average daily deliveries for every day, every other day, and every third day, respectively.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APPENDIX B

Producer Facilities, Investment, and Costs for a Selected Bulk Milk Route, Virginia, 1959

Appendix Table 1. - Existing Storage Tanks and Storage Requirements - - All Producers on a Selected Bulk Milk Route, Virginia, 1959[a]

Producer	Tank make	Tank type	Present EOD storage requirements[b]	Present tank size	Minimum tank available for EOD storage	Existing surplus storage capacity
500	Esco	IB[c]	498	425	500	-63
501	Esco	IB	223	425	350	+120
502	Esco	IB	192	300	200	+108
503	Esco	IB	331	425	350	+94
504	Esco	IB	309	500	350	+191
505	Kraft	IB	209	330	240[d]	+121
506	Esco	IB	127	200	150	+73
508	Moj[e]	DE[f]	363	425	400	+62
509	Unico	DE	304	400	400	+96
510	D-Kool	IB	220	300	250	+80
511	D-Kool	IB	353	300	400	-52
514	Esco	IB	318	300	350	-18
515	Kraft	IB	267	330	300[h]	+63
517	Esco	IB	359	425	425	+66
523	Esco	IB	856	1000	1000	+144
524	Esco	IB	324	350	350	+26
507	D-Kool	IB	158	250	200	+92
513	D-Kool	IB	242	300	250	+58
518	D-Kool	IB	220	250	250	+30
519	D-Kool	IB	182	250	200	+68
520	Esco	IB	259	475	300	+216
521	D-Kool	IB	324	300	400	-24

a Expressed in gallons.
b Based on peak month production plus twenty percent reserve capacity.
c Denotes ice-bank type cooler.
d Data unavailable for Kraft equipment - this is an Esco tank.
e Abbreviation for Mojonnier Bulk Milk Cooler.
f Denotes direct expansion type cooler.
g Abbreviation for Dari-Kool Bulk Milk Cooler.
h Data unavailable for Kraft equipment - this is an Esco tank.

Appendix Table 2. - Producer Storage Facilities and Investment on a Selected Bulk Milk Route, Virginia, 1959

	Every-Day Pick-up				Every-Other-Day Pick-up				Every-Third-Day Pick-up			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Producer	Str[a] req	Req tank size	Tank cost	H.P.[b]	Str req	Pres tank size	Tank cost	H.P.	Str req	Req tank size	Tank cost	H.P.
500	248	300	$2497	1-1/2	498	425	$3102	1	746	800	$4224	2
501	112	150	$1761	3/4	223	425	$3102	1	335	no change	$3102	1
502	96	100	$1417	1/2	192	300	$2594	1	288	no change	$2594	1
503	165	200	$2161	1	331	425	$3102	1	497	500	$3514	1-1/2
504	155	200	$2161	1	309	500	$3628	1-1/2	464	475	$3358	1-1/2
505	105	150	$1761	3/4	209	330	$2716	1	314	no change	$2716	1
506	64	100	$1417	1/2	127	200	$2161	3/4	191	no change	$2161	3/4
508	182	250	$2022	1-1/2	363	425	$2462	2	545	545	$2824	3
509	152	160	$1608	1-1/2	304	400	$2571	2	456	500	$2924	3
510	110	150	$1907	1/2	220	300	$2270	1	330	400	$3182	1
511	176	200	$2247	3/4	353	300	$2770	1	529	650	$4015	1
514	159	200	$2161	1	318	300	$2594	1	476	500	$3514	1-1/2
515	133	150	$1761	3/4	267	330	$2716	1	400	425	$3102	1
517	179	200	$2161	1	359	425	$3102	1	538	650	$3980	2
523	428	475	$3472	2	860	1000	$4783	3	1284	1-1000gal[c]	$4783	3
										1- 300gal	$2497	1
524	163	200	$2161	1	324	350	$2741	1	490	500	$3514	1-1/2
507	79	100	$1550	1/2	158	250	$2451	3/4	237	no change	$2451	3/4
513	121	150	$1907	1/2	242	300	$2770	1	363	400	$3182	1
518	110	150	$1907	1/2	220	250	$2451	3/4	331	400	$3182	1
519	91	100	$1550	1/2	182	250	$2451	3/4	273	300	$2745	1
520	127	150	$1761	3/4	255	475	$3472	1-1/2	382	no change	$3472	1-1/2
521	162	200	$2247	3/4	324	300	$2770	1	486	500	$3615	1-1/2
Total investment:			$43,597				$63,278				$74,651	

