

Economies of Scale in the Operation of Country Milk Plants

with

Special Reference to New England

By

R. G. BRESSLER, JR.

*Executive Secretary, New England Research Council on Marketing and
Food Supply, 1937-39*

THE NEW ENGLAND RESEARCH COUNCIL ON MARKETING AND FOOD SUPPLY
THE MAINE AGRICULTURAL EXPERIMENT STATION
THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION
THE NEW HAMPSHIRE AGRICULTURAL EXPERIMENT STATION
THE RHODE ISLAND AGRICULTURAL EXPERIMENT STATION
THE STORRS (CONNECTICUT) AGRICULTURAL EXPERIMENT STATION
THE VERMONT AGRICULTURAL EXPERIMENT STATION
AND
THE UNITED STATES DEPARTMENT OF AGRICULTURE

BOSTON, MASS.

JUNE 1942

ACKNOWLEDGMENTS

As a contribution to the milk marketing program of the New England Research Council, the study on which this report is based was made possible through the cooperation of numerous agencies and individuals. The project had the active support of all the Agricultural Experiment Stations in New England and of the United States Department of Agriculture. The Dairy Committee of the Council followed the progress of the study and offered many suggestions and criticisms. Several companies that operate country dairy plants or manufacture creamery equipment have given generous cooperation. In addition, the findings of several studies of milk marketing and country-plant operations have been utilized throughout the study and the report.

D. O. Hammerberg and Alan MacLeod, both as representatives of the Storrs and the New Hampshire Agricultural Experiment Stations and as representatives of the Council, were helpful in organizing the study and in formulating the report. F. V. Waugh, R. O. Been, and other members of the Bureau of Agricultural Economics, United States Department of Agriculture, have taken an active interest throughout. Caroline B. Sherman and R. G. Hainsworth of the Bureau have helped in the preparation of the manuscript for publication. New England Dairies, Inc., made basic data available. C. W. Dingman, Springfield Bank for Cooperatives, Farm Credit Administration, gave aid with respect to the design of milk plants and the costs of construction.

The following list includes the agencies that have contributed most to the progress of the study. Others aided. Detailed credits to agencies and individuals occur throughout the publication.

- The New England Research Council on Marketing and Food Supply.
- The Agricultural Experiment Stations of the six New England States.
- The United States Department of Agriculture.
- The Farm Credit Administration.
- The Vermont Department of Agriculture.
- The New Hampshire Department of Agriculture.
- The New England Dairies, Inc.
- The United Farmers Cooperative Creamery Association, Inc.
- The Milton Cooperative Dairy Corporation.
- The Richmond Cooperative Creamery Association, Inc.
- The H. P. Hood & Sons, Inc.
- The Whiting Milk Company.
- The New England Fire Insurance Rating Association.
- The E. S. Adsit Coal Company, Inc.
- The Titusville Iron Works Company.
- The Cherry-Burrell Corporation.
- The York Ice Machinery Corporation.
- The Creamery Package Manufacturing Company.
- The Lathrop-Paulson Company.

FOREWORD

Our present marketing system is the result of decades of slow growth and evolution under conditions far different from those envisioned by the classical economist. Lags, imperfections, and elements of monopoly have been important and have molded the development of the system until today it is characterized by duplication, unutilized capacity, and an excessive number of processing and marketing plants. The almost unlimited number of grocery stores, drug stores, service stations and sales agencies are examples of this wasteful situation in the general field of marketing, while in agriculture the redundant and duplicating dairy plants, grain elevators, produce markets, and many other types of processing and handling plants are familiar. As a result of these inefficiencies, the marketing services are provided at unnecessarily high costs.

This publication explains the use of a budgetary or synthetic approach in the determination of plant costs under efficient operating conditions. The method may be used to develop approximate descriptions of the economies of scale for plants of any type—information that is essential in judging the existing system or in planning more efficient marketing organizations. With the synthetic method the research worker may determine the effects of revisions in the lay-out and operation of actual plants and may project the cost curves for individual plants and for the industry. The concrete application in this bulletin has been limited to a relatively simple type of dairy plant. Similar analyses may be used to study handling and processing plants of all types and for all commodities, and in many instances may be the only practical means of describing the efficient level of costs for the operation in question. The method should be a useful tool for students of marketing organization and reorganization, especially when drastic changes in the system are imperative. The war emergency is already emphasizing the need for studies of this type, and this need will probably continue or even increase in the reconstruction period that comes after the war.

CONTENTS

	PAGE		PAGE
Introduction	7	Centralized bookkeeping and supervision	55
Trends in country-plant operations in New England	8	Plant loss or shortage.....	55
Some production characteristics	15	Summary of plant costs	59
Average cost-volume relationships..	17	The economics of scale.....	62
Excess capacity in milk-plant operations	19	Comparison of the economy curve with average cost-volume relationships	64
The concept of economies of scale...	21	Some modifications to the economy curve	65
Methods used in the determination of economies of scale	22	Variations in electrical-power rates	65
Effects of changes in volume on variable costs	24	Variations in prices of coal.....	66
Costs of electricity	24	Variations in fixed costs.....	67
Costs of fuel	30	Variations in labor costs.....	68
Costs of supplies other than fuel..	33	Combined effects of variations in eight cost elements	70
Costs of labor	34	Effect of seasonal variation.....	71
Secondary plant costs	40	Changes in the receiving period..	74
Investments in land, buildings, and equipment	41	The combination of plant and collection costs	75
Investment in land	41	Plant costs under efficient organization	79
Investment in buildings	43	Country plant allowances	80
Investment in equipment	46	Summary and conclusions	83
Total investment in land, buildings, and equipment	47	Literature cited	84
Fixed costs of plant	48	Appendix	85
Depreciation costs	49	Buildings and equipment for six theoretical plants	85
Interest charges	51		
Other fixed costs	52		

INTRODUCTION

As markets expand and reach farther afield for their milk supplies, the costs of direct shipment from farm to market increase until a point is reached at which it is more economical to collect the milk at country plants and to ship from these plants to market. This system transfers certain operations, such as cooling, testing, and record keeping, to the country points and makes possible the more efficient transportation of milk and other dairy products. Economies resulting from these changes, as well as possible improvements in the physical condition of the products, are primarily responsible for the existence of country plants.

Country dairy plants in New England developed during the period when fast transportation for long distances was possible only by rail. Plants were established to receive milk from producers and to prepare it for shipment to market. Slow and expensive transportation by wagon or sled limited the territory from which any plant could draw its supplies. As a result, the peripheries of large metropolitan milksheds were dotted with relatively small country milk plants. In places farther removed from market, small processing plants were established for the manufacture of butter and cheese.

With the advent of motortruck transportation and improved highways, the physical and economic limitations to plant size were reduced. At the same time the metropolitan markets were growing and their fluid milksheds were being expanded into country previously devoted to the manufacture of dairy products. This has been the general situation in the northern New England States—Maine, New Hampshire, and Vermont.

The combination of these forces made pronounced shifts economically desirable in the number, type, and location of country dairy plants. These shifts have been impeded by the more-or-less natural reaction against change on the part of both producers and plant operators and by the long-time nature of investments. In addition, there has been a growing tendency for vertical and horizontal integration in the dairy industry. This, together with the elements of spatial monopoly involved, lessened the effectiveness of competitive forces and so prevented or retarded the evolution towards the most efficient organization. Despite important reductions in the number of plants and changes in plant types, the adjustment appears to be far from complete.

The problem of the most economical organization of country plants is really a combination of the problems involved in the collection and transportation of milk and in plant operation. In this broad sense the

solution is beyond the scope of the study here reported. Although several parts of this publication are devoted to illustrations of the way in which the several elements should be combined in order to arrive at the general solution, the major emphasis is on the operation of country plants that receive and ship fluid milk, especially the determination of the costs that would characterize efficient operation, and the relationship between these "efficient" costs and plant size.

The methods employed in these computations are applicable not only to country milk plants but to all types of processing and manufacturing plants. The results here reported apply only to milk plants, of course, and more specifically to plants operating in the northern New England States. Wherever possible the relationships have been developed in terms of physical inputs, however, and then converted into costs by the application of suitable cost rates or prices. The nature of the physical relationships indicates that the physical inputs are generally applicable to all country plants receiving whole milk and shipping it in tanks, although they will undoubtedly be modified by future technological developments.

Cost rates, on the other hand, are subject to important geographical variations and these will have to be considered in applying the results of this study to any particular location in New England or in other areas. This may be accomplished with little difficulty through the substitution of the appropriate rates for those used in the present calculations. Cost rates are also subject to pronounced historical variations. These may be corrected for in the manner indicated above, but it is important to realize that economy curves are essentially long-run in nature and that their major usefulness as contemplated in this study is in connection with the planning of future market organizations. From this standpoint the cost rates used should reflect normal or long-run conditions and not the short-run conditions associated with periods of depression or inflation.

Before embarking on this consideration of the economies of scale in the operation of country milk plants, brief descriptions of the present organization and operation of the plants in northern New England and the evolution that has been taking place during the last few years are needed. These are presented in the pages immediately following.

TRENDS IN COUNTRY-PLANT OPERATIONS IN NEW ENGLAND (1)¹

Production of milk in the three northern New England States has been fairly stable since 1925 but sales of milk and cream by producers have increased 10 to 15 percent, primarily as a result of the decline in

¹ Italic numbers in parentheses refer to literature cited, pp. 84 and 85.

the marketing of farm butter. In the same period the number of country dairy plants has dropped from more than 250 to less than 150, a decline of nearly 45 percent. Plant consolidations were most pronounced in the early 1930's, and the number of plants reached a low point about 1935. Average plant volume nearly doubled during the period.

Approximate locations of country plants in operation in those states on January 1, 1938, are given in figure 1. More than three-fourths of the plants are located in Vermont. Changes in the number and size of plants for this State, the only one for which continuous series are available, are given in table 1. These tabulations include some plants that are the "city" plants of small local dealers and so are not strictly representative of the country-plant situation, but the nature of the changes are indicative of the movements that have taken place.

Trends in the number and size of country plants were accompanied by, and to some extent were the result of, trends in the type of country-

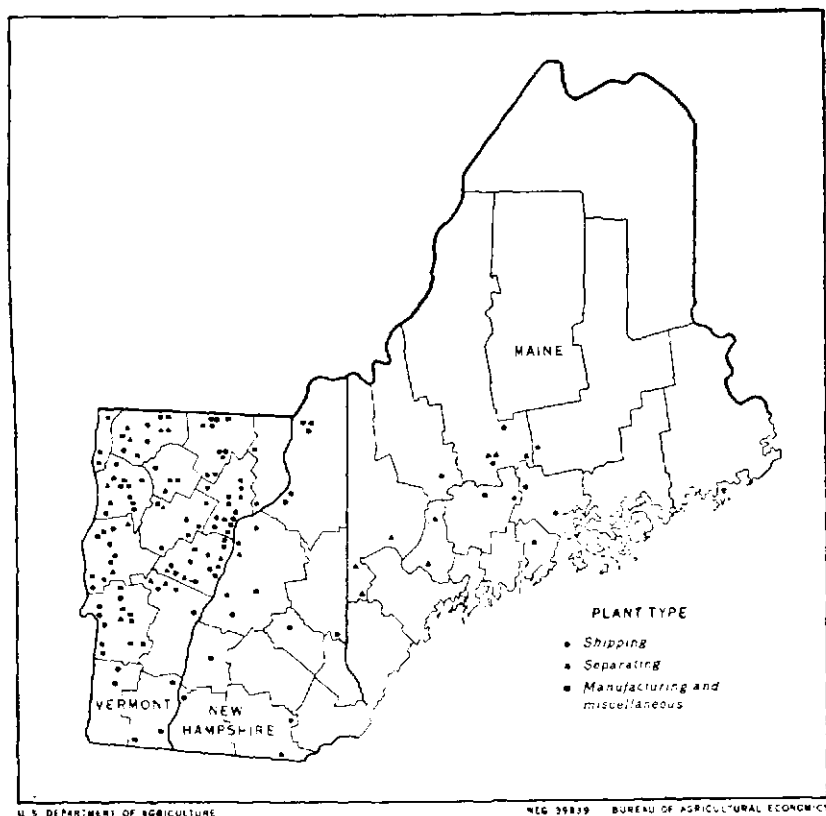


FIG. 1. Approximate location and type of 145 country dairy plants in northern New England, January, 1938.

TABLE 1.—CHANGES IN THE NUMBER OF DAIRY PLANTS AND IN AVERAGE VOLUME PER PLANT, VERMONT, 1920-39

Year	Plants ¹	Volume per plant ²
	Number	Million pounds
1920	224	3.9
1921	225	4.2
1922	221	4.4
1923	210	4.7
1924	209	4.7
1925	204	4.8
1926	203	4.8
1927	200	4.9
1928	197	4.8
1929	193	4.7
1930	182	5.3
1931	167	6.0
1932	145	6.9
1933	140	7.1
1934	135	6.9
1935	130	7.6
1936	134	7.6
1937	135 ³	7.4
1938	133	7.3
1939	131	7.6

¹ Includes some plants that are the city plants of local distributors.

² Average volume of milk and cream in terms of equivalent of cream from producers.

³ Reported as 134 plants in a recent revision of the Vermont law requiring very small local plants to register. Average volume per plant for all plants that 78 plants are comparable to price in 1937. Some adjustments were made in 1938 and 1939.

Compiled from reports of the Vermont Department of Agriculture.

plant operations. The Boston and the New York markets were reaching farther and farther into northern New England for fluid milk and cream, thereby displacing the manufacture of milk and butterfat products such as cheese and butter. Trends in the utilization of butterfat at plants in Vermont (table 2) are fairly representative of the shifts that were taking place in the whole area. During a period of 15 or 20 years, from the early 1920's to the middle and late 1930's, milk and cream increased from about 27 and 30 percent of total plant shipments to approximately 48 and 46 percent respectively. In the same period the use of milk and cream in the manufacture of butter dropped from about 35 percent of the total to 5 percent, a decline of more than 80 percent. The combined production of whole-milk cheese and condensed whole milk accounted for approximately 8 percent of total shipments from these plants in the early part of the period but only 1 percent in more recent years.

The increasing volume of cream shipments plus a pronounced shift from farm separation resulted in a steadily expanding quantity of skim milk at country plants. As a consequence, the manufacture of skim-milk products has been growing in importance. The production of casein in plants in Vermont tripled between 1924 and 1934, and then fell off

TABLE 2.—ANNUAL VOLUME OF DAIRY PRODUCTS (3.7-PERCENT MILK EQUIVALENT) HANDLED BY DAIRY PLANTS, VERMONT, 1920-39

Year	Milk	Cream ¹	Butter	Cheese ²	Condensed ³	Total
	Million lbs.	Million lbs.	Million lbs.	Million lbs.	Million lbs.	Million lbs.
1920	239	243	302	38	44	866
1921	243	295	344	30	37	949
1922	290	326	307	19	16	958
1923	328	333	273	21	33	988
1924	335	340	252	14	24	965
1925	399	330	199	12	32	972
1926	398	395	145	13	34	985
1927	441	372	139	9	15	976
1928	440	357	120	11	20	948
1929	476	323	93	7	12	911
1930	446	416	86	14	9	971
1931	507	405	72	6	10	1,000
1932	513	419	58	4	2	996
1933	462	435	49	9	3	958
1934	438	443	39	5	..	925
1935	444	478	53	8	..	983
1936	459	489	54	13	4	1,019
1937	488	448	57	4	..	997
1938	470	441	55	7	2	975
1939	454	485	43	9	3	994

¹ Includes small quantities of ice-cream mix.² Cheddar cheese, cream cheese, and other soft whole-milk cheese.³ Includes both condensed and evaporated whole milk.

Computed from reports of the Vermont Department of Agriculture.

TABLE 3.—UTILIZATION OF SKIM MILK BY DAIRY PLANTS, VERMONT, 1924-39

Year	Returned ¹	Shipped ²	Manufactured into				Estimated total ³
			Casein	Powder	Condensed ⁴	Cheese ⁵	
	Million lbs.	Million lbs.	Million lbs.	Million lbs.	Million lbs.	Million lbs.	Million lbs.
1924	..	11	56	..	23	13	178
1925	..	13	28	..	36	12	140
1926	9	13	58	..	44	15	173
1927	12	9	71	..	54	7	166
1928 ⁶	..	..	..	..	..	..	190
1929	6	25	66	6	72	1	180
1930	7	22	122	7	63	1	184
1931	12	19	113	..	45	2	242
1932	12	16	80	7	38	3	134
1933	7	18	115	14	51	3	278
1934	11	26	158	16	49	15	244
1935	63	48	135	57	63	6	414
1936	44	54	99	139	77	39	427
1937	66	108	97	104	45	7	378
1938	22	107	92	93	69	49	363
1939	45	163	48	97	63	19	380

¹ Returned to producers.² Includes shipments to market, and to other country plants, and so is in part a duplication of skim milk manufactured where received from other plants.³ Condensed and evaporated skim milk.⁴ Cottage cheese and other soft skim-milk cheeses.⁵ Estimate from total fluid-milk receipts and the use of milk in whole-milk shipments, condensed and evaporated whole milk, and whole-milk cheese. The difference between the total of these last items and total milk receipts was taken to represent the quantity of milk separated at country plants, and skim milk was estimated as 90 percent of this quantity.⁶ Not available.

Compiled from reports of the Vermont Department of Agriculture.

with the rapid increase in the manufacture of skim-milk powder. Condensed skim milk has accounted for 15 to 20 percent of the total skim during the period. These movements are given in detail in table 3.

Changes in the utilization of milk at country plants were, of course, associated with changes in the type of plant operations and with marked shifts in the relative importance of certain types of plants. The number of plants shipping milk and cream increased during the 1920's and then declined with the consolidation of plants and the consequent expansion in average volumes. The number of plants engaged in the manufacture of butter, cheese, and condensed whole milk decreased rapidly, especially between 1920 and 1930. On the other hand, there was some expansion in the number of plants manufacturing skim-milk products, although most of the increased production appears to have resulted from increased volume per plant.

Shifts in plant type can be presented more accurately through a comparison of detailed cross-section descriptions for two periods. Such descriptions are presented in table 4 for plants in Vermont during 1925

TABLE 4.—DISTRIBUTION OF COUNTRY DAIRY PLANTS BY SIZE AND TYPE, VERMONT, 1925 AND 1937

Type of plant ¹	Year	Size of plant—million pounds of milk equivalent per year ²								Plant ³	Average size of plant ⁴
		0-2.9	4-7.9	8-11.9	12-15.9	16-19.9	20-23.9	24-27.9	28 and over		
Milk	1925	12	12	4	..	..	..	..	..	28	4.5
	1937	9	9	12	4	3	1	..	..	38	8.7
Cream	1925	15	2	3	..	..	..	..	..	20	3.7
	1937	4	1	2	1	1	1	..	..	10	8.5
Milk and cream	1925	9	14	8	2	2	..	..	..	35	7.1
	1937	8	7	9	1	2	1	2	4 ⁵	34	14.3
Butter	1925	38	7	1	..	..	..	..	..	46	2.6
	1937	3	1	1	..	..	..	..	..	5	4.6
Cheese	1925	6	..	..	..	..	..	..	..	6	1.0
	1937	3	..	..	..	..	..	..	..	3	1.0
Diversified ⁶	1925	13	13	9	3	4	2	2	..	46	8.6
	1937	4	1	3	2	1	..	1	2 ⁷	14	14.3
Total ⁴	1925	93	48	25	5	6	2	2	..	181	5.3
	1937	31	19	27	8	7	3	3	6 ⁷	104	10.9

¹ Based on reported shipments of milk, cream, butter, whole-milk cheese, and condensed or evaporated whole milk. Skim-milk operations have not been considered. Any of the products enumerated that accounted for 5 percent or more of the total milk equivalent was considered in classifying the plants.