[d]

a Denotes storage requirements in gallons.
b Denotes horsepower.
c Least-cost combination is obtained with the two tanks and associated prices indicated.
d Procedure for computing:
(1) average daily production during peak production month (taken from Table 3, Appendix A) served as base figures for computing - - to each figure, twenty percent (reserve capacity) was added for every-day, EOD, and every-third-day pick-up.
(2) resultant in (1) above was divided by 8.6 (pounds of milk per gallon) to convert to storage requirements in gallons.

Appendix Table 3. - Average Operational Cost of Storage - - All Producers on a Selected Bulk Milk Route, Virginia, 1959[a]

(1) Producer	(2) Average production for every-day pick-up[b]	(3) Cost per hundred pounds	(4) Actual producer cost - every-day pick-up	(5) Projected producer cost - EOD pick-up	(6) Projected producer cost - 3rd day pick-up
500	1200	.045	.54	1.08	1.62
501	700	.062	.43	.86	1.29
502	500	.074	.37	.74	1.11
503	900	.061	.55	1.10	1.65
504	800	.068	.54	1.08	1.62
505	600	.073	.44	.88	1.32
506	300	.123	.37	.74	1.11
508	1000	.055	.55	1.10	1.65
509	900	.061	.55	1.10	1.65
510	700	.062	.43	.86	1.29
511	1000	.055	.55	1.10	1.65
514	1000	.055	.55	1.10	1.65
515	800	.068	.54	1.08	1.62
517	1000	.055	.55	1.10	1.65
523	2400	.021	.50	1.00	1.50
524	800	.068	.54	1.08	1.62
507	500	.074	.37	.74	1.11
513	700	.062	.43	.86	1.29
518	600	.073	.44	.88	1.32
519	500	.074	.37	.74	1.11
520	600	.073	.44	.88	1.32
521	900	.061	.55	1.10	1.65
Total cost per collection period			$10.60	$21.20	$31.80

a Procedure for computing:
(1) Producer annual production divided by 365 to obtain average pounds produced daily
(2) Daily pounds produced multiplied by cost per hundred pounds to obtain actual producer cost per day
(3) Resultant in column (4) above multiplied by factors of two and three to project storage costs for every-other-day and every-third-day pick-up, respectively.

b Average daily production rounded to nearest hundred pounds to conform to the cost scale used.

Appendix Table 4. - Annual Average Rate of Storage Tank Utilization - - All Producers on a Selected Bulk Milk Route, Virginia, 1959[a]

(1)	(2)	(3)	(4)	(5)
Producer	Total annual production[b]	Average production for EOD pick-up	Tank size	Annual average rate of tank utilization
500	447501	2452	425	67%
501	244951	1342	425	37%
502	194490	1066	300	41%
503	345729	1894	425	52%
504	282222	1546	500	36%
505	207313	1136	330	40%
506	115740	634	200	32%
508	347284	1904	425	52%
509	315595	1730	400	50%
510	246620	1352	300	52%
511	387166	2002	300	74%
514	354353	1942	300	75%
515	281473	1542	330	54%
517	356708	1984	425	54%
523	866907	4750	1000	55%
524	295483	1620	350	54%
507	165095	904	250	42%
513	259534	1422	300	55%
518	209342	1148	250	53%
519	184756	1012	250	47%
520	213385	1170	475	29%
521	311417	1706	300	99%
Total	6,633,054			c

a Procedure for computing:
- (1) producer annual production was divided by 365 to obtain average pounds produced daily
- (2) resultant in (1) multiplied by a factor of two to obtain the average pounds stored for EOD pick-up
- (3) resultant in (2) was divided by 8.6 (pounds of milk per gallon) to convert resultant in (2) to gallons
- (4) resultant in (3) was divided by individual producer's tank size to obtain the average rate of utilization.

b Expressed in pounds.

c Average rate of utilization - 52 percent.