² The 4-percent milk equivalent of the products shipped. As shipments are made between plants, the plant sizes as here measured are larger than the receipts from producers by about 20 percent.

³ Does not include plants that are primarily the city plants of local dealers. Also omitted are 13 plants in 1925 and 7 in 1937 which could not be classified on basis of available information.

⁴ These plants ranged up to 89 million pounds annually, and averaged 53.8 million pounds.

⁵ Plants manufacturing one or more products and shipping milk, cream, or both.

⁶ These plants ranged up to 63 million pounds, and averaged 45.4 million pounds.

⁷ Average annual receipts of 51.0 million pounds.

Basic data obtained from the Vermont Department of Agriculture. The 1925 data were summarized and classified by Schoenfeld.

and 1937.² The plants have been classified according to the reported shipments of milk, cream, butter, whole-milk cheese, and condensed whole milk. Utilization of skim milk has not been considered. As the shipment data include shipments to and from other plants, the indicated plant volumes are higher than the receipts from producers. The table shows that the number of plants shipping milk and cream has remained fairly constant, although there has been a decrease in the number of specialized cream-shipping plants and a corresponding increase in the number of milk-shipping stations. Average shipments for these plants doubled during the 12-year period. The number of specialized butter and whole-milk cheese plants dropped 85 percent, while the number of plants that combined manufacturing operations with milk and cream shipments declined 70 percent. In short, the elimination of whole-milk and butterfat manufacturing plants was almost complete, and the milk formerly handled by these plants was diverted to milk- and cream-shipping plants.

TABLE 5.—DISTRIBUTION OF COUNTRY DAIRY PLANTS IN NORTHERN NEW ENGLAND BY TYPE AND BY VOLUME OF ANNUAL RECEIPTS FROM PRODUCERS

Annual receipts in million pounds ¹	Type of plant ²				All plants ³
	Shipping	Separating	Manufacturing	Unclassified	
	Number	Number	Number	Number	Number
0.0-1.9	6	2	15	..	23
2.0-3.9	12	5	4	3	24
4.0-5.9	8	3	3	..	14
6.0-7.9	6	6	8	2	22
8.0-9.9	10	2	7	1	20
10.0-13.9	10	5	1	..	16
14.0-17.9	4	..	3	..	7
18.0-21.9 .....	..	1	4	..	5
22.0-29.9	1	1	3	..	5
30.0-49.9 .....	..	..	1	..	1
50.0-69.9 .....	..	..	..	1	1
Total plants ³	57	25	49	7	138
Average receipts ¹	7.5	7.6	8.7	13.9	8.3

¹ Four percent milk equivalent of milk and cream received from producers.

² Shipping stations ship more than 95 percent of their receipts without further processing; separating plants separate at least 5 percent of the milk equivalent received but perform no other processing operations; manufacturing plants process at least 5 percent of their receipts into whole-milk, butterfat, or skim-milk products; and unclassified plants are those for which incomplete data or unusual operations prevent classification.

³ Does not include plants that opened or closed during the year.

Basic data obtained from the Vermont and New Hampshire Departments of Agriculture and from G. F. Dow of the Maine Agricultural Experiment Station. New Hampshire and Vermont data are for 1937 while Maine data are for 1939.

A more detailed description of plant type is given in table 5 for the recent period. This classification has been based on skim-milk as well as whole-milk operations and divides the plants into three main groups:

² The 1925 data were summarized and analyzed by W. A. Schoenfeld, but for the most part were not included in his report, "Some Economic Aspects of the Marketing of Milk and Cream in New England," U. S. D. A. Circular No. 16 (1927).

(1) plants that receive milk and cream and ship to other plants or to market without further processing of any kind; (2) plants that separate part or all of the milk received and ship milk, cream, and skim milk; and (3) plants that manufacture a significant part of their receipts into whole-milk, butterfat, or skim-milk products.

Of the 138 plants that operated throughout the entire year 57 were classified as shipping stations, 25 as separating plants, 49 as manufacturing plants, and 7 could not be classified as to type because of incomplete information. The shipping stations included 46 plants with average annual receipts of 8.4 million pounds of milk that received and shipped only milk, and 11 plants with average annual receipts of 3.8 million pounds of milk equivalent that received and shipped cream or both milk and cream. The 25 separating plants converted an average of approximately 60 percent of their receipts into cream, while 8 of them separated 95 percent or more. Annual receipts of these plants ranged from less than 4 million to more than 22 million pounds of milk equivalent, and averaged 7.6 million pounds. The 49 manufacturing plants included 16 plants that manufactured whole-milk or butterfat products, 26 that manufactured skim-milk products, and 7 that made both types of products.

In addition to the receipts of milk and cream from producers, some of these plants received relatively large shipments from other plants. It is estimated that nearly 20 percent of the total receipts of milk equivalent from producers was shipped to other plants in 1937. The quantity received by shipping stations from other plants was relatively small, but for manufacturing plants the receipts from other country plants

TABLE 6.—INTERPLANT SHIPMENTS OF MILK, CREAM, AND SKIM MILK, COUNTRY DAIRY PLANTS, NORTHERN NEW ENGLAND, 1937¹

Distance shipped in miles ²	Volume of product shipped per year			
	Milk	Cream ³	Skim milk	Total ⁴
	Million lbs.	Million lbs.	Million lbs.	Million lbs.
0-9	28	4	17	45
10-19	38	..	18	56
20-29 .....	..	5	12	19
30-39	9	13	29	39
40-49	2	1	11	13
Total	83	23	87	172
Average distances in miles.....	14	28	25	20

¹ Based only on those reports for which destination of shipments were given.

² Air-line distances between plants. Actual road distances would be somewhat longer.

³ In terms of 4-percent milk equivalent.

⁴ Including cream as 40-percent cream, not as 4-percent milk equivalent.

Basic data obtained from the Vermont and New Hampshire Departments of Agriculture and from G. E. Dow of the Maine Agricultural Experiment Station.

averaged more than 40 percent of the direct receipts from producers. In addition to the milk and cream shipments, a considerable volume of skim milk was diverted from separating plants to plants engaged in the manufacture of skim-milk products. The reports of these interplant movements are not complete, but table 6 gives some idea of their magnitude and of the distances involved in the transfers. The average milk shipments were transported about 14 miles; for the more concentrated cream the average length of haul was 28 miles. Surprisingly, the bulky and low-valued skim milk was moved an average of 25 miles, or nearly as far as cream. All three products were transferred for distances up to 50 miles.

SOME PRODUCTION CHARACTERISTICS

Several characteristics of producers' deliveries to plants have an effect on plant operations. The most important of these is the seasonal variation in receipts (table 7). Using the ratio of daily average receipts in June relative to January and December as an index of the variation for any given year, it is seen that the variation in total production decreased from 1925 to 1930 and then increased. For the State the average high-low ratio in the period 1932-37 was about 1.8, with geographical variations

TABLE 7.—SEASONAL VARIATION IN PLANT RECEIPTS AND RECEIPTS OF WHOLE MILK AS A PERCENTAGE OF ALL RECEIPTS, VERMONT, 1924-39

Year	Seasonal ratios ¹			Whole milk as percentage of all receipts ³
	Whole milk	Cream	All receipts ²	
1924	1.8	2.1	2.0	58
1925	2.0	2.1	2.1	62
1926	1.9	2.2	2.0	65
1927	1.9	2.2	2.0	66
1928	1.8	2.1	1.9	72
1929	1.8	2.1	1.8	76
1930	1.5	2.0	1.6	80
1931	1.6	1.9	1.6	79
1932	1.5	2.2	1.7	78
1933	1.5	2.3	1.7	82
1934	1.7	1.9	1.7	89
1935	1.8	2.1	1.9	93
1936	1.8	2.2	1.9	93
1937	1.8	2.4	1.8	92
1938	2.0	2.2	2.0	93
1939	1.8	2.2	1.8	94

¹ Ratio of daily average receipts in June to daily average receipts in January and December of the same year, the 2-month low period being used as an approximate correction for trends.

² Four-percent milk equivalent of milk and cream received from producers. Data for previous years indicate that this ratio was 2.6 in 1937 and 2.4 in 1929.

³ Whole-milk receipts expressed as a percentage of total milk equivalent received from producers.

Computed from reports of the Vermont Department of Agriculture.

of from less than 1.5 in the southeastern to more than 2.5 in the north-western parts.

A more exact description of seasonal variation may be had from index numbers of daily average receipts, by months. Such index numbers, found in table 8 for whole milk and for the milk equivalent of milk and cream received at country plants, indicate that production was low in the winter, expanded rapidly during the spring to a maximum in June, then contracted during July and August, and declined more slowly during the fall until the low level was reached in November.

TABLE 8.—INDEX NUMBERS OF THE SEASONAL VARIATION IN RECEIPTS FOR ALL VERMONT PLANTS, ANNUAL 1937, AVERAGE 1932-37¹

Month	Receipts of whole milk		Receipts of milk equivalent	
	1937	1932-37 average ²	1937	1932-37 average ²
January	87	82	86	82
February	90	84	89	83
March	102	95	100	95
April	117	107	117	109
May	128	125	128	126
June	141	138	143	141
July	117	116	118	117
August	97	100	96	100
September	93	98	93	96
October	86	94	86	93
November	70	81	71	79
December	72	80	72	79
Average	100	100	100	100

¹ Based on daily average receipts of whole milk and 4-percent equivalent of milk and cream at plants in Vermont.

² Index numbers for the average of the 6-year period 1932-37, with correction for trend.

Computed from reports of the Vermont Department of Agriculture.

In terms of the index numbers, production averaged about 80 percent of the annual level from November to February, reached a peak of approximately 140 in June, fell to 100 in August and to 94 in October, and finally returned to the winter level of around 80 in November.

The second characteristic that has an effect on the type of plant operation is the proportion of deliveries that are received in the form of whole milk. Farm separating has been an influential factor in the past and appreciable quantities of cream are still delivered to country plants in certain places, but table 7 indicates that this operation is rapidly disappearing. In 1924, less than 60 percent of the milk equivalent received from producers was in the form of whole milk. By 1935 this had increased to more than 90 percent. In 8 of the 14 counties of Vermont, more than 95 percent of total receipts was in the form of whole milk in 1937. Receipts of cream were most important in the east-central part of the State, where from 20 to 30 percent of the total receipts

was in that form. But even there a marked and fairly rapid shift to whole milk has been evident.

AVERAGE COST-VOLUME RELATIONSHIPS

Costs of country dairy plants have been scrutinized in many research studies. Usually these studies have ascertained annual volumes and average costs per hundredweight for a number of country plants. On the basis of these observations, average costs have been computed for the whole sample and usually for particular volume groups within the sample. From this break-down it has been possible to describe the average relationship between unit costs and plant volumes. Relationships of this type have been presented by a number of investigators (2, 3, 4, 5, 6, 7). Some of these results are plotted in figure 2, where

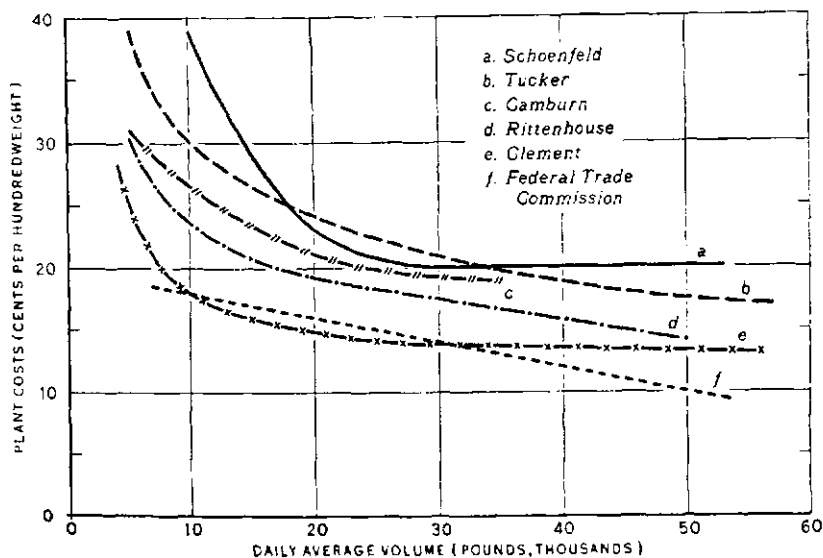
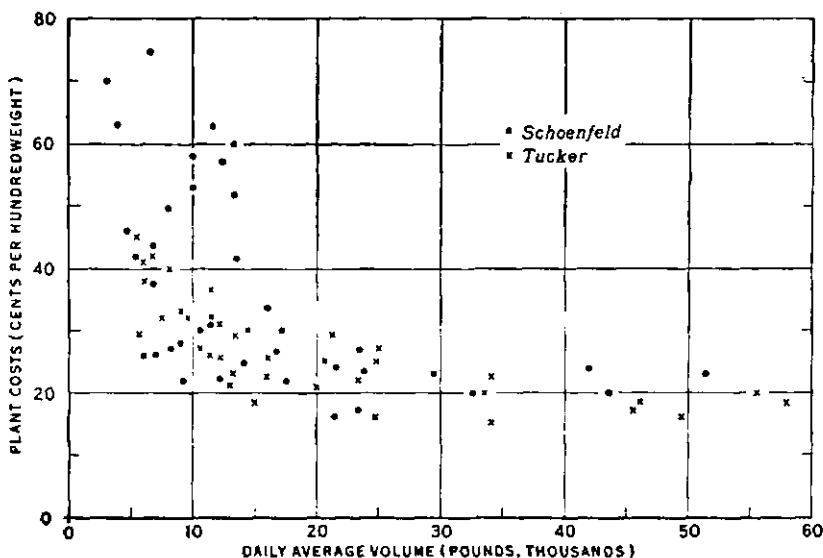


FIG. 2. Average cost-volume relationships as reported by various investigators.

group averages have been converted into smoothed curves. The curves apply only to milk receiving and shipping plants, the type of plant considered in detail in this publication, and are not applicable to the more complex plant types.

Although each study disclosed a pronounced tendency for unit costs to decrease as average plant volumes increased, the results are far from homogeneous in other respects. In figure 2, the indicated average costs for any particular volume cover a range of nearly 10 cents per hundred-

weight of milk in the higher volume ranges, and even larger spreads are found for volumes of less than 20,000 pounds daily. Furthermore, individual observations scatter widely around the averages (fig. 3). The



U. S. DEPARTMENT OF AGRICULTURE

REG. 39920 BUREAU OF AGRICULTURAL ECONOMICS

FIG. 3. Volume and average costs for individual fluid-milk plants as reported by two investigators of plant operations in 1925.

plotted observations in this diagram represent cost and volume data for individual plants as presented in two of the previously mentioned studies (2, 3).

It may be noted that the studies made in the 1925-26 period generally found costs at a higher level than did the studies made in the 1935-38 period. This suggests that part of the discrepancies between the findings of the several studies resulted from changes in the prices of such elements as fuel and labor. Although such changes have undoubtedly influenced plant costs, it seems probable that technological changes in plant operation have been more important, as consolidation took place. There can be little doubt that this adjustment resulted in more efficient use of the remaining plants.

In addition, notable changes were occurring in the methods of handling and transporting milk. In the early period practically all the milk was transported in cans, whereas in the later period most of the milk supply was shipped to market in tank cars and tank trucks (8, 9). This had a pronounced effect on the amount of labor required to handle

milk in country plants, and so could be expected to result in lowered plant-operating costs. The shift takes on added significance when it is realized that labor constitutes one of the largest elements in the total cost of operating country milk plants.

A further explanation for the spread between the results obtained in the cited studies, perhaps the chief one, is suggested by the wide scatter in the individual observations shown in figure 3. It is possible that the sampling procedure used in some of the studies did not result in representative selections, and that the differences in the shape and level of the curves are the results of this procedure.

EXCESS CAPACITY IN MILK-PLANT OPERATIONS

For any plant the cost elements involved in daily operation may be divided into two general categories: those that are fixed or constant regardless of the volume handled, and those that vary with changes in plant volume. Fixed costs are primarily those associated with land, buildings, and equipment, although there may be a considerable degree of fixity or of discontinuity in such elements as labor and supplies. Fixed costs per hundredweight decrease in a hyperbolic curve as plant volume increases, of course, since the total fixed cost is allocated among an increasing number of units. Variable costs per hundredweight are usually thought of as increasing at an increasing rate with volume increases and the resulting intensification on the fixed factors, although they may be fairly constant per unit for considerable ranges in volume.

When fixed and variable costs are combined, average total costs for any plant will ordinarily be found to decrease with volume increases in the low volume range as a result of the reductions in unit fixed costs and finally to increase as the increases in variable costs more than offset the decreases in fixed costs.

With this picture of the average costs for any given plant, it is clearly seen that a wide range in costs may be obtained from a given plant by varying the volume handled. In a similar fashion a wide range in the costs of handling a given volume of milk will result from differences in the capacities of the plants handling that volume. If capacity is well adjusted to the volume, the costs will be relatively low, but if the plant capacity exceeds the volume by a considerable amount, the allocation of fixed costs will result in relatively high average costs per hundredweight. The presence, then, of varying amounts of excess plant capacity can be expected to result in relatively wide variations in average costs for a group of plants.

It has been mentioned that the forces at work in the country phases of milk marketing are far different from those that would characterize a system of perfect competition. The imperfections and monopolistic conditions that are present will prevent the appearance of the most efficient system and can be expected to result in such inefficiencies as excess capacity. The results of a survey made in New England during the summer of 1939 to ascertain the relation between seasonal peak volumes and plant capacities substantiate this conclusion. Capacity was defined as the maximum volume that could be handled by the existing plant and equipment during the normal receiving period, and was estimated by each plant manager. Disregarding several plants where there were obvious maladjustments in particular items of equipment that could be corrected at fairly low expense, 17 fluid-milk plants were found to have peak loads ranging from less than 40 percent to more than 90 percent of capacity. The average for the group was 65 percent, so these plants could have handled more than 50 percent of additional volume. These results are summarized in table 9.

TABLE 9.—SEASONAL PEAK VOLUME RELATIVE TO PLANT CAPACITY FOR 17 FLUID-MILK PLANTS IN NEW ENGLAND, 1939

Peak volume as percentage of capacity	Plants
Percent	Number
30-39	1
40-49	1
50-59	3
60-69	7
70-79	2
80-89	2
90-99	1
Number of plants	17
Average percentage ¹	65

¹ Equivalent to 54 percent excess capacity.

In establishing this description of excess plant capacity, only the seasonal peak volumes were considered. Seasonal fluctuations in production will result in similar fluctuations in plant volumes, and so will make inevitable some average excess capacity. By limiting the consideration to peak volumes, however, it has been possible to indicate the excess capacity in addition to the normal or unavoidable excess. This measure represents the amount by which peak volumes could be expanded and, if the seasonal variation were unchanged, the possible percentage increase in average volumes for the entire year.

THE CONCEPT OF ECONOMIES OF SCALE

The primary purpose of this bulletin is to disclose the effects of the scale of operation on unit costs for country milk plants. The previously cited publications have pointed out that average costs tend to decrease with increases in plant volumes, but their results have differed widely with respect both to the general level of costs and to the nature of the cost-volume relationship. Furthermore, the studies reported were designed to disclose existing conditions and so have been affected by factors that have no place in a true description of the economies of scale. Chief among these factors are maladjustments within individual plants, and the most important of these is excess plant capacity.

Economies of scale represent the decreases in unit operating costs that accompany increases in the scale of operation, under the most efficient operating conditions. This is illustrated graphically in figure 4.

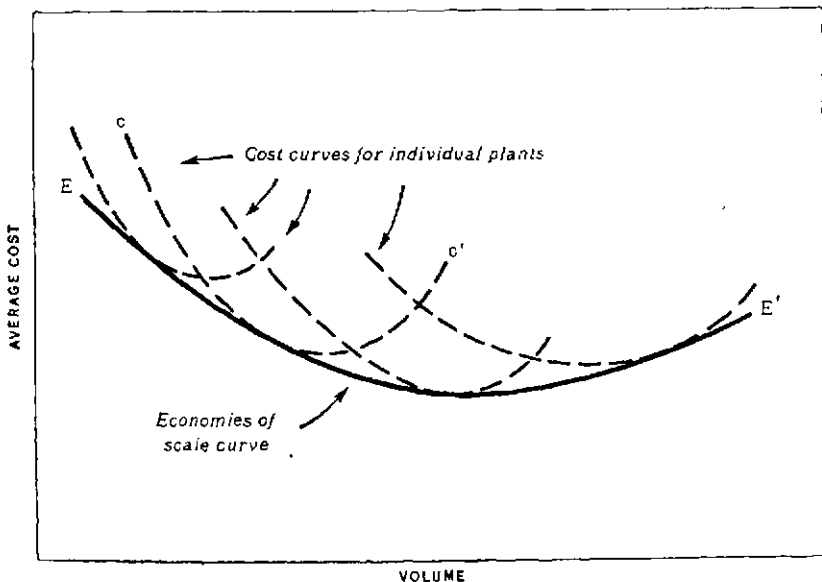


FIG. 4. Relationship between cost curves for individual plants and the curve representing the economies of scale. The broken curves such as cc' represent average cost curves for individual plants of several capacities. The solid curve EE' represents the economies of scale and is an envelope curve drawn tangent to the plant curves when plant capacities form a continuous series. Note that the minimum cost as indicated by the economy curve is lower than the least-cost points on the plant curves when the economy curve is negatively inclined. This means that, with competitive conditions but a small market, the most economical plant will be one that is operating at less than its least-cost volume. If the market is large, however, the competitive adjustment will involve plants operating at their least-cost volumes and at the lowest point on the economy curve.

Average costs for individual plants of several capacities (represented by the broken curves) are definitely affected by plant volume, first decreasing with the spreading of fixed costs and then increasing with the diminishing returns that result from intensification on the fixed factors.

Now, an increase in plant scale may be thought of as a shift from a small capacity plant to one of larger capacity. If average costs at the most efficient volumes are lower for large than for small plants, it is apparent that there are economies of scale. Eventually these economies may be dissipated or may be more than offset by dis-economies. This is the situation shown in figure 4. In some lines of endeavor there may be little if any tendency for unit costs to decrease as the scale of operation increases; such cases are termed constant-cost industries. In others, economies of scale, if present at all, are quickly exhausted and unit costs increase through most of the range in scale; these are known as increasing cost industries (10).

It may be noted that the economy curve has been drawn tangent to the individual-plant cost curves in the diagram. This will be the case if it is possible to have fairly continuous variations in scale. If plant capacities form a discrete series, the economy curve will consist of segments of the plant curves and will have a scalloped appearance. If plant volumes are subject to unavoidable fluctuations, such as those arising from the seasonal variation in milk production, the economy curve will be drawn secant to or intersecting the plant-cost curves. In all cases, however, the economy curve will represent the costs under the most efficient organizations for all volumes. Because it shows the costs that may be achieved with optimum organization and not the costs that may characterize an actual but inefficient system, the curve has sometimes been called a "planning" curve. The following pages attempt to derive and describe with some exactness this planning or economy curve for country milk plants.

METHODS USED IN THE DETERMINATION OF ECONOMIES OF SCALE

In the light of this discussion, it is apparent that a description of the economies of scale could logically be derived from a sample of plants of widely varying capacities and with volumes well adjusted to capacities within the limits imposed by the seasonal variation in production. Two factors preclude the use of this simple and direct attack: (1) the dearth of plants for which detailed information may be obtained which have widely varying capacities and at the same time no abnormal excess capacity, and (2) the difficulties involved in establishing a satisfactory measure of capacity.

This second point requires some elaboration. Volume in a given plant may be expanded until some limiting factor or bottleneck is reached. If the bottleneck is with respect to some variable factor such as labor, additional men may be hired and plant volume may be expanded further. If the bottleneck involves some item of equipment, however, the factor is relatively fixed. If new equipment is installed or additions are made to the plant, the plant and hence the plant capacity are being altered. As a great number of plants have been established for some time, adjustments in such items have taken place and it is not uncommon to find that a piece of equipment like a can washer or milk cooler is a limiting factor in a plant that in other respects would be able to handle much larger quantities of milk. The crux of the matter is that, in order to represent economies of scale, the plants included in the sample must not only have volume adjusted to capacity, but capacity should represent the real capacity of the plant and not that of a single item of equipment. In short, these plants should be designed in all respects to handle the volumes they receive.

The obvious, and perhaps only, solution to these difficulties is to make detailed case studies of a limited number of plants covering wide ranges in both volumes and capacities. On the basis of these studies, the costs that could be obtained if all internal maladjustments were eliminated may be estimated through analyses of the budget type. Finally, the average cost curves for individual plants may be synthesized and extended up to the plant capacities. The economies of large-scale operation could then be described in the way that has been indicated in figure 4.

This approach was used in making the analyses for the study here reported. Eight fluid-milk plants, selected to represent a wide range in volumes and capacities, were studied in detail. The volumes and capacities for these sample plants are indicated in table 10. All of the

TABLE 10.—OPERATING VOLUMES AND ESTIMATED CAPACITIES FOR SAMPLE MILK PLANTS LOCATED IN NEW HAMPSHIRE AND VERMONT, 1937 AND 1938

Item	Unit	Plant							
		A	B	C	D	E	F	G	H
	Daily cwt.								
Average volume . . .	of milk	34	76	102	97	91	175	251	236
Low volume	do.	25	60	60	70	40	130	180	180
High volume	do.	45	110	210	170	250	320	420	330
Estimated capacity ¹ .	do.	60	130	220	260	320	400	500	640
Floor space	100 sq. ft.	15	19	17	10	36	19	50 ²	29

¹ The maximum daily volume that could reasonably be handled with the existing plant and equipment, as estimated by the plant manager.

² Nearly half of this space is used for living quarters, etc., and so is not an essential part of the milk plant.

plants were fluid-milk receiving and shipping stations, and all shipped in tanks by motortruck or by rail. Detailed information as to volumes and inputs of the several variable cost elements were obtained by months or by 15-day periods, during 1937 and 1938. These data were used to ascertain the relations between volume and costs for the variable elements. The buildings, equipment, and plant lay-out were revised to eliminate maladjustments and normal investments and fixed costs were estimated. In the final analysis, these relationships were used to synthesize the cost curves for six reorganized plants with capacities ranging from 6,000 to 65,000 pounds of milk daily and the economy curve was constructed from these individual-plant cost curves.

EFFECTS OF CHANGES IN VOLUME ON VARIABLE COSTS

Few if any of the cost elements involved in country-plant operation are perfectly variable. Plant labor is essentially a variable cost, for example, but the necessity or common practice of adding labor in one-half or one-man intervals results in fairly wide ranges in the volume of a given plant throughout which the labor force is constant and labor costs are fixed. In spite of the fact that there are such elements of fixity, several items of cost do vary with volume and therefore may be classified as primarily variable in nature. These items were grouped under four headings: electricity, fuel, supplies, and labor. Each of these groups was studied and the resulting cost-volume relationships are next described. In addition to the relationships within individual plants, the interplant relationships or the effects of changes in plant capacity have been noted.

Costs of Electricity

Electricity plays an important part in the operation of modern milk plants. It is the source of power for pumps, conveyors, and compressors, and, less important from the cost standpoint, it is the source of light. The amount of electricity used for power within a plant may logically be expected to be dependent chiefly on the volume of milk handled. But the use of electricity for lighting will be unaffected by variations in plant volume. In addition to the effect of volume on the use of electrical power, weather conditions will exert an influence in those plants in which the milk is cooled by mechanical refrigeration, for the milk is usually delivered at higher temperature during warm weather.

Data on the kilowatt hours of electricity used for power were available by months for each of the eight sample plants. These were converted to a daily basis and related to daily average volumes. At the

same time, the effect of season of the year was included through the use of the average monthly temperatures for New Hampshire and Vermont during 1937 and 1938. In essence, this procedure consisted of fitting to the data an equation of the type: $KWH = (a + bT)V$; where KWH represents the daily average use of electricity for power in terms of kilowatt-hours, T the average monthly temperature, and V the daily average volume. The constant "a" will represent, then, the basic kilowatt-hours per hundredweight of milk, and "b" will represent the modifications to "a" that accompany each degree change in temperature.

The results of this analysis are given for the various plants in table 11. As temperatures averaged 45° F. in the New Hampshire and Vermont

TABLE II.—EFFECTS OF DAILY PLANT VOLUME AND AVERAGE TEMPERATURE ON THE USE OF ELECTRICITY FOR POWER IN EIGHT COUNTRY MILK PLANTS, 1937-38

Item	Plant							
	A ¹	B	C	D ²	E	F	G	H
Daily average volume—								
cwt.	34	76	102	97	91	175	251	236
Standard deviation..	4	10	42	15	38	48	39	36
Daily average KWH								
of power	4.9	38	45	6.2	50	65	104	99
Standard deviation..	1.2	16	18	2.0	25	23	23	30
KWH of power per								
cwt. ³	0.14	0.47	0.45	0.06	0.55	0.35	0.46	0.42
Standard deviation ⁴ ..	0.007	0.017	0.018	0.003	0.025	0.016	0.009	0.017
KWH of power per								
degree F. ⁴ .....	....	0.008	0.004	....	0.005	0.005	0.002	0.005

¹ These plants did not use electrical power for mechanical refrigeration.

² Based on the net regression between volume and kilowatt-hours of electrical power, with adjustments to hold temperature constant at 45° F.

³ From the part correlation between volume and KWH. With a regression of the type $KWH = (a + bT)V$, the standard error of the regression coefficient will be represented by $\sigma(a + bT) = (\sigma_2)^2 / \sum X^2$, where σ_2 is the standard deviation of the residuals from the regression line with proper corrections for parameters, and X represents the independent variable volume. As the observations have been adjusted to represent a constant temperature (T) of 45 degrees, the regression coefficient reduces to a single parameter.

⁴ Based on the net regression between average temperature as reported by the United States Weather Bureau and KWH of electricity per hundredweight of milk. The temperature factor is applicable only to the plants that use electrical power for mechanical refrigeration.

area, the average kilowatt-hours per hundredweight have been given for that temperature. For the six plants with mechanical refrigeration, changes in volume explain about 50 percent of the variance in the electrical current used. The use of electrical current per day in these plants increased with volume at an average rate of about 0.4 kilowatt-hours per hundredweight. Temperature explains from 10 to 20 percent of the variance in consumption of power for these plants. As temperature increased the use of power increased, the kilowatt-hours per hundredweight changing by 0.002 to 0.008 per degree change in temperature. For the two plants without mechanical refrigeration, the power per hundredweight was about 0.1 kilowatt-hour.

As both temperature and volume vary seasonally, there is a marked degree of interrelationship between these two variables. As a result, it must be recognized that changing the regression between one of these variables and daily kilowatt-hours will change in the opposite direction the regression between the other variable and kilowatt-hours. In other words, it is difficult to determine exactly the influence and importance of either variable. (In fact, this problem is impossible of exact statistical solution.) This also means that any comparison between plants can be accepted only as an approximate measure.

Refrigeration needs of a plant can be satisfied in several ways. The refrigeration load is usually concentrated within a few hours, the receiving period. Refrigeration compressors can be installed that are large enough to handle the peak load directly, or smaller compressors can be used in conjunction with brine or water tanks. The smaller compressors would operate over a longer period of time and would "store" refrigeration by cooling the brine or water contained in the tank. Furthermore, the amount of refrigeration developed by a given sized compressor is not a fixed quantity, but may vary over a wide range, depending on the back pressure.

The rated capacities for various sizes of compressors are given in table 12, together with the theoretical brake horsepower. As a brake horsepower is the equivalent of 0.746 kilowatts, it is possible to estimate the current requirements by multiplying the kilowatts by the hours of operation. In actual practice, the kilowatt requirements are somewhat

TABLE 12.—THEORETICAL RATING OF VARIOUS SIZED REFRIGERATION COMPRESSORS IN TERMS OF TONS OF REFRIGERATION, BRAKE HORSEPOWER, AND KILOWATTS OF ELECTRICAL CURRENT

Size of compressor ¹	Refrigeration capacity ²	Power required	Estimated power required per ton capacity ³	Estimated electric current per cwt. of milk ⁴
		Brake horsepower	Kilowatts	Kilowatt-hours
3" x 3" single	1.05	1.73	1.65	0.41
3" x 3" double	2.10	3.48	1.66	0.42
4" x 4" do.	4.71	7.11	1.51	0.38
5" x 5" do.	8.94	13.40	1.50	0.38
6" x 6" do.	15.60	21.80	1.40	0.35
6½" x 6½" do.	20.10	28.30	1.41	0.35
7½" x 7½" do.	31.20	42.70	1.37	0.34
8" x 8" do.	38.70	52.30	1.35	0.34
9" x 9" do.	47.50	62.70	1.32	0.33
10" x 10" do.	67.20	86.90	1.29	0.32

¹ Size and number of cylinders.

² Ratings of the American Society of Refrigeration Engineers under standard test conditions of 20 pounds suction pressure and 155 pounds condensing pressure.

³ On the basis of one brake horsepower equal to one kilowatt rather than the theoretical 0.746 kilowatts. This is to allow for such losses as motor inefficiencies.

⁴ On the basis of 400 pounds of milk per hour equal to a ton of refrigeration.

above 0.746, owing to such factors as motor efficiency, and it is a common procedure to call one brake horsepower the equivalent of one kilowatt. On this basis the estimated kilowatts per ton of refrigeration have been calculated, and appear in column four of table 12. The average kilowatts per ton are approximately 1.45, with a range from less than 1.3 kilowatts for large to more than 1.6 for small compressors (11).

A ton of refrigeration is a rate of cooling and is defined as the extraction of heat at the rate of 12,000 British thermal units per hour. If milk is received at an average temperature of 70° F. and cooled to 40°, a ton of refrigeration may be represented by the cooling of 400 pounds of milk per hour. On this basis the theoretical kilowatt-hours of electricity per hundredweight of milk have been calculated and are given in the last column of table 12. This estimate covers refrigeration only, but the total kilowatt-hours per hundredweight may be approximated by adding 0.1 kilowatt-hours to the refrigeration requirements, since this was the average power requirement for the two plants without mechanical refrigeration.

Use of electricity for lighting is primarily affected by the hours of plant operation in relation to the hours of daylight. The results of relating time of sunrise to the daily kilowatt-hours of electricity for lighting are shown in table 13. On the average, a change of 1 hour in the time of sunrise was associated with a change of about 0.6 kilowatt-hours in the daily use of electricity, except when the sun rose before 5:00 a.m. During the summer, when this was true, the amount of electricity used was fairly constant. As most plants open between 5:00 and 6:00 a.m., they would be operating wholly in daylight during these months.

Variation between plants in the use of electricity for lighting may be due to several factors such as size of plant, plant lay-out, and operating schedule. The first of these is of prime importance to a study of

TABLE 13.—RELATIONSHIP BETWEEN DAILY CONSUMPTION OF ELECTRICITY FOR LIGHTING AND TIME OF SUNRISE, SEVEN MILK PLANTS¹

Item	Plant							Average all plants
	A	B	C	D	E	F	H	
KWH per day.....	0.3	1.0	0.4	1.6	2.1	0.9	1.8	1.3
Floor space 100 sq. ft....	15	19	17	10	36	19	29	21
KWH per hour change in sunrise ²	0.1	0.5	0.2	0.7	1.0	0.4	0.8	0.6
Coefficient of correlation ³	.712	.469	.738	.812	.833	.659	.857	.971
Standard error of correlation .....	.061	.174	.097	.095	.076	.146	.068	.018

¹ Data not available for Plant G.

² Does not apply when sun rises before 5:00 a.m.

³ All coefficients and standard errors corrected for parameters.

the effects of capacity on plant costs. Measuring plant size in terms of approximate floor area, the average daily kilowatt-hour increases about 0.6 with every increase of 1,000 square feet of floor area.³

TABLE 14.—DISTRIBUTION OF MILK PLANTS BY DOLLAR COST PER MONTH OF 1,500 KILOWATT-HOURS OF POWER, NORTHERN NEW ENGLAND, 1939

Cost of 1,500 KWH per month	Plants
Dollars	Number
30.00-39.99	1
40.00-49.99	44
50.00-59.99	30
60.00-69.99	9
70.00-79.99 .....	..
80.00-89.99	1
Total	85

The power and lighting relationships discussed are presented in physical terms. When expressed as costs, the relationships are subject to a disrupting influence in the form of geographical differences in the charges made for electricity. Table 14 shows the variations reported in power costs for 85 towns in Maine, New Hampshire, and Vermont, where country dairy plants are located (12). This distribution refers to the January, 1939, charges for 1,500 kilowatt-hours of current per month, and may be considered as fairly representative of plants receiving from 10,000 to 15,000 pounds of milk daily and cooling it with mechanical refrigeration. The range in monthly bills is from \$37.50 to \$84.70, and the average is \$51.45. These correspond to costs per kilowatt-hour of \$0.0250, \$0.0565, and \$0.0343 respectively.