APPENDIX C

Operational Times and Load Schedules for the Hauler on a Selected Bulk Milk Route, Virginia, 1959

Appendix Table 1. - Load Table - - Every-Other-Day Pick-up on a Selected Bulk Milk Route, Virginia, 1959[a]

Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage
520 984		520 876		520 980		520 1012		520 1212		520 1020		520 816		520 1224		520 1600		520 1824		520 1504		520 1160	
513 1460		513 1232		513 1572		513 1112		513 1468		513 1364		513 1208		513 1480		513 1732		513 1676		513 1340		513 1664	
521 1748		521 1572		521 1368		521 1372		521 1548		521 1580		521 1412		521 1680		521 2212		521 2324		521 2144		521 1812	
507 672		507 652		507 756		507 872		507 992		507 1132		507 1008		507 1032		507 1080		507 1060		507 888		507 796	
500 2256		500 2166		500 2616		500 2472		500 2428		500 2020		500 2348		500 2676		500 2600		500 3768		500 2972		500 2808	
523 4808		523 4024		523 4372		523 4136		523 4460		523 3520		523 4412		523 5308		523 6052	53	523 4828	53	523 5404		523 5096	
524 1342	60	524 1068	60	524 1180	60	524 1532	60	524 1536	60	524 1264	60	524 1536	60	524 1812	60	15276		15480		524 1144	60	524 1880	60
13270		11590		12844		12688		13744		11900		12740		15212						15396		15216	
506 520		506 444		506 392		506 436		506 504		506 548		506 720		506 880		506 896		506 912		506 788		506 688	
501 1116		501 852		501 816		501 740		501 1000		501 1528		501 1560		501 1592		501 1600		501 1412		501 1288		501 1452	
509 1592		509 1512		509 1676		509 2080		509 2180		509 1900		509 1552		509 1208		509 1632		509 2132		509 1856		509 1724	
514 1920		514 1820		514 1888		514 2104		514 2216		514 2100		514 2020		514 1944		514 2276		514 2160		514 1864		514 1984	
502 928		502 936		502 1088		502 1148		502 1036		502 928		502 1088		502 1244		502 1376		502 1232		502 932		502 820	
503 1448		503 1372		503 1848		503 2372		503 2264		503 2052		503 1972		503 1892		503 2244		503 2184		503 1740		503 1742	
508 1760		508 1752		508 1836		508 2156		508 2012		508 1516		508 1460		508 1404		508 1996		508 2604		508 2348		508 2312	
505 936		505 756		505 752		505 860		505 1184		505 1164		505 1364		505 1500		505 1488	56	505 1388	56	505 1216		505 1188	
511 2228		511 1912		511 1948		511 2364	60	511 2252	60	511 1932		511 1944		511 1984		13508		14024		511 2264	60	511 2344	60
515 1504	60	515 1364	60	515 1244	60	14260		14648		515 1432	60	515 1508	60	515 1584	60					14296		14254	
13452		12720		13488						15100		15188		15232									
										523 ..		523 ..		523 ..		523 ..		523 1100		523 ..		523 ..	
										524 ..		524 ..		524 ..		524 2260		524 2324		524 ..		524 ..	
517 1984		517 1444		517 1468		517 1624		517 1876		517 1712		517 1984		517 2256		517 2572		517 2372		517 2184		517 2184	
510 1360		510 1092		510 1228		510 1524		510 1472		510 1532		510 1352		510 1172		510 1040		510 1572		510 1524		510 1524	
518 1548		518 796		518 800		518 1156		518 1436		518 1060		518 1328		518 756		518 740		518 1276		518 1480		518 1580	
519 1192		519 1064		519 1132		519 1184		519 1076		519 888		519 636		519 544		519 840		519 1244		519 1136		519 1304	
504 1436		504 1204		504 1264		504 1496		504 1424		504 1428		504 1620		504 1808		504 2216		504 2028		504 1520		504 1372	
515 ..	48	515 ..	48	515 ..	48	515 1504	48	515 1640	48	515 ..	48	515 ..	48	511 ..	48	511 2144		511 2528	58	511 ..		511 ..	
7520		5600		5884		8488		8924		6620		6920		6536		515 1912	55	14444		515 1552	48	515 1624	48
																13724				9396		11388	
																		515 1892	0				
																		1892					
Mileage totals:	168		168		168		168		168		168		168		168		164		167		168		168