Geographical variations in charges for electricity for lighting are also pronounced. For monthly consumption of 40 kilowatt-hours, which represents approximately the average found for the seven plants previously discussed, the monthly light bills for 104 dairy-plant locations in New England ranged from \$2.20 to \$3.80, and averaged \$2.89. In terms of rates per kilowatt-hour, these correspond to \$0.055, \$0.095, and \$0.072 respectively.

In addition to the geographical variation in rates, it is customary for the rates per kilowatt-hour in any community to decrease as the amount used increases. The average relationships between monthly bills and monthly consumption of electricity for power and for lighting are indicated in table 15. Power rates drop from an average of \$0.056 per

³ This regression results in a corrected coefficient of correlation of 0.577 with a standard error of 0.293 when applied to the averages for the seven plants for which data are available. In Plant D, however, the lay-out and lighting arrangements are very poor. For the six plants with reasonably efficient arrangements, the regression results in a corrected coefficient of 0.804 with a standard error of 0.176.

TABLE 15.—AVERAGE CHARGES FOR ELECTRICITY AT SELECTED LEVELS OF CONSUMPTION, NORTHERN NEW ENGLAND, 1939

KWH per month	Electricity for power ¹		KWH per month	Electricity for lighting ²	
	Average charge			Average charge	
	Per month	Per KWH		Per month	Per KWH
	Dollars	Dollars		Dollars	Dollars
150	8.40	0.056	15	1.23	0.082
375	16.19	.043	25	1.99	.080
750	28.25	.038	40	2.89	.072
1,500	51.45	.034	100	4.91	.049
6,000	149.31	.025	250	8.10	.032

¹ Based on data for 85 plant locations.

² Based on data for 104 plant locations.

kilowatt-hour for 150 kilowatt-hours per month to \$0.025 for 6,000 kilowatt-hours per month. Average lighting rates per kilowatt-hour decline from \$0.082 to \$0.032 with increases in monthly consumption from 15 to 250 kilowatt-hours.

On the basis of these average charges and the previously developed physical relationships, the cost relationships for the several independent factors may be developed. As this study was primarily interested in the effects of plant capacity on costs, only these relationships have been considered. The resulting cost curves are given in figures 5 and 6. Power costs per hundredweight of milk drop from nearly \$0.02 for

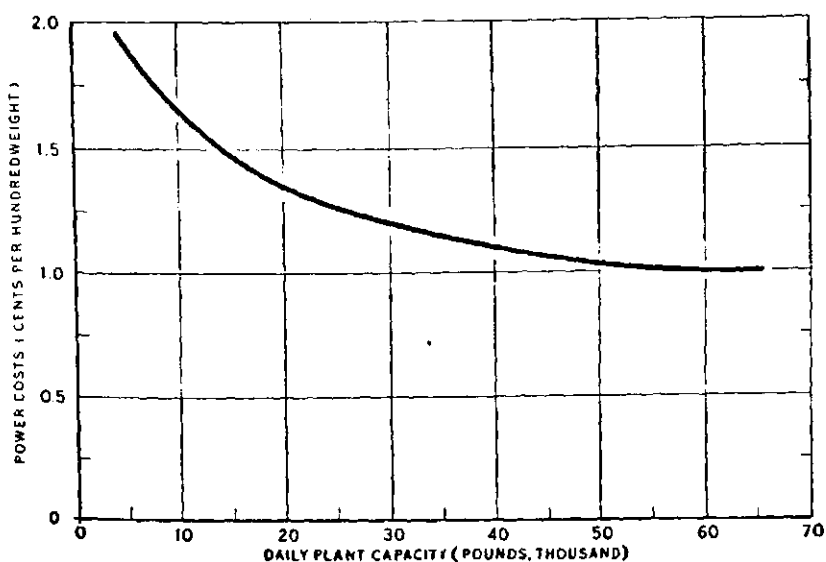
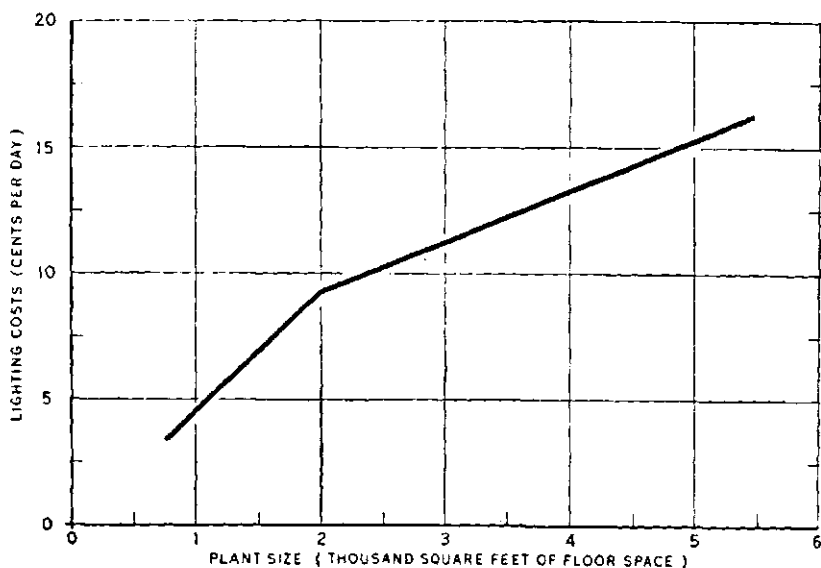


FIG. 5. Effect of plant capacity on costs of electrical power per hundredweight of milk.

plants with capacities of less than 10,000 pounds per day to approximately \$0.01 for plants with daily capacities of over 60,000 pounds. Daily costs for lighting increase with floor area at a decreasing rate, ranging from about \$0.05 for a plant with 1,000 square feet of area to \$0.12 for a plant of 3,000 square feet. As plant volume and capacity increase much more rapidly than floor area, as will be pointed out later, it is apparent that large plants are more efficient with respect to costs for lighting than are small plants.

Costs of Fuel

Coal is used in country milk plants to provide steam and hot water for the operation of can washers, for general cleaning, and to heat the plant. As the number of cans to be washed will depend primarily on



U. S. DEPARTMENT OF AGRICULTURE

NEG. 31823 BUREAU OF AGRICULTURAL ECONOMICS

FIG. 6. Effect of size of plant on the costs of daily lighting.

the plant volume, it is reasonable to expect that the daily consumption of coal will be partly a function of volume. Differences in the type and efficiency of can washers will make for imperfections in this relationship, as will differences in the type, size, and efficiency of boilers and the abilities of the firemen. Heating requirements, on the other hand, will be related to the physical size and insulating qualities of the building and will vary inversely with outside temperatures.

As in the case of electricity, the independent variables volume and temperature are inter-related, and therefore present some difficulties in analysis. Moreover, available data on consumption of coal per month are based on receipts during the month, with corrections for changes in inventories. As inventory changes are only rough approximations, the basic data are less accurate than the data obtained from electrical meters, and show wide variations from month to month as a result of inventory errors. Before using these data it was necessary to smooth out the random fluctuations through the use of moving averages.

When the independent variables were related to coal consumption it was found that an increase of 100 pounds in plant volume resulted in an average increase in daily consumption of about 3 pounds, while each degree increase in outside temperatures lowered daily consumption by about 7 pounds. The nature of these relationships varied greatly from plant to plant (table 16). Some of this variation is undoubtedly a result

TABLE 16.—EFFECTS OF DAILY PLANT VOLUME AND AVERAGE TEMPERATURE ON THE USE OF COAL AT EIGHT COUNTRY MILK PLANTS, 1937-38

Item	Unit	Plant							
		A ¹	B	C	D	E	F	G	H
	Hundred-								
Daily average volume	weight	34	76	102	97	91	175	251	236
Standard deviation		4	10	42	15	38	48	39	36
Daily average amount of coal.	Pound	300	390	380	290	560	820	1,370	850
Standard deviation		138	57	121	57	156	310	109	192
Amount of coal per cwt. ²	Pound	5.0	6.0	1.6	3.6	1.5	3.0	1.3	3.8
Standard error ³		0.58	0.13	0.19	0.08	0.12	0.17	0.07	0.09
Amount of coal per degree F. ⁴	Pound	5.0	1.0	3.8	2.6	9.0	16.0	5.0	16.0
Estimated amount of coal per day at 45° and zero volume	Pound	230	250	300	220	490	770	1,320	620

¹ This plant burned cord wood. To make the results comparable with other plants, the wood has been converted to a "coal equivalent" based on prices of the two fuels, which averaged \$1 per cord of wood and \$7.50 per ton of coal.

² Based on the net regression between volume and the daily use of coal, with adjustments to hold temperature constant at 45° F.

³ From the part correlation between volume and pounds of coal. See table 11, footnote 3.

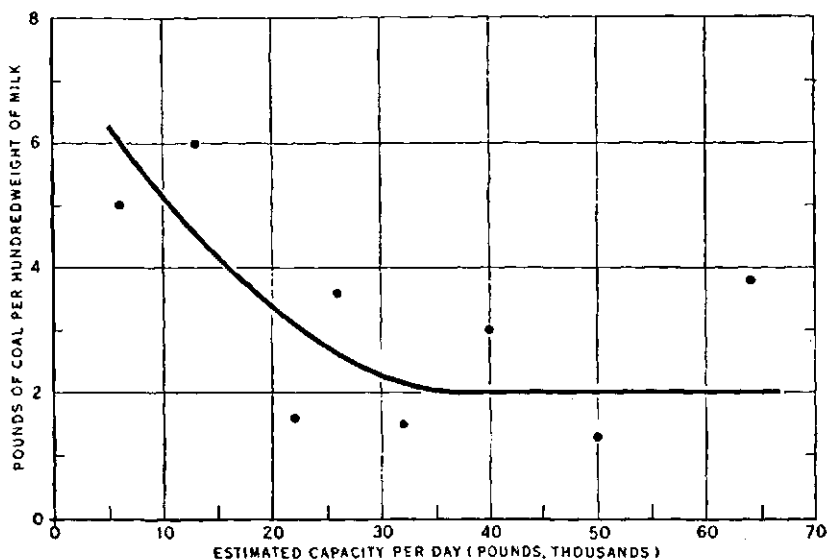
⁴ Based on the net regression between average temperature as reported by the United States Weather Bureau and the daily use of coal, holding plant volume constant.

of the previously mentioned factors, but part of it is related to changes in plant capacity. When pounds of coal per hundredweight of milk are correlated with plant capacities, as in figure 7, large plants are found to be more efficient than small plants. This regression explains more than 40 percent of the variance between plants.⁴

From the standpoint of volume changes within a given plant, a large proportion of the consumption of coal is constant or fixed. This is indicated by the size of the estimates of pounds of coal per day at zero

⁴ r (corrected) = 0.645 ± 0.238.

volume and average temperatures, given in the last line of table 16. When these estimates are related to plant size as measured by the floor area, an increase of 1,000 square feet in area is found to result in an average increase in daily coal consumption of approximately 250 pounds.



U. S. DEPARTMENT OF AGRICULTURE

NEG. 39824 BUREAU OF AGRICULTURAL ECONOMICS

FIG. 7.—The effect of plant capacity on the quantity of coal used per hundredweight of milk.

More than 70 percent of the variance between plants may be attributed to this factor.⁵

To convert these physical relationships into costs, it is necessary to have representative prices for coal delivered to country plants. Most of the coal used in the plants in New England is mined in West Virginia or in the southwestern part of Pennsylvania. The type of coal commonly used was priced at about \$2.15 per ton at the mine in 1939.⁶ The mine price plus carload freight rates results in delivered prices at "on-rail" plants ranging from less than \$6 to more than \$8 and averaging about \$6.90 per ton (table 17). Prices are low in western Vermont and high in central Maine, while equal price zones run in irregular fashions diagonally across New England from the southeast to the northwest.

These prices do not include unloading costs. No attempt has been made to investigate thoroughly these costs but data were obtained from

⁵ r (corrected) = 0.846 ± 0.116 .

⁶ The discussion of coal prices is based primarily on data obtained from the E. S. Adsit Coal Company of Burlington, Vt.

TABLE 17.—DISTRIBUTION OF DELIVERED-COAL PRICES PER TON EXCLUSIVE OF UNLOADING COSTS FOR 88 DAIRY-PLANT LOCATIONS, NEW ENGLAND, 1939

Price per ton (Mine price plus freight)	Plant locations
Dollars	Number
5.50-5.99	5
6.00-6.49	22
6.50-6.99	19
7.00-7.49	29
7.50-7.99	9
8.00-8.49	4
Total number of plants.....	88
Average price	\$6.90

Compiled from records of E. S. Adsit Coal Co.

seven "on-rail" and eight "off-rail" plants relative to these items. For the on-rail plants, unloading costs ranged from \$0.18 to \$0.26, and averaged \$0.22 per ton. For the off-rail plants, the combined costs of handling and trucking ranged from \$0.34 to \$2.00 and averaged \$0.90 per ton. About two-thirds of the variance in these costs are related to the length of haul, the charge being approximately equal to \$0.50 plus \$0.07 for each mile off rail.⁷

Returning to the physical relationships and using a price of \$7.50 as representative of the coal costs including delivery and unloading charges, the variable cost of fuel per hundredweight of milk declines from about \$0.020 for plants with capacities of less than 10,000 pounds per day to \$0.008 for plants with capacities of 40,000 pounds and over. In this calculation possible economies of large scale buying are disregarded, for most fluid plants receive in carload lots and are affiliated with large organizations. Fuel costs that are fixed for an individual plant but vary between plants change in direct proportion to the area of the building, increasing \$0.94 for every 1,000 square feet increase in floor area.

Costs of Supplies Other Than Fuel

Creamery supplies constitute a relatively minor cost in country-plant operation. They include such items as washing powders and compounds, boiler-water treatment compound, ammonia, machine oil, paper towels, sponges and brushes, and laboratory supplies such as acid, preservative tablets, pipettes, and thermometers. Some of these items vary approximately with plant volume, some are relatively fixed for a given plant but vary with changes in plant capacity, and some are subject to both types of variation.

⁷ r (corrected) = 0.802 ± 0.146.

Data were obtained for the eight fluid-milk plants relative to the physical quantities of these items of creamery supplies. These were converted into supply costs on the basis of the cost rates that were in effect at the end of 1938. Because of the discontinuity of most of the elements, no attempt was made to relate daily costs to such factors as plant volume on a monthly basis. Instead, the several items were grouped roughly into variable and fixed costs for each plant and the daily average of each type of cost was calculated for each plant.⁸ The results of these computations are given in table 18 together with the daily average volumes and estimated capacities of the plants. Variable

TABLE 18.—AVERAGE DAILY VOLUME, PLANT CAPACITY AND DAILY COST OF SUPPLIES, EIGHT FLUID-MILK PLANTS, NORTHERN NEW ENGLAND, 1937 AND 1938

Plant	Average volume	Plant capacity	Daily average cost of supplies		
			Fixed	Variable	Total
	Cwt.	Cwt.	Dollars	Dollars	Dollars
A	34	60	.04	.13	.17
B	76	130	.16	.23	.39
C	102	220	.21	.15	.36
D	97	260	.27	.20	.47
E	91	320	.38	.16	.54
F	175	400	.67	.52	1.19
G	251	509	.79	.47	1.26
H	236	640	1.09	.53	1.62

supply costs tend to increase \$0.025 for every 1,000-pound increase in daily plant volume. The relationship explains more than 70 percent of the indicated variance.⁹ Fixed supply costs per day increase in direct proportion with plant capacity, each 1,000-pound increase in daily capacity being associated with a \$0.016 increase in daily fixed costs. This relationship makes it possible to explain more than 90 percent of the variance in costs.¹⁰

Costs of Labor

Pay rolls of country plants are one of the largest costs of plant operation. Labor costs are variable costs from the theoretical standpoint, but in actual application the indivisibility of labor results in a considerable degree of fixity. There are wide ranges in volume in individual plants where the labor force will be constant or fixed, and the volumes at which labor is hired or laid off are not clearly defined.

⁸ The division of supply costs into fixed and variable classifications has been made on logical, and somewhat arbitrary, grounds rather than on the basis of empirical relationships. Some supplies are obviously fixed in character in that they tend to remain constant for a given plant regardless of the volume handled. Others increase as plant volume increases, and so are variable in character. In many cases the distinction is not clearly defined, however, and so the items have been classified as primarily fixed or variable, while in a few instances the costs were arbitrarily divided equally between the two groups.

⁹ r (corrected) = 0.844 ± 0.118 .

¹⁰ r (corrected) = 0.956 ± 0.034 .

As a result, there may be wide ranges in the volumes of actual plants where one- and two-man or two- and three-man operations overlap. Finally, the relationship between plant capacity and labor requirements is complicated by the substitution of machinery for labor.

The number of men employed in the eight sample plants and the volume ranges handled by each number are summarized in table 19.

TABLE 19.—VARIATIONS IN PLANT VOLUME AND LABOR STAFF, EIGHT FLUID-MILK PLANTS, 1937 AND 1938

Plant	Range in daily volume in plants employing ¹			
	1 man	1½ men	2 men	3 men
	Cwt.	Cwt.	Cwt.	Cwt.
A	25- 45	.....	35- 45	.....
B	60-110	.....	.....	.....
C	60- 90	70-110	80-220	.....
D .....	.....	70-144	80-170	.....
E	40- 80	60-170	60-250	.....
F .....	.....	.....	130-320	.....
G .....	.....	.....	.....	180-420
H .....	.....	.....	.....	180-330

¹ Does not include extra labor on plant and equipment repairs.

This table does not include extra labor hired to make plant repairs, for that item is included later as a part of fixed costs. A striking fact disclosed by this table is the overlapping of the amount of labor used to handle various volumes. In plant C, for example, one man handled from 60 to 90 hundredweights of milk daily and with the addition of a half-time assistant the range was from 70 to 110 hundredweights, while two full-time men handled from 80 to 220 hundredweights daily. Part of this duplication is presumably the result of the disturbed conditions that existed in the milkshed during 1937. The managers of country milk plants customarily perform a certain amount of field work, especially in connection with the control of quality in milk. With the "milk war" in progress at that time it was often difficult to obtain and keep producers on their lists, so an abnormal amount of field work on producer relationships may have been necessary to maintain plant volumes. As this represents an unusual condition, such labor can hardly be considered as a part of normal plant operation.

In an effort to resolve these difficulties, estimates were obtained from the managers of 13 fluid-milk plants as to the labor staff that would be required to handle various volumes in their plants. The peak loads that could be handled by various numbers of men are indicated in table 20. It should be emphasized that these figures do not represent absolute physical capacities, but rather the daily volumes that the labor staff could reasonably be expected to handle. In several instances the plant manager

TABLE 20.—ESTIMATED DAILY CAPACITY WITH VARIOUS LABOR STAFFS, 13 FLUID-MILK PLANTS, NORTHERN NEW ENGLAND, 1939¹

Plant	Volume of milk that can be handled by		
	1 man	2 men	3 men
	Cwt.	Cwt.	Cwt.
1 ²	60	...	...
2	135	...	...
3 ² .....	...	190	...
4	110	260	...
5 .....	...	320	...
6	200	...	...
7 .....	...	220	340
8 .....	...	...	500
9	250	...	...
10	250	...	...
11 .....	...	450	600
12	250	...	...
13 .....	...	470	640

¹ Estimated by plant managers for existing plants; they estimated the daily volume that could be handled with existing plant and labor force, and in some instances the increase in peak volume that would accompany addition of another assistant.

² These plants have maladjustments in equipment that make volume expansion impossible. All plants may have bottlenecks that become limiting factors, but these are the only plants in the group that have obvious and serious blocks to volume expansion.

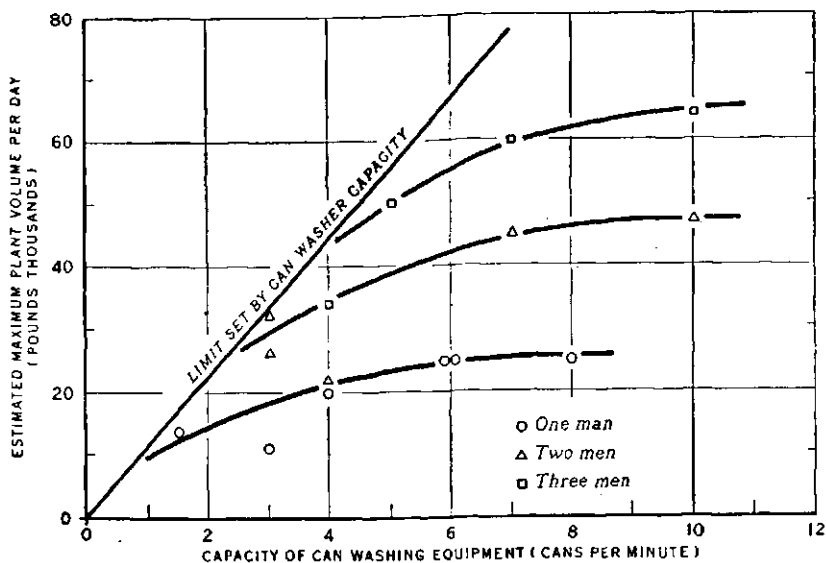
indicated that volumes handled in some previous period had been too much for the existing staff, and estimated a "reasonable" volume as somewhat lower.

These estimates are of little use by themselves, for the quantity of milk that a given labor force can handle will vary with the amount of capital in the form of plant and equipment that is combined with the labor. Equipment is considered in some detail later, so the present discussion involves only a simple treatment of the question. As an index of the amount of equipment in the above plants, the size or capacity of the can-washing equipment has been selected. When maximum plant volumes are plotted against this index, as in figure 8, the net effects of labor and of equipment on plant capacity may be seen.¹¹

The curves in the above diagram indicate the increasing volume that can be handled by a given labor force as the amount of equipment (represented by the capacity of the can washer) combined with the labor is increased. Moving from curve to curve at a constant size of can washer, on the other hand, indicates the increasing volume that can be put through a given plant as the amount of labor is increased. This last is of primary importance here, and it should be noted that the volume increases made possible by additional labor are less than proportionate to the physical labor increases. This means that the average physical

¹¹ The three curves in figure 8 have not been drawn independently, since the relationship is actually in the nature of a surface showing the joint effect of labor and equipment on maximum plant volume. These curves, or the surface, account for about 85 percent of the variance between the estimates given in table 20. This is equivalent to a corrected coefficient of correlation of 0.925.

inputs per unit of output are increasing as the plant and equipment is subjected to more intensive use or, conversely, that the operation is subject to diminishing physical returns. This may be clarified by considering the labor and volume adjustments for a plant of a given size. Figure 9, A shows the inputs of labor per unit of output for a plant having a seven-can-per-minute washer and the other items of equipment that would normally accompany such a can washer. In accordance with



U. S. DEPARTMENT OF AGRICULTURE

REG. 38825

BUREAU OF AGRICULTURAL ECONOMICS

FIG. 8. The effects of labor and equipment on the maximum daily volumes that can be handled by fluid-milk plants. The size of the can-washing equipment has been used as a rough indication of the amount of equipment in the various plants.

the relationship developed in figure 8, this diagram indicates that one man could operate such a plant and could handle daily volumes up to about 26,000 pounds. Up to that range the inputs of labor per unit of output or volume decrease as output increases, since the total labor input is constant and is spread over a larger and larger volume. At 26,000 pounds it is necessary to add a helper and correspondingly to increase the input per unit of output sharply. With these two men the plant volume can be expanded to 45,000 pounds and inputs per unit of output correspondingly reduced. If volume is to be further expanded, it will be necessary to add a third man, and with this labor force the peak volume can be pushed to 60,000 pounds. Further expansion is virtually impossible because of the limitations of plant and equipment,

and the addition of more labor will merely increase the inputs of labor per output of milk without increasing the maximum volume.

It will be observed that, while inputs per unit of output decrease within the one-, two-, and three-man ranges, the overall result is that inputs per unit of output increase gradually until the plant capacity is reached, and then very sharply if further expansion is attempted. This

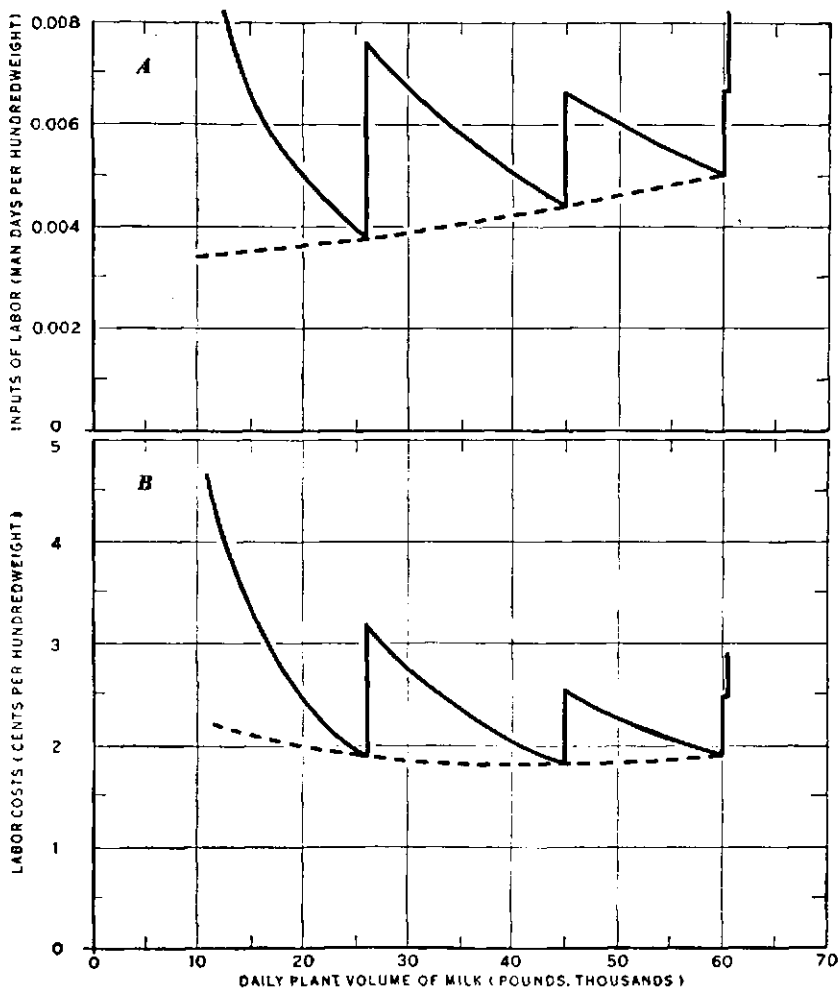


FIG. 9. Inputs of labor per output of milk for a fluid-milk plant with peak capacity of 60,000 pounds daily: (a) in physical terms, and (b) in economic terms. This corresponds to plants with can-washer capacities of seven cans per minute (fig. 8). Labor has been added in one-man intervals, which accounts for the discontinuity of the curves. If labor were completely divisible, the curves would approximate the dotted lines.

would be more clear if labor could be added in very small increments, in which event the curve would approximate the dotted line in figure 9, A.

The economic counterpart of this physical input-output relationship is given by the cost curve in figure 9, B. To arrive at this curve it is necessary to combine the physical inputs with appropriate cost rates or wages. Although the two relationships are very similar, they differ in one important respect. The physical curve indicates that expansion in plant volume can be obtained only by increasing applications of labor per unit of volume. The economic average cost curve, however, indicates that labor costs per unit of volume are nearly constant up to the point of plant capacity. This is, of course, a reflection of the difference in the wage rates applicable to the plant manager and to his assistants. In the illustration given, the daily cost for the manager is \$4.43, while for the assistants it is only \$3.29.

TABLE 21.—WAGE RATES FOR PLANT MANAGER AND FULL-TIME ASSISTANT, EIGHT FLUID-MILK PLANTS, 1937-39

Plant	Peak volume per day	Labor cost per man per week ¹			
		Manager		Full-time assistant	
		1937-1938	1939	1937-1938	1939
	Cwt.	Dollars	Dollars	Dollars	Dollars
A	45	26	26	23	..
B	110	26-33	33	21	21
C	210	25-31	31	20	20
D	170	28	28	24	24
E	250	28-33	33	21-26	26
F	320	35	35	23-25	25
G	420	30	30	23	23
H	330	31	31	22	22
Average ² .....	...	26-35	31	20-26	23

¹ 1937-38 figures represent range in labor costs per man, whereas 1939 figures represent rate in effect on January 1, 1939. All figures include Social Security payment and allocated vacation with pay.

² Average for 1939 figures; range for 1937-38 figures.

These wage rates were determined on the basis of actual costs in the eight sample plants already mentioned. The rates are influenced by many factors such as the individual's experience and length of service, his alternative opportunities for employment, and by the size and profitability of the plant in which he is hired. As a result of these influences, actual rates are subject to wide variation. The rates that were in effect in the eight plants on January 1, 1939, are given in table 21, together with the range in the rates that existed during 1937 and 1938. These have been rounded to the nearest dollar and include insurance and tax payments under the Social Security Act as well as the allocated cost of an annual vacation of 2 weeks with pay for each employee. The actual

weekly pay checks received by employees averaged about 10 percent less than these cost rates.

The rates indicate that there is no consistent tendency for the wages of assistants to be related to plant volume. The managerial cost per week shows a slight tendency to increase as plant size increases, but the relationship is not of great statistical significance. Furthermore, the indi-

TABLE 22.—AVERAGE LABOR COST PER HUNDREDWEIGHT OF MILK FOR SIX HYPOTHETICAL PLANTS OF WIDELY VARYING VOLUME¹

Plant	Daily average volume of milk	Months operated with			Season average labor cost	
		1 man	2 men	3 men	Per day	Per cwt.
	Cwt.	Number	Number	Number	Dollars	Dollars
U	42	12	..	..	4.43	0.105
V	90	12	..	..	4.43	.049
W	200	4	8	..	6.62	.033
X	300	..	9	3	8.53	.028
Y	400	..	7	5	9.08	.023
Z	480	..	6	6	9.36	.020

¹ Amounts of labor were obtained from relationships shown in figure 7 and normal seasonal variation in production (table 8). These were converted into cost on the basis of a weekly wage of \$31 for managers and \$23 for assistants.

cated increase in managerial wages is not large enough to make an appreciable difference in the total labor cost per hundredweight of milk.¹² In the following calculations the average weekly rates of \$23 for assistants and \$31 for managers were used.

Using these rates and the physical relationships given in figure 8, labor costs per hundredweight have been computed for six hypothetical plants of widely varying capacity. These results show (table 22) that labor is much more efficiently used in large than in small plants, the season average labor costs per hundredweight increasing from less than \$0.02 for the plant with daily average volume of 48,000 pounds to more than \$0.10 for the plant with average volume of only 4,200 pounds daily.

SECONDARY PLANT COSTS

Several relatively unimportant costs are nearly constant regardless of volume fluctuations but they probably fall outside of the usual categories of fixed costs. In this bulletin, these other costs have been called secondary costs, and include such items as costs of telephone and telegraph, postage, and office supplies. There may be some slight tendency for these to change as individual plant volumes change, but the important variation seems to be between plants rather than within plants.

¹² See pages 68 to 70 for a more specific discussion of the difference in labor costs when managerial rates vary with plant capacity, effect of other wage rates than the averages here used, and effect of employing helpers for the peak load period of each day instead of full-time helpers.

The daily average cost of these items was computed for each of the eight sample plants and are summarized in table 23. The daily average secondary costs for a plant may be approximated by the use of a linear regression equation where "a" or the zero capacity intercept is equal to

TABLE 23.—DAILY SECONDARY COST FOR EIGHT FLUID-MILK PLANTS, 1937 AND 1938

Plant	Daily capacity	Secondary cost per day
	Cwt.	Dollars
A	60	0.22
B	130	.36
C	220	.45
D	260	.34
E	320	.42
F	400	.49
G	500	.70
H	640	.79

\$0.16 and where "b" or the slope of the regression line is equal to \$0.01 per thousand-pound increase in daily plant capacity. This regression describes accurately the secondary costs, accounting for approximately 90 percent of the variance in costs.¹³

INVESTMENTS IN LAND, BUILDINGS, AND EQUIPMENT

Data on the value of fixed investments are basic to the determination of the fixed costs of plant operation. Such data may be obtained from the books of the companies that own and operate country milk plants. These valuations will ordinarily deviate from replacement costs, however, as it is common practice in both accounting procedure and economic theory to depreciate investments as they are used and to value these fixed investments on the basis of their productivity.¹⁴ In the following paragraphs the book values of these items are summarized. In those instances in which there are considerable deviations from replacement values, an attempt was made to develop such values. By so doing, it will be possible to achieve comparability between plants and at the same time to eliminate maladjustments within plants that have no place in a discussion of the economies of scale.

Investment in Land

The investment in land and permanent improvements for 18 country dairy plants in New England during 1937-38 ranged from \$100 to \$2,500.

¹³ r (corrected) = 0.935 ± 0.051 .

¹⁴ Note that if valuation on the basis of productivity were followed completely, the cost for every plant would equal the established allowances. Investments in plants with high real costs would be depreciated until indicated costs were equal to returns, while plants with low real costs would appreciate investments or capitalize profits so that the indicated costs would also equal returns.

The average land value was \$750. The distribution of values is given in table 24.

TABLE 24.—DISTRIBUTION OF LAND VALUES FOR 18 COUNTRY PLANTS, 1937 AND 1938

Class land values	Frequency of plants
Dollars	Number
0-399	5
400-799	5
800-1,199	3
1,200-1,599	2
1,600-1,999	1
2,000-2,399	1
2,400-2,799	1
Total number	18
Average value	\$750

The variations in land investment may be attributed to three main sources: (1) the size of the plant and as a result the needed amount of land; (2) the location with respect to railroads, towns, and villages, for this will largely determine the cost per unit of land; and (3) the amount of improvements on land that have been included in the recorded value. From the standpoint of the study here reported, the first of these is of prime importance. To obtain the relationship between plant size and investment in land, the values given in table 24 have been correlated to average daily volumes. This procedure resulted in a regression equation with the estimated value of land equal to \$300 plus \$53 per thousand pounds of milk handled. This is in terms of average volumes, however, and when converted to a plant-capacity basis becomes \$300 plus \$25 per thousand pounds of daily capacity.¹⁵ This regression explains slightly more than 50 percent of the variance in land values.¹⁶ The remaining variance is presumably related to the other factors already mentioned.

It is not possible here to analyze the effects of location on land value. Certainly the value of the land will be conditioned by these factors, and for any given plant they will determine to a considerable extent the land investment. Plants located in villages or cities will have higher land costs than those located in the open country, and in a similar fashion plants located on important highways and on railroads will probably have to pay more for land than those located in more isolated territory. The cost of making more or less permanent improvements will also vary

¹⁵ The normal seasonal variation in plant receipts was discussed in pages 15 to 17. Peak volumes were found to be 138 percent of average volumes. Excess plant capacity has been described, and the average plant capacity was found to be 154 percent of the peak load. On the basis of these two factors, plant capacity is estimated to be 212 percent of daily average volume. This has been used to convert the average volume regression into a regression describing land values in relation to plant capacities.

¹⁶ The coefficient of correlation, corrected, is 0.720 with a standard error of 0.120.

from location to location. An example of this is the cost involved in providing the plant with an adequate water supply. In some localities it is possible to satisfy the needs by one or two shallow wells dug at low cost, whereas in others it is necessary to drill wells that may cost thousands of dollars. The relationship between size of plant and land investment that has been given is a generalized or average solution, and as such it may not represent the situation for any specific plant.

Investment in Buildings

The recorded or book values of country-plant buildings are usually determined on the basis of three considerations: (1) the construction or replacement cost, involving the physical size and shape of the building as well as the type of construction; (2) the age of the building together with some appropriate depreciation rate; and (3) the profitability of the plant operation, involving the plant volume and its effect on costs and returns. When it is realized that plants operate with a varying amount of excess capacity with respect to both equipment and buildings, and that any sample of actual plants will cover a wide range in age and profitability, it is not surprising to find that book values are not closely related to physical size of plant or to volume.

Data as to the area, volume, approximate capacity, and recorded value have been collected for 10 fluid-milk plants (table 25). Area and volume explain about half of the variance in these values. The partial regression equation between value and area, holding plant volume constant, is: $I = \$1,000 + \$3A$; where "I" represents the recorded or book value of buildings and "A" the physical size of the plant in terms of square feet of floor space. This relationship eliminates about 47 percent of the variance in values.¹⁷ The partial regression equation between

TABLE 25.—SIZE, VOLUME, CAPACITY, AND RECORDED INVESTMENT IN BUILDINGS FOR 10 COUNTRY MILK PLANTS, NEW ENGLAND, 1939

Case number	Floor space	Daily average volume	Daily capacity	Recorded investment in buildings
	Sq. ft.	Cwt.	Cwt.	Dollars
1	1,500	35	60	3,500
2	1,400	270	425	4,300
3	1,700	100	220	5,000
4	1,900	75	130	6,000
5	1,700	480	650	7,200
6	2,900	235	640	8,500
7	2,400	510	850	10,000
8	1,900	175	400	10,200
9	3,600	90	320	10,200
10	2,800	270	510	14,400

¹⁷ r (corrected) = 0.688. This is a partial coefficient.

value and volume, holding size constant, is: $I = -\$2,000 + \$8V$; where "I" again represents the book value and "V" represents the daily average plant volume in hundredweights of milk. This factor is less important, explaining only 16 percent of the variance.¹⁸

No attempt has been made to include the age of the buildings as a factor, because of the difficulties involved in plant repairs, replacements, and additions. There can be little doubt, however, that this factor or combination of factors is of considerable consequence. As an example of its effect, it may be pointed out that the low value of plant 1 is partly a reflection of the fact that this plant is 30 years old, whereas the high value of plant 10 may in part be explained by the fact that it has been in operation only 1 year.