a Amounts expressed in pounds.

Appendix Table 2. - Load Table - - Every-Day Pick-up on a Selected Bulk Milk Route, Virginia, 1959[a]

Jan			Feb			Mar			Apr			May			Jun			Jul			Aug			Sep			Oct			Nov			Dec		
Prod	lbs	mil-eage	Prod	lbs	mil-eage	Prod	lbs	mil-eage	Prod	lbs	mil-eage	Prod	lbs	mil-eage	Prod	lbs	mil-eage	Prod	lbs	mil-eage	Prod	lbs	mil-eage	Prod	lbs	mil-eage	Prod	lbs	mil-eage	Prod	lbs	mil-eage	Prod	lbs	mil-eage
520	492		520	438		520	490		520	506		520	606		520	510		520	408		520	612		520	800		520	912		520	752		520	580	
513	730		513	616		513	786		513	556		513	734		513	604		513	604		513	838		513	866		513	838		513	670		513	832	
521	874		521	786		521	684		521	686		521	774		521	790		521	706		521	840		521	1106		521	1162		521	1072		521	906	
507	336		507	326		507	378		507	436		507	498		507	566		507	504		507	516		507	540		507	530		507	444		507	398	
500	1128		500	1083		500	1308		500	1236		500	1264		500	1174		500	1174		500	1338		500	1300		500	1784		500	1486		500	1404	
523	2404		523	2012		523	2186		523	2068		523	2230		523	1760		523	2206		523	2654		523	3026		523	3068		523	2732		523	2548	
524	674		524	534		524	590		524	766		524	768		524	632		524	768		524	906		524	1130		524	1170		524	572		524	940	
517	992		517	722		517	734		517	812		517	938		517	856		517	992		517	1128		517	1286		517	1186		517	1156		517	1092	
510	680		510	546		510	614		510	762		510	736		510	766		510	676		510	586		510	520		510	786		510	788		510	762	
518	774		518	398		518	400		518	578		518	718		518	530		518	664		518	378		518	370		518	638		518	740		518	790	
519	596		519	532		519	566		519	592		519	538		519	444		519	318		519	272		519	420		519	622		519	568		519	652	
504	718		504	602		504	634		504	748		504	712		504	714		504	810		504	904		504	1108		504	1014		504	760		504	686	
506	260		506	222		506	196		506	218		506	252		506	274		506	360		506	440		506	448		506	456		506	394		506	344	
501	558		501	426		501	408		501	370		501	500		501	764		501	780		501	796		501	800		501	706	90	501	644		501	726	
509	796		509	756		509	838		509	1040		509	1090		509	950		509	776		509	604		509	816	112		14872		509	928		509	862	
514	960		514	910		514	944		514	1052		514	1108		514	1050		514	1010		514	972			14536					514	932		514	992	
502	464		502	468		502	544		502	574		502	518		502	464		502	544		502	622					509	1066		502	466	127	502	410	127
503	724		503	686		503	924		503	1186		503	1132	127	503	1026		503	986		503	946	127	514	1138		514	1080			15104			14924	
508	880	127	508	876		508	918		508	1078	127		15116		508	758		508	730	127		15254		502	688		502	616							
	15040		505	378		505	376			15264					505	582	127		15016					503	1122		503	1092		503	870		503	866	
			511	956		511	974	127				508	1006			15128					508	702		508	998		508	1302		508	1174		508	1156	
505	478		515	682	127		14992		505	430		505	592					505	682		505	750		505	744		505	694		505	608		505	594	
511	1114			14955					511	1182		511	1126		511	966		511	972		511	992		511	1072		511	1264		511	1132		511	1172	
515	752	3				515	622	0	515	752	3	515	820	6	515	716	3	515	754	3	515	792	6	515	956	19	515	946	35	515	776	15	515	812	15
	2344		515	..			622			2364			3544			1682			2408			3236			6718			8060			4560			4600	
Mileage totals:		130			127			127			130			133			130			130			133			131			125			142			142

a Amounts expressed in pounds.

Appendix Table 3. - Load Table - - Every-Third-Day Pick-up on a Selected Bulk Milk Route, Virginia, 1959[a]

Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage	Prod lbs	mil-eage
520 1476		520 1314		520 1470		520 1518		520 1818		520 1530		520 1224		520 1836		520 2400		520 2736		520 2256		520 1740	
513 2190		513 1848		513 2358		513 1668		513 2202		513 2046		513 1812		513 2220		513 2598		513 2514		513 2010		513 2496	
521 2622		521 2358		521 1952		521 2058		521 2322		521 2370		521 2118		521 2520		521 3318		521 3486		521 3216		521 2718	
507 1008		507 978		507 1134		507 1308		507 1488		507 1698		507 1512		507 1548		507 1620		507 1590		507 1332		507 1194	
500 3384		500 3249		500 3924		500 3708		500 3792		500 3030		500 3522		500 4014		500 3900		500 5154	53	500 4458		500 4212	
523 4800	53	523 5733	53	523 4642	53	523 5220	53	523 3858	53	523 4806	53	523 5292	53	523 3342	53	523 1644	53	15480		523 2208	53	523 3120	53
15480		15480		15480		15480		15480		15480		15480		15480		15480				15480		15480	
																		500 192					
523 2412		523 303		523 1916		523 984		523 2832		523 474		523 1326		523 4620		523 7434		523 7434		523 5988		523 4524	
524 2020		524 1602		524 1770		524 2298		524 2304		524 1896		524 2304		524 2718		524 3390		524 3510	45	524 2916		524 2820	
517 2976		517 2166		517 2202		517 2436		517 2814		517 2568		517 2906		517 3384		517 3858	45	12906		517 3468		517 3276	
510 2040		510 1638		510 1842		510 2286		510 2208		510 2298		510 2028		510 1758		14682				510 2364	44	510 2286	
518 2322		518 1194		518 1200		518 1734		518 2154		518 1590		518 1992		518 1134				517 3558		14736		518 2370	44
519 1788	46	519 1596		519 1698		519 1776		519 1614	46	519 1332		519 954		519 816	46	510 1560		510 2358				15276	
13558		504 1806		504 1902		504 2244		13926		504 2142		504 2430		14430		518 1110		518 1914		518 2220			
		506 666		506 588		506 654	64			506 822		506 1086	64			519 1260		519 1860		519 1704		519 1956	
504 2154		501 1278		501 1224	64	14412		504 2136		501 2292	64	15026		504 2712		504 3324		504 3042		504 2280		504 2058	
506 780		503 2058	77	14342				506 756		15414				506 1320		506 1344		506 1368	65	506 1182		506 1032	
501 1674		14307				501 1110		501 1500				501 2340		501 2388		501 2400		14100		501 1932		501 2178	
503 2172				503 2772		503 3558		503 3396		503 3078		503 2958		503 2838		503 3366	73			503 2610		503 2598	
502 1392		502 1404		502 1632		502 1722		502 1554		502 1392		502 1632		502 1866		14364		501 2118		502 1398	72	502 1230	
514 2880		514 2730		514 2832		514 3156		514 3324	56	514 3150		514 3030		514 2916	56			503 3276		13326		514 2976	74
509 2388	61	509 2268		509 2514		509 3152	42	12666		509 2850		509 2328		14040		502 2064		502 1848				14028	
13440		508 2628		508 2754		12698				508 2274		508 2190	46			514 3414		514 3246		514 2796			
		505 1134		505 1128	34			509 3270		505 1746	34	14478		509 1812		509 2448		509 3198	41	509 2784		509 2586	
508 2640		511 2868		13632		508 3234		508 3018		14490				508 2106		508 2994		13686		508 3522		508 3468	
505 1434		515 2046	28			505 1290		505 1776				505 2046		505 2250		505 2232	37			505 1824		505 1782	
511 3342		15078		511 2922		511 3546		511 3378		511 2898		511 2916		511 2976		13151		508 3906		511 3396	33	511 3516	
515 2256	6			515 1866	3	515 2256	6	515 2460	26	515 2148	3	515 2262	3	515 2376	26			505 2082		14322		515 2436	26
9672				4788		10326		13902		5046		7224		11520		511 3216		511 3792				13788	
																515 2868	3	515 2838	6	515 2328	0		
																6084		12618		2328			
Mileage totals:	166		158		154		165		181		164		148		181		211		210		202		197