In order to apply the relationship between plant size and evaluation to the problem of economies of scale, it is necessary to develop the relationship between size in terms of floor space and capacity in terms of hundredweights of milk. To this end, estimates of plant capacity are included in table 25. These are similar to the estimates by plant managers given previously. They represent the maximum daily volume that can be handled by the existing plant and equipment during normal hours of operation. Almost invariably the limiting factor has been some item of equipment, and so these estimates are poor indications of the capacity of the building as compared with the equipment capacity. In many instances there are large amounts of unused and unneeded floor space. As a result, plant capacity explains only 14 percent of the variance in floor space.¹⁹ Furthermore, the regression equation indicates that size changes 1 square foot for each hundredweight change in capacity, and approaches 1,600 square feet as capacity approaches zero. This seems so completely unrealistic that further analysis is necessary.

To insure comparability of fixed costs between plants, some students of the problem have substituted replacement costs for the recorded or book values (3). As this study was not only interested in eliminating differences associated with the age of buildings and equipment but also in eliminating the various maladjustments that give rise to excess capacity, this procedure was adopted and carried one step further. Six hypothetical plants were designed, based primarily on the details incorporated in some of the more modern plants in New England.²⁰ Each of these plants was organized to handle a certain daily maximum volume. The relation between plant floor area and daily capacity for these plants

¹⁸ r (corrected) = 0.393. This is a partial coefficient.

¹⁹ r (corrected) = 0.369 \pm 0.305.

²⁰ See appendix for floor plans, equipment lists, and details of cost estimations. The author is indebted to C. W. Dingman, of the Springfield Bank for Cooperatives, for suggestions relative to design and for basic estimates as to construction costs.

indicates that floor space increases at a slightly increasing rate as plant capacity is increased, and that size approaches 600 square feet as capacity approaches zero. As a result of these two elements, the daily average pounds of milk per square foot of floor space increases rapidly as capacity is increased in the lower ranges, but the increase is less pronounced in the higher ranges. It is significant that, although most of the plants included in the sample are larger than the redesigned plants, there are a few for which the volume-area ratios compare favorably with those obtained in the redesigned plants. These are obviously plants in which the buildings and equipment are in good relation to each other and to the existing plant volume.

Estimates of construction costs were prepared for both frame and tile construction for the six redesigned plants. These estimates (table 26)

TABLE 26.—ESTIMATED CONSTRUCTION COST FOR FLUID-MILK PLANTS, 1939¹

Plant	Floor area	Daily average volume	Frame cost		Tile cost	
			Total	Per sq. ft.	Total	Per sq. ft.
	Sq. ft.	Cwt.	Dollars	Dollars	Dollars	Dollars
U	620	42	2,400	3.87	2,900	4.68
V	660	90	2,600	3.94	3,100	4.70
W	880	200	3,400	3.86	4,000	4.55
X	1,100	300	4,200	3.82	4,900	4.45
Y	1,320	400	5,100	3.86	5,800	4.39
Z	1,540	480	5,900	3.83	6,700	4.35

¹ See appendix for details.

indicate that costs per square foot average about \$3.85 for frame buildings and \$4.50 for tile and masonry construction. The reported construction costs for several modern plants built during the 1937-39 period ranged from \$3.54 to \$5.14 per square foot for concrete-block construction.

Table 26 also illustrates the pronounced advantage that large plants have over small plants with respect to investment in buildings per hundredweight of milk. The smallest, redesigned Plant U, has a peak capacity of about 6,000 pounds per day or, with the normal seasonal fluctuation, an average volume of 4,200 pounds daily. Using tile construction to illustrate, this plant will have an investment in buildings of \$69 per daily hundredweight of milk. The largest, Plant Z, on the other hand, has a daily capacity of 65,000 pounds and a season average volume of 48,000 pounds per day. Building investment per daily average hundredweight of milk is only \$14. Investment per daily average hundredweight decreases at a decreasing rate as average volumes and capacities increase. Although it is beyond the range of the present

observations, the investment per hundredweight seems to reach a low point of about \$13 at a daily average volume between 60,000 and 70,000 pounds.

Investment in Equipment

Recorded evaluations of milk-plant equipment are subject to the same general limitations that were discussed when considering building investments. In addition, equipment is made up of a number of separate items, all of which depreciate at rates that are characteristically their own. The estimates of daily capacity that have been presented, however, are much more applicable to plant equipment than to buildings. Therefore it is not surprising to find a relatively high correlation between the reported value of equipment and the plant capacity. Data relative to these items are summarized in table 27 for 12 fluid-milk plants. For

TABLE 27.—VOLUME, CAPACITY, AND RECORDED INVESTMENT IN EQUIPMENT FOR 12 FLUID-MILK PLANTS, 1939

Case number	Daily average volume	Daily capacity	Recorded investment in equipment
	Cwt.	Cwt.	Dollars
1	34	60	1,100
2	76	130	2,900
3	102	220	5,500
4	91	320	9,100
5	175	400	8,000
6	270	420	11,100
7	270	510	26,300
8	236	640	14,700
9	480	650	22,600
10	274	700	17,600
11	380	700	18,100
12	510	850	18,500

these plants the investment tends to increase about \$0.25 for each pound increase in daily capacity, approaching zero as capacity approaches zero. This relationship explains more than 60 percent of the variance in equipment evaluations.²¹ Taking into account the normal seasonal variation, this is synonymous with an investment of about \$0.35 per pound of daily average volume if there were no excess capacity. Earlier it was pointed out that fluid-milk plants were operating with a considerable amount of excess capacity, and that the average plant utilized only 65 percent of its capacity in the peak season. When this ratio is applied to the above investment the estimated investment per pound of actual daily volume becomes \$0.54.

²¹ This corresponds to a corrected coefficient of correlation of 0.788 with a standard error of 0.120.

TABLE 28.—ESTIMATED INVESTMENT IN EQUIPMENT FOR SIX THEORETICAL FLUID-MILK PLANTS, 1939

Item	Unit	Plant					
		U	V	W	X	Y	Z
Daily capacity	Hundred-weight	60	120	280	410	560	650
Average volume	do.	42	90	200	300	400	480
Investment in equipment:							
Receiving	Dollars	1,400	1,400	1,550	1,550	2,100	2,100
Can washing	do.	770	770	1,280	1,400	2,100	3,600
Cooling	do.	2,800	3,475	5,735	7,015	8,805	10,500
Storage	do.	1,450	1,750	2,600	3,400	5,200	6,000
Boiler	do.	550	630	730	820	970	1,130
Other	do.	830	1,175	1,605	1,985	2,075	2,330
Total equipment	do.	7,800	9,200	13,500	16,170	21,250	25,660
Investment per pound ¹	do.	1.86	1.02	0.68	0.54	0.53	0.53

¹ Total investment divided by daily average pounds handled.

The nature of this relationship, coupled with the fact that the newer plants fall in the high-capacity ranges, makes its applicability to the problem of scale very dubious. To insure perfect comparability, the previously mentioned hypothetical plants were used and estimates of the costs of equipping them prepared. (For details and sources, see appendix.) Capacities of these six plants range from 6,000 pounds per day to 65,000 pounds. The estimated costs of equipment for these plants are given in table 28.

These estimates are higher than most of the reported evaluations for similar capacities, partially as a result of depreciation. Original or replacement costs increase at an increasing rate that averages about \$250 per thousand pounds of capacity and they approach \$6,000 as capacity approaches zero. Recorded or book values, on the other hand, increase at about the same rate but are generally lower and approach zero as capacity approaches zero. In terms of the average volume handled, both the reported and the estimated values average about \$0.50 per daily hundredweight for volumes in excess of 30,000 pounds. (This average volume is based on the capacity and the normal seasonal variation, with volume equal to capacity in the flush or peak season. In other words, there is no excess capacity except that induced by the seasonal variation.) For lower volumes, however, the estimated investments per hundredweight increase sharply while the book values vary around the \$0.50 average.

Total Investment in Land, Buildings, and Equipment

Despite the apparent differences between the reported investments or evaluations and those calculated for the hypothetical plants, the total

value of land, buildings, and equipment are not greatly different. The relatively high reported values of buildings more or less balance off the relatively low evaluation of equipment, with the net result that total investment is nearly the same for reported values as for estimated replacement or construction values. These are compared in table 29, as are investments per pound of milk handled.

TABLE 29.—TOTAL INVESTMENT IN LAND, BUILDINGS, AND EQUIPMENT FOR ACTUAL AND THEORETICAL PLANTS OF VARYING SIZE¹

Item	Size of plant—daily average volume in hundredweight					
	42	90	200	300	400	480
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Actual plants:						
No excess capacity: ²						
Total investment	10,100	12,100	17,500	21,800	26,200	30,300
Investment per pound ³	2.41	1.35	0.88	0.71	0.66	0.63
Existing conditions: ⁴						
Total investment	11,200	12,700	18,400	23,600	28,700	32,900
Investment per pound	2.67	1.41	0.92	0.79	0.72	0.69
Theoretical plants:						
Frame construction:						
Total investment	10,800	12,500	17,900	21,600	28,000	33,500
Investment per pound	2.56	1.39	0.90	0.72	0.70	0.70
Tile construction:						
Total investment	11,300	13,000	18,500	22,300	28,700	34,300
Investment per pound	2.68	1.44	0.92	0.74	0.72	0.72

¹ Based on relationships between recorded investments and capacity and volume for actual plants. These may be summarized in the equation: Total investment = \$8,100 + \$0.335 × capacity in pounds. The six hypothetical plants are those already mentioned. Investment figures have been rounded to nearest \$100.

² Based on the actual relationships as summarized in pages 41 to 46, with assumption that the plants are operated without excess capacity in peak season.

³ Total investment per pound of daily average volume.

⁴ Similar to conditions noted above except that the normal or average amount of excess capacity has been included—under these conditions a plant that receives an average daily volume of 20,000 pounds will have a peak volume of about 28,000 pounds and the plant will have capacity adjusted to that volume. When the average amount of excess capacity is included, the peak volume will remain at 28,000 pounds but the plant will have a daily capacity of about 43,000 pounds. This will be approximately representative of plant operation in New England.

On the basis of the results calculated for the theoretical plants, the total investment per daily pound of milk varies from about \$2.60 for the smallest plant where the daily volume averages only 4,200 pounds to approximately \$0.70 for the largest plant where daily volumes average 48,000 pounds. This decline in investment per daily pound of milk is at a decreasing rate, and most of the economies or efficiencies have been obtained when daily average volume reaches 20,000 pounds. These daily volumes presuppose that the plant will be operated to full capacity in the peak season.

FIXED COSTS OF PLANT

The fixed costs of country-plant operation are those costs that are unaffected by volume changes within the plant. In general, they are

associated with the investments just described, and include depreciation, interest, maintenance and repair, rent, taxes, and insurance. The calculations of most of these costs are simple, involving the application of rates or percentages to the investment data. But they represent some of the most puzzling theoretical problems that are encountered in cost analysis. Rates are often determined in the most superficial and arbitrary manner, and so may fail to represent the true situations. This is not the result of a wish to be arbitrary on the part of plant operators, but rather of the difficulties involved in establishing more realistic rates.

This problem may be illustrated with reference to depreciation rates. These rates presumably are based on the useful life of particular items of equipment and buildings. If a given type of building with normal care will last 25 years, then a depreciation rate of 4 percent will be appropriate. But obviously it is difficult to foretell the useful life of a building. The best approximation that can be made must be based on the past history of similar structures. This will be affected by the expenditures made for maintenance and repairs, and the life may be continued almost indefinitely if the age of many buildings in New England is any indication. Even if a suitable estimate of the physical deterioration and consequent useful life can be made, the progress of inventions and the passing of more stringent laws and regulations governing the operation of milk plants will introduce an element of obsolescence that is difficult if not impossible to predict accurately.

With these qualifications, the following estimates of fixed costs are presented. They have been based on available material and are undoubtedly subject to some error. In order to take these errors into account, the effect of other rate assumptions are examined later (pp. 67 to 68).

Depreciation Costs

If a plant is to operate over a long period of years, it is necessary for the returns from plant operation to be high enough to enable the operator to replace equipment and buildings as they wear out or become obsolete. Annual depreciation costs are therefore determined by investment on one hand and on the years of life on the other. This assumes that these are "fixed" costs—that they are associated with time rather than with use or volume handled. Some exceptions are obvious, but in general, deterioration and especially obsolescence will occur regardless of volume handled. Investment data have been discussed; depreciation costs will be determined by applying depreciation rates to these evaluations.

Depreciation rates are at best only rough approximations. The following tabulation summarizes the estimates of the useful life of country milk-plant buildings and equipment that have been reported in several studies of depreciation. The last column gives the depreciation rates

TABLE 30.—YEARS OF USEFUL LIFE AND DEPRECIATION RATE FOR BUILDINGS AND FOR PRINCIPAL ITEMS OF EQUIPMENT, FLUID-MILK PLANTS

Item	Years of life		Depreciation rate per year ³
	Estimate A ¹	Estimate B ²	
	Number	Number	Percent
Buildings:			
Frame .....	..	..	4
Masonry .....	..	..	3
Equipment:			
Weigh cans	9	7	13
Vats—copper	14	14	7
Vats—tin	6	10	13
Can washers	7	8	13
Conveyors .....	..	14	7
Cooling coils	14-17	12	7
Compressors .....	..	14	7
Condensers .....	..	14	7
Storage tanks—glass .....	..	20	5
Storage tanks—copper	12	14	8
Weigh can scales	8	14-20	9
Milk pumps	10	10	10
Sanitary piping	4	8	17
Well pumps	14-17	..	7
Steam boilers	17-33	..	5
Average for all equipment ⁴.....	..	..	8

¹ Tucker, p. 22 (3).

² "Studies of Depreciation," by the Bureau of Internal Revenue.

³ Based on years of life as given, together with rates commonly used by the trade.

⁴ Weighted by investment.

that were used in this study. In most cases they are approximate averages of the rates indicated by the two studies quoted, but occasionally they represent the rates that are commonly used by the trade. Building rates are taken to be 3 and 4 percent per year for masonry and frame structures respectively, whereas equipment rates vary from 5 to 17 percent. The weighted average of these equipment rates is approximately 8 percent, and that figure is applied to the equipment investment in the following calculations.

On the basis of the investments in building and equipment given in the preceding section and the depreciation rates presented above, the daily costs of depreciation for the six theoretical plants vary from less than \$2 for Plant U to more than \$6 for Plant Z. Costs per hundred-weight of milk, however, decrease as size of plant increases, falling from more than \$0.046 for the small plant to \$0.013 for the large plant. These data are summarized in table 31. Estimates have been made for both

frame and tile buildings, and depreciation costs average approximately \$0.001 per hundredweight less for the tile construction. This will be offset to some extent by higher interest charges, as pointed out later.

An indication of the depreciation costs based on the investment relationships developed from the recorded values of actual buildings and equipment is also in table 31. These are given to indicate roughly the nature of the reported costs, rather than the absolute level, since the recorded values have presumably been depreciated to some extent. This, plus the other limitations of recorded investments already discussed, would render the use of costs based on reported values inappropriate.

TABLE 31.—DEPRECIATION COSTS ON BUILDINGS AND EQUIPMENT FOR FLUID-MILK PLANTS

Item	Size of plant—daily average volume in hundredweight					
	42	90	200	300	400	480
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Annual depreciation cost:						
Theoretical plants: ¹						
Frame	720	840	1,216	1,456	1,900	2,292
Tile	711	829	1,200	1,435	1,870	2,257
Actual plants ²	397	592	1,108	1,529	1,950	2,350
Daily depreciation costs:						
Theoretical plants:						
Frame	1.97	2.30	3.33	3.99	5.21	6.28
Tile	1.97	2.27	3.29	3.93	5.12	6.18
Actual plants	1.09	1.62	3.04	4.19	5.34	6.44
Depreciation cost per hundredweight of milk:						
Theoretical plants:						
Frame	0.047	0.026	0.017	0.013	0.013	0.013
Tile .....	.046	.025	.016	.013	.013	.013
Actual plants .....	.026	.018	.015	.014	.013	.013

¹ Based on previously presented data on investment and depreciation rates for buildings and equipment, for the six theoretical plants discussed.

² Based on regressions between recorded investment and plant capacity, with allowance for average amount of excess capacity. As these investments have been depreciated to an unknown extent, these calculations are rough approximations. If it were assumed, for example, that existing buildings and equipment were already 50 percent depreciated, then the calculated values of depreciation costs for "actual" plants would be twice as large as there indicated.

Interest Charges

Investments in land, buildings, and equipment have to be financed, and the cost of obtaining capital is a legitimate cost of doing business. Interest rates are fairly uniform, although there has been some change over a period of time. Some years ago a rate of 6 percent per year would probably have been appropriate. At present, at least the cooperative plants are able to finance the major part of their investments for 4 percent annually, and there are probably very few plants that pay as high as 6 percent. For the present calculation of interest charges or costs, a rate of 5 percent has been used. This rate is applied to the full value of land and to one-half the value of buildings and equipment. Buildings

TABLE 32.—INTEREST COSTS ON LAND, BUILDINGS, AND EQUIPMENT FOR FLUID-MILK PLANTS

Item	Size of plant—daily average volume in hundredweight					
	42	90	200	300	400	480
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Annual interest charges:						
Theoretical plants: ¹						
Frame	282	330	472	572	742	885
Tile	295	342	488	590	760	905
Actual plants ²	286	363	565	730	895	1,052
Daily interest costs:						
Theoretical plants:						
Frame	0.77	0.90	1.29	1.57	2.03	2.42
Tile .....	.81	.94	1.34	1.62	2.08	2.48
Actual plants .....	.78	.99	1.55	2.00	2.45	2.88
Interest costs per hundredweight of milk:						
Theoretical plants:						
Frame	0.018	0.010	0.006	0.005	0.005	0.005
Tile .....	.019	.010	.007	.005	.005	.005
Actual plants .....	.019	.011	.008	.007	.006	.006

¹ Based on value of land and one-half of value of buildings and equipment for theoretical plants, with interest rate of 5 percent per year.

² Based on regressions between recorded investments and capacity for operating plants, with value of land and one-half of buildings and equipment, and with interest rate of 5 percent per year.

and equipment are depreciated and the depreciation costs applied to reduce the investment. This means that over the life of the item the investment has varied from full value to zero, or the average investment is approximately equal to one-half of the original value.

The calculated interest costs for the six theoretical plants are given in table 32. Similar calculations were made for the book values of actual plants, and are included in the table. It should be noted, however, that these values are depreciated to some extent, and that as a result the indicated costs for "actual" plants are lower than the true costs for such plants in actual operation.