a Amounts expressed in pounds.

Appendix Table 4. - Average Farm-Stop Time of the Hauler on a Selected Bulk Milk Route, Virginia, 1959[a]

	Every-Day Pick-up				Every-Other-Day Pick-up				Every-Third-Day Pick-up			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Producer	Gals. pumped[b]	Fixed time opr.[c]	Var. time opr.[d]	Total time per stop	Gals. pumped	Fixed time opr.	Var. time opr.	Total time per stop	Gals. pumped	Fixed time opr.	Var. time opr.	Total time per stop
500	286	9.0	5.7	14.7	572	9.0	11.4	20.4	758	9.0	15.0	24.0
501	78	9.0	1.6	10.6	156	9.0	3.0	12.0	234	9.0	4.7	13.7
502	62	9.0	1.2	10.2	124	9.0	2.5	11.5	186	9.0	3.7	12.7
503	110	9.0	2.2	11.2	220	9.0	4.4	13.4	330	9.0	6.6	15.6
504	90	9.0	1.8	10.8	180	9.0	3.6	12.6	270	9.0	5.4	14.4
505	66	9.0	1.3	10.3	132	9.0	2.6	11.6	198	9.0	4.0	13.0
506	36	9.0	.7	9.7	72	9.0	1.4	10.4	108	9.0	2.0	11.0
508	110	9.0	2.2	11.2	220	9.0	4.4	13.4	330	9.0	6.6	15.6
509	100	9.0	2.0	11.0	200	9.0	4.0	13.0	300	9.0	6.0	15.0
510	78	9.0	1.6	10.6	156	9.0	3.0	12.0	234	9.0	4.5	13.5
511	124	9.0	2.5	11.5	248	9.0	5.0	14.0	372	9.0	7.4	16.4
514	112	9.0	2.2	11.2	224	9.0	4.5	13.5	336	9.0	6.7	15.7
515	90	9.0	1.8	10.8	180	9.0	3.6	12.6	270	9.0	5.4	14.4
517	114	9.0	2.3	11.3	228	9.0	4.6	13.6	342	9.0	6.8	15.8
523	276	9.0	5.5	14.5	552	9.0	11.0	20.0	828	9.0	16.6	25.6
524	94	9.0	1.9	10.9	188	9.0	3.8	12.8	282	9.0	5.6	14.6
507	51	9.0	1.0	10.0	102	9.0	2.0	11.0	156	9.0	3.0	12.0
513	84	9.0	1.7	10.7	168	9.0	3.4	12.4	252	9.0	5.0	14.0
518	66	9.0	1.7	10.3	132	9.0	2.6	11.6	198	9.0	4.0	13.0
519	60	9.0	1.2	10.2	120	9.0	2.4	11.4	180	9.0	3.6	12.6
520	68	9.0	1.4	10.4	136	9.0	2.7	11.7	204	9.0	4.0	13.0
521	50	9.0	1.0	10.0	100	9.0	2.0	11.0	150	9.0	3.0	12.0
Total average stop time:		3 hours, 59.0 mins.				4 hours, 46.0 mins.				5 hours, 26.0 mins.		