Interest charges range from less than \$1 per day for the smallest plants considered to approximately \$2.50 for the largest. In terms of cost per hundredweight of milk handled, interest costs range from about \$0.02 per hundredweight for the smallest plant to about \$0.005 for the largest. The calculations based on book values for "actual" plants indicate a lower cost per hundredweight for small volumes, and higher for large volumes.

Other Fixed Costs

In addition to depreciation and interest costs, fixed costs include such items as property tax and insurance payments, rentals if any land, buildings, or equipment is rented, and the expenditures made for main-

tenance and repair. Taxes and insurance are the most important of this group and are directly proportionate to investments. The rates are subject to wide geographic variations. Tax rates and assessments are determined locally and so the tax costs for a milk plant of a given value will vary from town to town and from State to State. Insurance rates are based on location with respect to other buildings and to fire-protection equipment, as well as on the construction of the building and the percentage of coverage, and so insurance costs will differ from locality to locality.

Annual tax payments made by the eight sample plants ranged from less than \$6 per thousand invested to more than \$30 per thousand and averaged about \$17. This average rate has been used in computing the tax costs for the hypothetical plants that are summarized in table 33. The daily fixed cost of taxes thus amounts to \$0.50 for the smallest frame plant and increases to \$1.56 for the largest. Tax payments for tile-constructed plants average about \$0.03 per day higher than for comparable frame plants.

Insurance rates range from less than \$2 to more than \$22 per thousand. In most cases the same rate applies to both plant and contents, although contents are sometimes listed at a higher or lower rate. The rates applicable to buildings of tile construction such as have been set up in this report are about one-half the rates on comparable frame buildings. Representative rates may be taken to be \$7.50 per thousand for tile and masonry plants and their contents and \$15 for frame plants. These rates are for insurance covering at least 80 percent of the total investment, since the rates applicable for less complete coverage are approximately 45 percent higher. When these rates are applied to the investments in buildings and equipment for the theoretical plants, the daily cost of insurance is found to range from \$0.42 to \$1.29 for the hypothetical plants of frame construction and from \$0.22 to \$0.66 for these plants when tile construction is used (table 33).

When part or all of the land, buildings, or equipment is leased, rent becomes one of the fixed costs. In the present instance, fixed costs have been calculated on the assumption that none of the items are leased. As a result, rents have no part in the cost picture. In some instances, however, rents will appear and other items such as interest and depreciation will be correspondingly lowered.

The costs of maintenance and repairs are items of fixed costs that are closely related to depreciation. If buildings and equipment are well cared for and kept in good repair, their useful life will be increased. This will mean that the depreciation rates that are applicable will be

TABLE 33.—DAILY COSTS FOR TAXES, INSURANCE, REPAIRS, AND MAINTENANCE, SIX HYPOTHETICAL MILK PLANTS

Item	Unit	Plant					
		U	V	W	X	Y	Z
Daily capacity	Hundred-weight	60	120	280	410	550	650
Daily average	do.	42	90	200	300	400	480
Frame construction—daily costs:							
Taxes	Dollars	0.50	0.58	0.83	1.01	1.30	1.56
Insurance	do.	.42	.48	.69	.83	1.08	1.29
Repairs and maintenance	do.	.16	.33	.77	1.13	1.51	1.79
Total	do.	1.08	1.39	2.29	2.97	3.89	4.64
Cost per hundredweight	do.	0.026	0.015	0.011	0.010	0.010	0.010
Tile construction—daily costs:							
Taxes	do.	0.53	0.61	0.86	1.04	1.34	1.60
Insurance	do.	.22	.25	.36	.43	.55	.66
Repairs and maintenance	do.	.16	.33	.77	1.13	1.51	1.79
Total	do.	0.91	1.19	1.99	2.60	3.40	4.05
Cost per hundredweight	do.	0.022	0.013	0.010	0.009	0.008	0.008

somewhat lower than would otherwise be the case. In the preceding discussion of depreciation, the rates used were based on the tacit assumption of "normal" maintenance and repair. It is necessary, therefore, to estimate the costs involved in this maintenance. Detailed figures are available for the sample plants showing the costs of building and equipment repairs. These figures, which include the costs of labor hired for maintenance and repair work, indicate that the costs are directly related to the capacity of the plant and average \$0.0275 per thousand pounds of daily capacity. The relationship explains more than 80 percent of the variance in these costs.²²

The total daily costs of taxes, insurance, and maintenance and repairs are summarized in table 33 for the six hypothetical plants. Costs increase as capacity of plant increases, and at a slightly increasing rate. When converted to a cost per hundredweight basis, these decline from \$0.026 per hundredweight for Plant U to \$0.01 for Plants X, Y, and Z with frame construction and from \$0.022 per hundredweight for Plant U to \$0.008 for Plants Y and Z when tile construction is used. In both cases the costs per hundredweight decrease at a decreasing rate and are practically constant in the high-volume ranges.

As tax and insurance rates are subject to variation, the costs for any actual plant will be higher or lower than those indicated if the rates applicable for the particular location are above or below those used in

²² r (corrected) = 0.900 ± 0.078 .

the present calculations. The effect of higher and lower rates is pointed out in pages 67 to 68.

CENTRALIZED BOOKKEEPING AND SUPERVISION

Most of the fluid-milk plants in New England are operated by companies or cooperatives that control several plants. In these cases it is customary for the detailed bookkeeping involved in cost records and payments to producers to be performed by central offices, the bookkeeping at the individual plants consisting of simple records of the weights and tests for individual producers. In addition to bookkeeping, a certain amount of administrative and supervisory work is centralized. The expenses of these centralized functions are then allocated to the country plants. This can be accomplished in a variety of ways, but the most logical methods are on the basis of the numbers of producers or of the plant volumes. These two alternatives are synonymous, of course, if producers average the same daily volume. Where daily deliveries per producer are high, however, the allocated cost per hundredweight of milk would be relatively low if the allocation were made on the basis of the number of producers.

From the standpoint of the comparative efficiencies of plants of various capacities, the method of allocation is not important, for the ultimate result will be a constant addition to costs per hundredweight regardless of plant capacity or volume. These additions do not affect the slope of the economy-of-scale curve, in other words, but they do affect the level of the curve.

The centralized costs of bookkeeping and supervision have been determined for a concern operating a large number of country plants. During 1937 and 1938 these costs averaged nearly \$0.05 per producer per day. In terms of volume of milk the average cost was approximately \$0.02 per hundredweight, since daily average deliveries per producer averaged about 240 pounds for northern New England. In view of these facts, unit plant costs have been increased \$0.02 per hundredweight to cover centralized costs in the summaries that follow.

PLANT LOSS OR SHORTAGE²³

The one remaining element of plant cost to be investigated is known as loss or shortage. It represents any discrepancy that may occur between the weights and butterfat content of the milk reported as re-

²³ Credit for the development of this section goes to Robert Hunter of New England Dairies, Inc., who has made several studies of tests, weights, and plant shortages. Much of the material summarized in the following pages was drawn directly from reports he made available to the author.

ceived from producers and the weights and tests of the milk reported as shipped from the plant or received by buyers. The physical bases for this loss are the adhesion of the milk to the equipment and containers to which it comes in contact and the occasional loss from spilling. If these were the only causes of plant loss, the daily or monthly shortage for any given plant would tend to be fairly constant regardless of the volume handled. But actual records indicate that shortage is far from constant. In the eight plants subjected to intensive analysis the reported shortage fluctuated violently from period to period. In all cases there were months when the reported shipments were larger than reported receipts, or when plant shortages were actually "overages." The distribution of the reported monthly plant losses during 1937 and 1938 are given for these plants in table 34.

TABLE 34.—FREQUENCY DISTRIBUTION OF MONTHLY PLANT LOSS FOR EIGHT SAMPLE PLANTS AND FOR A GROUP OF PLANTS OF ALL TYPES AND SIZES, 1937-38

Plant loss as percentage of receipts ¹	Plant								Group of mixed plants ²
	A	B	C	D	E	F	G	H	
5.0 and over	2	2	..	1	..	..	2	..	..
4.0 to 4.9 .....	..	2	1	2	..	..	1	..	..
3.0 to 3.9	1	5	2	..	..	..	..	1	3
2.0 to 2.9	3	9	7	..	..	1	2	1	9
1.0 to 1.9	6	4	5	1	..	7	1	1	6
0.0 to 0.9	5	2	5	3	4	10	4	3	3
-0.1 to -1.0	6	..	3	5	2	3	2	3	..
-1.1 to -2.0 .....	..	..	..	3	7	..	4	2	..
-2.1 to -3.0 .....	..	..	1	..	4	..	2	2	..
-3.1 to -4.0	1	..	..	2	1	..	2	1	..
-4.1 to -5.0 .....	..	..	..	..	..	..	1	1	..
-5.1 and under .....	..	..	..	..	..	..	1	..	..
Number of months.....	24	24	24	17	18	21	22	15	21
Daily average cwts.....	34	76	102	97	91	175	251	236	..
Average percent loss...	1.2	2.9	1.5	0.2	-1.3	0.2	-0.4	-0.5	2.1
Percent in 1937 ³	1.8	2.6	2.0	3.2	-1.4	-0.3	0.9	1.7	2.4
Percent in 1938 ³	0.6	3.1	0.8	-1.0	-1.4	0.3	-2.5	-0.4	0.9

¹ Negative figures represent plant gains, when reported shipments exceeded reported receipts.

² A large group of plants of all types, sizes, and efficiencies. Figures are averages for group.

³ Averages for identical months in 1937 and 1938. Where reports are not available for the full 24 months, these averages are based only on those months that were reported in both years. In these cases the average of the figures given for 1937 and 1938 will not check with the average given for the entire period.

Although plant shortage was not constant for these plants, it also failed to show any consistent tendency to vary with plant volume. Nor did comparisons between plants reveal a consistent relationship between shortage and plant capacity. In fact, the most notable characteristic of these reports was the absence of any such relationships. Variations appeared to be completely random in nature. Yet this chance variation

is easily understood when plant operations of receiving and shipping are examined.

When milk is received at a country plant, each producer's milk is weighed and sampled. The weights are recorded and the sample is incorporated in a composite sample that is usually tested every 15 days. The cumulative weight and the composite test form the basis for producer payments in any period. After being weighed and sampled, the milk is cooled and prepared for shipment. In this process the milk of all producers is combined. The total shipment is weighed and sampled, the sample being tested to ascertain the average butterfat content of the shipment. Thus in the operation of the plant there are opportunities for random or chance errors to occur in the weighing and in the butterfat testing. Both of these are present as the milk is received and as it is shipped.

The possibility of random errors in weighing, eliminating the chance of faulty scales, is not of great importance, for any errors will tend to balance off, over a period of time. One exception should be noted. In some instances milk is sold to city dealers in 40-quart cans. The customs of the business require that the cans be filled to the 40-quart mark, or that the quantity of milk delivered be determined by volume. The actual weight of 40 quarts of milk will depend on the butterfat content, the temperature, and the age, or the time elapsed since milking. Theoretically a 40-quart container will hold more than 86 pounds of 4-percent milk at a temperature of 40°. The Federal Order operating in the Boston market, however, specifies that a 40-quart can shall be taken to hold 85 pounds of milk. As a result of this discrepancy, it is apparent that when milk is sold by volume and charged for on the basis of 85 pounds per 40-quart can, the seller may incur a loss or shortage of as much as 1 pound per can. Fortunately, most milk is sold in bulk and on a weight basis.

The butterfat test constitutes the most important source of loss and of variation. The butterfat content of the milk is determined by the Babcock test, which gives rise to random errors both because of the human element involved and of the natural limitations of the method. Table 35 illustrates the random or chance variations that occurred in successive tests of a large number of samples of identical milk. In all cases the tests were made by qualified testers, using new equipment and standardized materials.

The shape of this distribution indicates clearly the chance nature of the variation. More than 60 percent of the check tests were within the 0.1 percent limits of the method, but in a few cases the first test was

TABLE 35.—DIFFERENCE BETWEEN SUCCESSIVE BUTTERFAT TESTS OF 1,341 MILK SAMPLES

Difference in percentage of butterfat in successive tests	Frequency of samples
Percent	Number
-0.4	4
-0.3	2
-0.2	12
-0.1	224
0.0	799
+0.1	267
+0.2	26
+0.3	3
+0.4	4
Total number of samples.....	1,341

above or below the second by as much as 0.4 percent of butterfat. This would represent an extreme error of plus or minus 10 percent for 4-percent milk. The average deviation was 0.06 percent of butterfat, or an average error of plus or minus 1.5 percent for 4-percent milk.

Casual examination would seem to reveal that these random errors would again balance off, and that the butterfat test would not result in an uncompensated error. Check tests made for buyers and for producers prevent this from taking place. Buyers often check the test and protest if the reported test seems high. In these cases it is customary to make some adjustments. If all milk sold were check tested by the buyers, and adjustments made on all "high" tests, it is apparent that the chance errors would not average out, for there would be a tendency to cut off one side of the distribution. If the buyer's test was accepted in all cases the result would be an apparent plant butterfat loss of nearly 0.8 percent. Not all the milk is check tested, and adjustments are usually a compromise between the two tests, so the loss to be expected from this factor will be below the 0.8 percent level. On the other hand, the plant tests for individual producers is subject to similar checks, and protests of low tests will result in an indicated or apparent loss comparable to that just described. It would seem, then, that errors in testing butterfat will give rise to variations in plant loss, and that protests by producers and buyers may result in an appreciable paper loss or shortage. Even though these do not represent actual disappearances of milk or butterfat, they will constitute a real cost of plant operation.

Returning to table 34, the last column gives the distribution of the combined shortage for a large number of plants of mixed type, size, and efficiency. These plants had an average shortage of 2.1 percent during the 21 months of 1937 and 1938 for which data were available. In

6 months during the last half of 1937 the daily average volume of milk handled by these plants was 329,000 pounds and the plant shortage averaged 2.4 percent. During the same months of the following year the daily volume was almost the same, 338,000 pounds, whereas plant shortages had been reduced to 0.9 percent. These averages may be compared with the 1935 average reported by Rittenhouse of 1.25 percent (5). This last is again based on plants of all type, sizes, and efficiency, and covers about 70 percent of the country plants in the Boston milkshed. The percentage loss applicable to fluid-milk plants would be somewhat lower than these averages, for separating and manufacturing plants are subject to important losses in addition to those encountered by fluid-milk plants.

To convert plant loss into cost terms, it is necessary to establish a value for the milk or butterfat. Under the terms of the Boston Federal Order, reasonable amounts of loss are valued at the class II price.²⁴ The class II price at plants in New England fluctuated from more than \$1.80 to less than \$1 per hundredweight during the period in 1937 and 1938 in which the Federal Order was in effect. The average for the period was about \$1.30 per hundredweight. To represent the out-of-pocket costs to plant operators, this average must be reduced by the station allowance of \$0.26 for class II milk, or the average cost of plant shortage was approximately \$1.04 for each hundredweight of milk or milk equivalent lost. If a seemingly liberal allowance for efficient operation of 1 percent shortage is used, the cost per hundredweight of milk handled amounts to approximately 1 cent. As this loss appears to be random in nature, the cost will be a uniform addition to the unit costs for all plants regardless of volume or capacity.

SUMMARY OF PLANT COSTS

When the various elements of plant costs are brought together, it becomes apparent that relatively large plants are more efficient than small plants, in almost all respects. The costs of electricity for power and for lighting, of fuel, of labor, and of all of the fixed elements such as depreciation and interest show marked economies for the large plants. Only in the costs of supplies, of centralized bookkeeping and supervision, and of plant loss are small plants on the same level as the large. Total costs per hundredweight average almost \$0.30 for Plant U with daily capacity of 6,000 pounds. As plant capacity is increased, the unit costs decrease

²⁴ It may be argued that loss should be accounted for at the class I price. This can be justified only if the plant operator is required to pay for shortage into the market pool at the class I price. If country-station operating allowances were unchanged, this suggestion would have the effect of narrowing the margin, and so would be beneficial to producers and detrimental to plant operators.

rapidly, although at a decreasing rate. With a capacity of 65,000 pounds per day, Plant Z has costs of slightly more than \$0.10 per hundredweight. These costs are based on the assumption that the plants operate to capacity during the peak season and that the seasonal variation is similar to the average seasonal fluctuation given earlier. The elements of costs are summarized in table 36 for the six redesigned plants already described.

Total plant costs per hundredweight will vary above and below these averages as daily volumes are smaller or larger than the average daily volume. The average cost curve for any plant will consist of three elements: (1) a rectangular hyperbola representing the allocation of the fixed or non-variable costs; (2) a curve of constant costs per hundredweight representing the costs that vary with volume, there being no apparent tendency for these average costs to increase or decrease as volume increases; and (3) a discontinuous curve representing the costs of labor.

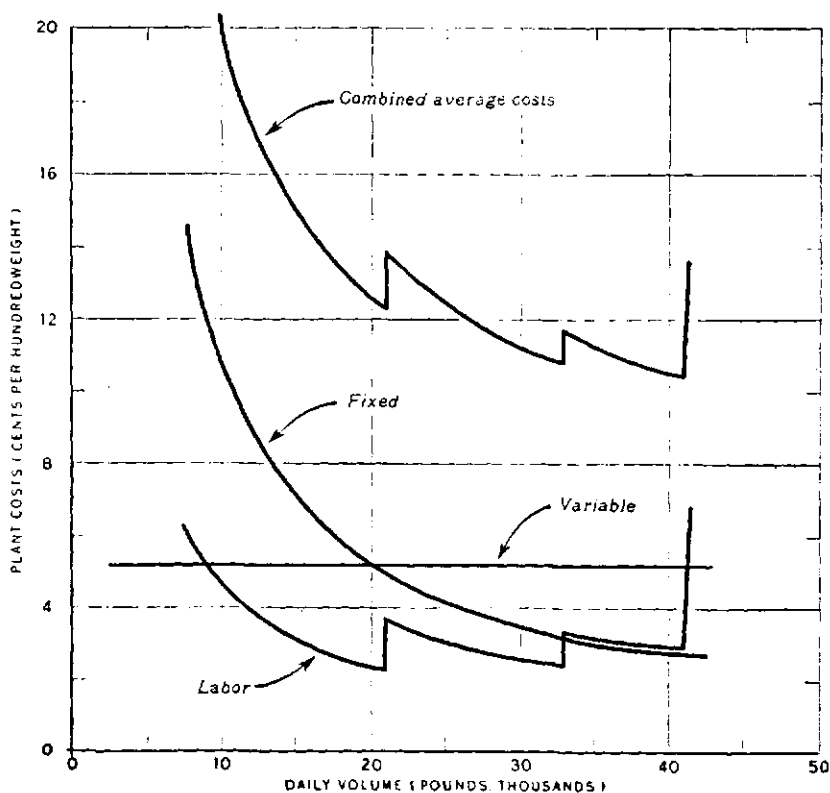


FIG. 10. Average cost curves for Plant X.