a Yearly average stop time for moving milk to receiving station under each frequency of pick-up.

b Columns (2), (6), and (10) computed as follows:
- (1) days of the year multiplied by a factor of 2 to obtain the figure of 730
- (2) each producer's yearly output (Table 3, Appendix A) was divided by 730 to provide the average pounds per milking
- (3) number of pounds per milking were divided by factor of 8.6 (pounds of milk per gallon) to obtain the number of gallons per milking
- (4) the resultant in (3) above was multiplied by factors of 2, 4, and 6 to obtain the average number of gallons pumped for each producer per trip for every-day, EOD, and every-third-day pick-up.

c Columns (3), (7), and (11) computed as follows:
- (1) operations were observed and timed at the farm with a range of from seven to eleven minutes
- (2) average time for fixed operations established at 9.0 minutes per farm stop.

d Columns (4), (8), and (12) were computed by dividing the figures in columns (2), (6), and (10) by a factor of fifty (gallons per minute pumping capacity).

e Columns (5), (9), and (13) were computed by adding columns (3)(4), (7)(8), and (11)(12) for each producer.

Appendix Table 5. - Receiving Station Unload Time under Every-Day, Every-Other-Day, and Every-Third-Day Collection of Milk on a Selected Bulk Milk Route, Virginia, 1959[a]

Every-Day pick-up		Every-Other-Day pick-up		Every-Third-Day pick-up	
Load number	Unload time[b]	Load number	Unload time	Load number	Unload time
1	35	1	32	1	36
2	8	2	33	2	34
-	-	3	20	3	32
-	-	-	-	4	25
-	-	-	-	5	16
Total unload time per collection	43 minutes		1 hour, 25 minutes		2 hours, 23 minutes

a Procedure for computing:
(1) total was determined for the average load hauled each month (Appendix C, Table 1)
(2) resultant in (1) was divided by twelve to obtain an average hauled for each load
(3) the average in (2) above was divided by 8.6 (pounds of milk per gallon) to convert to gallons hauled
(4) number of gallons was divided by fifty (gallons per minute pump capacity) to determine the average unload time for each load with every-day, every-other-day, and every-third-day pick-up.

b Time is expressed in minutes.

ABSTRACT

This was a case study of a selected sample bulk milk route embracing twenty-two Virginia grade-A milk producers and the hauler who served them. The study examined aggregate investment and costs associated with every-other-day storage and collection of milk presently practiced on the route studied. On the basis of data collected, projections were made of investment and costs associated with every-day and every-third-day storage and collection of milk, and comparisons were then made of the efficiency of resource use under the three frequencies of milk storage and pick-up.

Producer cost for storage was least with every-day storage and collection. Transportation cost was highest under this frequency of collection. As frequency of collection was extended to every-third-day, producers' investment and costs increased, while investment and costs associated with hauling decreased. The reduction in hauling costs was greater than the increase in producer storage cost so that aggregate cost was minimized under this frequency of storage and collection. From the standpoint of aggregate resource commitment, third-day storage and collection was found to be the most economical on the route studied.

Existing investment and costs for hauling were found to be reasonable and compared favorably with costs of similar equipment in other areas of the grade-A dairy industry; however, storage costs were unnecessarily high because of excess storage tank capacity.