These elements are illustrated in figure 10 for Plant X. The fixed-cost curve represents the allocation of a daily fixed cost of \$10.47 exclusive of labor. The constant cost of \$0.052 per hundredweight is the sum of the variable costs, again excluding labor. The labor curve is both fixed and variable in nature, since the application of labor is discontinuous. In this plant the manager alone can handle up to 21,000 pounds of milk daily. The daily labor cost in this range will be \$4.43. To handle between 21,000 and 33,000 pounds, an assistant is needed and the daily labor cost will become \$7.71, while two assistants are required beyond that volume and labor costs will be \$11 per day. These three men can push volume to 41,000 pounds per day, which represents the capacity of the plant in the normal 3-hour receiving period. The addition of labor beyond this point will increase labor costs and total costs but will not permit appreciable increases in volume as long as the normal receiving period is maintained. The combination of these three elements indicates that unit costs will be very high at low volumes or if labor is added beyond the capacity of the plant. The costs are lowest when the plant is operated exactly at capacity, amounting to \$0.104 per hundredweight. The normal seasonal variation in production causes a range in

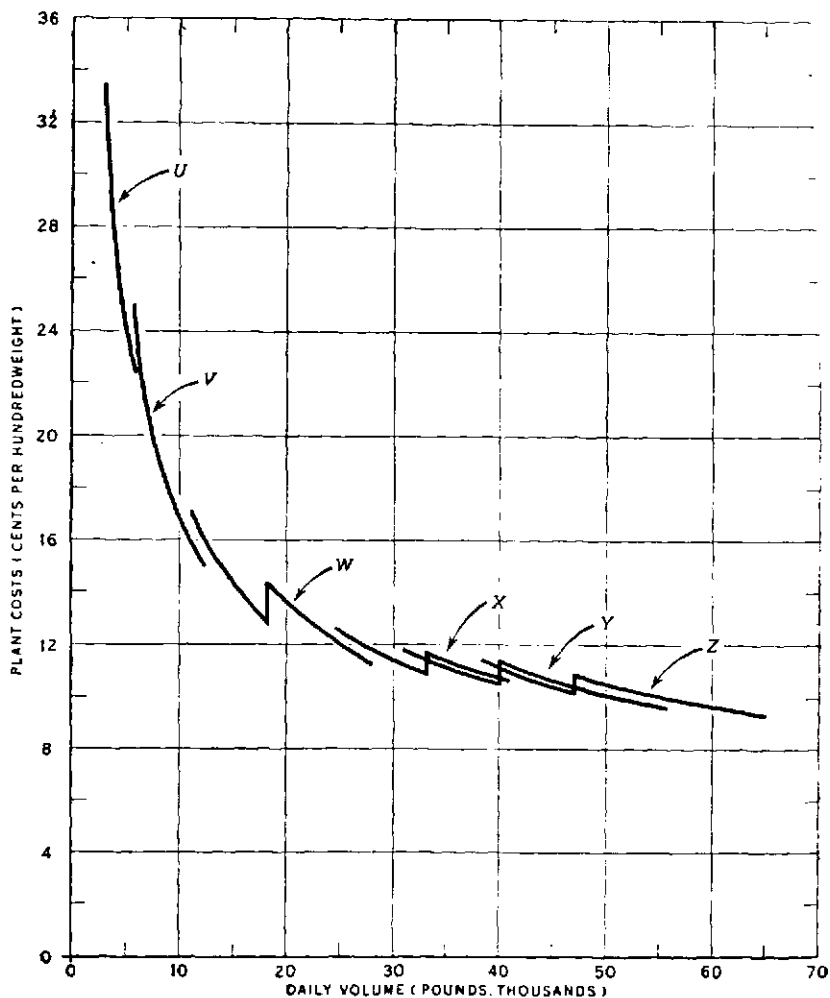
TABLE 36.—SUMMARY OF PLANT COSTS FOR SIX COUNTRY MILK PLANTS¹

Item	Unit	Plant					
		U	V	W	X	Y	Z
Daily capacity	Hundred-weight	60	120	280	410	560	650
Daily average volume....	do.	42	90	200	300	400	480
Plant cost:							
Power per cwt.	Dollars	0.018	0.015	0.012	0.011	0.010	0.010
Lighting per day	do.	.03	.04	.05	.06	.06	.07
Fuel per cwt.	do.	.022	.018	.011	.009	.008	.008
Fuel per day	do.	.58	.62	.83	1.03	1.24	1.45
Supplies per cwt.	do.	.002	.002	.002	.002	.002	.002
Supplies per day	do.	.10	.19	.45	.66	.90	1.04
Labor per day ²	do.	4.43	4.43	6.62	8.53	9.08	9.36
Secondary per day	do.	.22	.28	.44	.57	.72	.81
Depreciation per day ...	do.	1.95	2.27	3.29	3.93	5.12	5.18
Interest per day	do.	.81	.94	1.34	1.62	2.08	2.48
Other fixed per day ...	do.	.91	1.19	1.99	2.60	3.40	4.05
Centralized bookkeeping and supervision per cwt.	do.	.020	.020	.020	.020	.020	.020
Plant loss per cwt.	do.	.010	.010	.010	.010	.010	.010
Total non-variable per day ³	do.	8.93	9.96	15.01	19.00	22.60	25.44
Total variable per cwt..	do.	.072	.066	.055	.052	.051	.051
Average cost per cwt...	do.	.287	.177	.130	.115	.108	.104

¹ Items are listed under the general headings used in previous pages. Costs are rounded off in some cases, so the totals may not check exactly with the sum of the items as given in this table.

² Average for the entire season. Labor cost in any particular plant at any given volume may be above or below this, owing to the indivisibility of labor.

³ Including average labor costs per day.



U. S. DEPARTMENT OF AGRICULTURE

NEG. 39828 BUREAU OF AGRICULTURAL ECONOMICS

FIG. 11. Average cost curves for six redesigned plants.

plant volumes from about 24,000 to 41,000 pounds, however, and so makes this optimum adjustment impossible. The seasonal average cost for this plant will be about \$0.115 per hundredweight of milk.

Average cost curves for all six redesigned plants are given in figure 11 for the pertinent volume ranges.

THE ECONOMIES OF SCALE

The concept of economies of scale and the relationships between the average cost curves for plants of various capacities and the curve depict-

ing these economies have been discussed. Summarizing that discussion briefly, the industry curve is ordinarily drawn tangent to the individual-plant cost curves except in those cases where plant capacities form a discrete series or where there are unavoidable fluctuations in plant volume. Country milk plants are among those that are subject to volume fluctuations, the basis for which is the seasonal fluctuation in milk production. As a result, the industry curve or the curve showing economies of scale will be drawn through cost and volume positions that represent the most efficient operations possible under the limits imposed by the seasonal variation. The preceding section found these least average costs existing when daily volumes were adjusted to daily plant capacity in the period of peak production. Average volumes for an entire season were necessarily lower than capacities, the difference representing excess capacity that was unavoidable because of the seasonal nature of production.

The curve showing economies of scale for fluid-milk plants is given in figure 12. This curve is drawn through the least-average-cost points that are given in table 36. Economies are pronounced, especially in the low-volume ranges. Costs of operation drop rapidly as daily average plant volumes increase up to 20,000 pounds and less rapidly beyond that point. Some gains in efficiency are possible through the whole volume range covered by the diagram, but possible economies have been

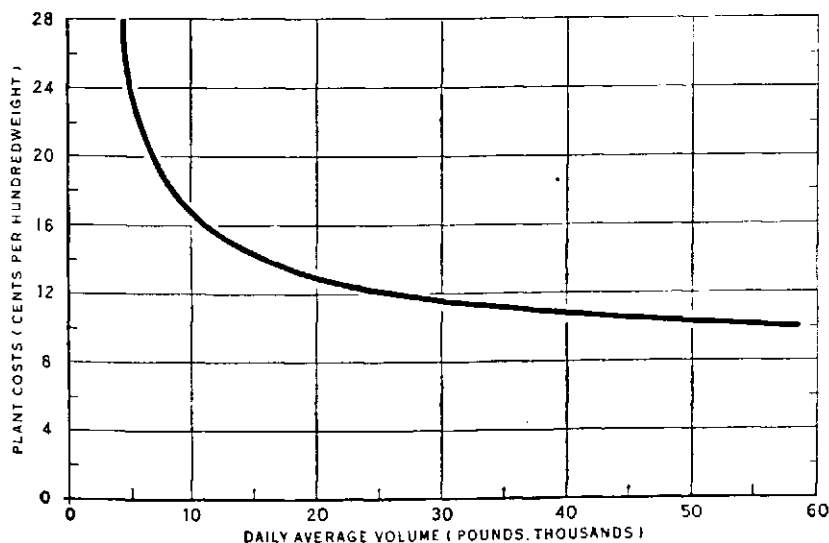


FIG. 12. Curve showing economies of scale for fluid-milk plants.

nearly exhausted in the high-volume range. This is made more apparent by the break-down of the curve into the general cost classifications given in table 37. Plant Z, with daily average volume of 48,000 pounds and

TABLE 37.—IMPORTANCE OF THE SEVERAL COST ELEMENTS IN THE ECONOMY-OF-SCALE CURVE

Item	Unit	Daily average volume in hundredweights					
		42	90	200	300	400	480
Cost per hundredweight:							
Variable	Dollars	0.042	0.036	0.025	0.022	0.021	0.021
Non-variable ¹	do.	.109	.061	.042	.035	.034	.034
Labor	do.	.105	.049	.033	.028	.023	.020
Central cost and loss.....	do.	.030	.030	.030	.030	.030	.030
Total ²	do.	0.287	0.177	0.130	0.115	0.108	0.104
Percentage of total cost:							
Variable	Percent	15	20	19	19	19	20
Non-variable ¹	do.	38	35	32	31	32	33
Labor	do.	37	28	26	24	21	18
Central cost and loss.....	do.	10	17	23	26	28	29
Total	do.	100	100	100	100	100	100

¹ This category is not limited to cost associated with building and equipment, but includes all cost associated with time rather than volume.

² May not check with additive totals because of rounding.

capacity of 65,000 pounds, has the same costs as the smaller Plant Y in all respects save labor. Apparently the economies of scale have been exhausted for the other costs when average volume reaches 40,000 pounds, while the gain with reference to labor cost between that volume and the 48,000-pound volume of Plant Z is only a fraction of a cent.

The second part of table 36 indicates the relative importance of the several general cost classifications. Variable costs average less than one-fifth of the total while non-variable costs average about one-third. The latter drop from 38 to 31 percent as average volumes increase from 4,200 to 30,000 pounds, and then increase to 33 percent with an average volume of 48,000 pounds per day. Labor costs fall from 37 to 28 percent as volume increases from 4,200 to 9,000 pounds, and then slowly to 18 percent for the largest plant. The centralized costs of bookkeeping and supervision and the costs of plant loss are fixed in absolute amount regardless of plant size, but vary in relative importance from 10 to 29 percent as volume increases and total average costs decrease.

COMPARISON OF THE ECONOMY CURVE WITH AVERAGE COST-VOLUME RELATIONSHIPS

The first parts of this bulletin emphasized the fact that average cost-volume relationships were not indicative of the economies that could be expected from changes in the scale of operation, since they combined

and confused two factors: (1) internal maladjustments such as excess capacity for individual plants, and (2) true economies of scale. When the economy curve is compared with the average cost-volume relationships presented in figure 2, it is found to differ from them with respect to both shape and location. The economy curve is lower than the average curves and it tends to decrease more rapidly in the low-volume ranges and less rapidly in the high-volume ranges.

The chief cause of these differences is that the cost-volume curves describe the average costs for a system involving efficient and inefficient plants, while the economy curve describes the costs that would result from an efficient organization of plants. This is emphasized by a comparison of the economy curve with the scatter diagram of individual-plant volumes and costs presented in figure 3. The economy curve represents approximately the lower limit of the scatter and so compares favorably with the most efficient plants. The individual plant costs were obtained from plants operating in the 1925-26 period, and are somewhat higher than would hold for plants that ship milk in tanks. This probably explains why none of the actual observations are quite so low as the costs indicated by the economy curve.

SOME MODIFICATIONS TO THE ECONOMY CURVE

The foregoing descriptions of the economies of scale in the operation of country milk plants are based on conditions that are typical or average for northern New England. Most of the cost elements are subject to variation, either geographically or in a random fashion, but the variations were disregarded. In the following pages these variations are considered more completely and their effects on the economy curve are investigated. Consideration is limited to the major items such as power, fuel, and labor, with some discussion of the modifications that will result from changes in the seasonal variation in production and in the plant-operating schedule.

Variations in Electrical-Power Rates

Costs of electrical power form one of the most important variable costs in plant operation. The actual magnitude of this cost will vary from location to location, however, as a consequence of the geographical variations in kilowatt-hour rates. The rates also vary with the amount of power used, ranging from an average of about \$0.04 for plants with daily volumes of less than 5,000 pounds of milk to approximately \$0.025 for plants with average volumes of 50,000 pounds. The geographical variation results in a range around these averages of from 70 to 160

percent. Few cases occur at these extremes, however, and two-thirds of the rates fall within a range of 15 percent of the average.

The modifications to the economy-of-scale curve that result from these variations are summarized in table 38. The highest rates would increase the level of the curve by amounts ranging from \$0.012 for small

TABLE 38.—EFFECT OF VARIATIONS IN ELECTRICAL-POWER RATES ON THE ECONOMY-OF-SCALE CURVE IN COST PER HUNDREDWEIGHT

Daily hundred-weight of milk	Kilowatt-hour rate as percent of average		
	160 percent	70 percent	15 percent
	Dollars	Dollars	Dollars
42	+0.0117	-0.0059	0.0030
90	+ .0096	- .0048	.0024
200	+ .0072	- .0036	.0018
300	+ .0066	- .0033	.0016
400	+ .0062	- .0031	.0016
480	+ .0060	- .0030	.0015

plants to \$0.006 for plants with daily volumes of 48,000 pounds. The lowest rates, on the other hand, would reduce the level of the curve by amounts ranging from \$0.006 to \$0.003 for small and large plants respectively. Two-thirds of the actual plant locations would fall within a range of \$0.003 of the standard curve for small plants and about \$0.0015 for large. This indicates that, in most cases, variations in costs of electrical power will change the economy-of-scale curve by only a fraction of a cent per hundredweight.

Variations in Prices of Coal

Prices for coal of the grade used in most country milk plants average about \$7.50 per ton, including delivery and unloading costs. The rates applicable for any given plant, however, depend on the location in New England and on the location with respect to railroad sidings. Prices are lowest in southwestern Vermont and highest in central Maine, ranging from less than \$6.50 to more than \$8.50 per ton. Prices

TABLE 39.—EFFECT OF VARIATIONS IN PRICES OF COAL ON THE CURVE SHOWING ECONOMIES OF SCALE IN COST PER HUNDREDWEIGHT

Daily hundred-weight of milk	Effect of deviation from average of	
	\$1.00 per ton	\$0.60 per ton
	Dollars	Dollars
42	0.0047	0.0028
90	.0034	.0020
200	.0020	.0012
300	.0016	.0010
400	.0015	.0009
480	.0015	.0009

applicable to two-thirds of the plant locations fall within a range of \$0.60 of the average, representing a variation of about 8 percent.

The effect of the approximate maximum deviation of \$1 per ton is to increase or decrease costs per hundredweight of milk less than \$0.005 in the smallest volume group and less than \$0.002 in the largest volume group. Two-thirds of the cases will deviate less than \$0.003 per hundredweight for small plants and less than \$0.001 for large plants. These modifications are summarized in table 39.

Variations in Fixed Costs

The principal items of fixed cost are depreciation, interest, insurance, and taxes. All of these are calculated by applying suitable rates to the total or partial investment in land, buildings, and equipment. In the previous pages, depreciation costs were based on rates of 3 and 4 percent for tile and frame buildings, respectively, and an average of 8 percent for equipment. Interest charges have been calculated at the rate of 5 percent, and the rate has been applied to the investment in land and to one-half of the investment in the depreciating items of building and equipment. Insurance costs have been calculated by applying rates of \$7.50 and \$15 per thousand of the original investment in tile and frame buildings and their contents. Tax payments have been computed by using a rate of \$17 per thousand of the total original investment.

All of these rates are subject to some variation, the exact magnitude of which is largely unknown. To indicate the effects of changes in the rates on the economy-of-scale curve, a variation of 20 percent was used. This is equivalent to a range of from 2.4 to 3.6 percent in the depreciation rates applicable to tile buildings, of from 6.4 to 9.6 percent in the depreciation rates for equipment, of from 4.0 to 6.0 percent in interest rates, of from \$6 to \$9 per thousand in insurance rates applicable to tile plants and their contents, and of from \$13.60 to \$20.40 per thousand in tax rates. The effects of these changes on costs per day and per hundredweight are summarized in table 40. In all cases the effect on costs per hundredweight is most pronounced for the small plant with average volume of 4,200 pounds daily. A 20-percent change in depreciation rates would result in a range in unit costs of less than \$0.01 above and below the previously determined average for this plant, while 20-percent changes in interest, insurance, and tax rates would result in changes of \$0.0038, \$0.0010, and \$0.0025 per hundredweight. For the plant with daily average volume of 48,000 pounds, on the other hand, the changes in unit costs accompanying 20-percent rate changes would be only

\$0.0026, \$0.0010, \$0.0003, and \$0.0007 for the four items in the previous order.

In addition to the effects of a 20-percent change in the several rates, table 40 shows the combined effect of a 20-percent increase in all four

TABLE 40.—EFFECTS OF A 20-PERCENT VARIATION IN FIXED COST ON COST PER DAY AND PER HUNDREDWEIGHT OF MILK, 6 HYPOTHETICAL PLANTS

Cost elements	Daily hundredweight of milk					
	42	90	200	300	400	480
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Change in cost per day:						
Depreciation	0.39	0.45	0.65	0.79	1.02	1.24
Interest .....	.16	.19	.27	.32	.42	.50
Insurance .....	.04	.05	.07	.09	.11	.13
Taxes .....	.11	.12	.17	.21	.27	.32
Total	0.70	0.81	1.16	1.41	1.82	2.19
Change in cost per cwt.: ¹						
Depreciation	0.0093	0.0050	0.0032	0.0026	0.0026	0.0026
Interest .....	.0038	.0021	.0014	.0011	.0010	.0010
Insurance .....	.0010	.0006	.0004	.0003	.0003	.0003
Taxes .....	.0025	.0014	.0009	.0007	.0007	.0007
Total	0.0167	0.0090	0.0058	0.0047	0.0045	0.0045

¹ These represent the modifications to the economy curve, and may be either additions or subtractions from the curve.

items. This combined effect is comparable to a 20-percent change in the investment in land, buildings, and equipment. Although it is not suggested that such a simultaneous range in all three items of investment is probable, the effect of such an occurrence would be to increase or decrease costs per hundredweight by a maximum of \$0.0167 for the smallest plant and a minimum of \$0.0045 for the two largest plants.

Variations in Labor Costs

Several types of variation in labor costs are of interest from the standpoint of their effect on the curve representing economies of scale. The first of these is comparable to the variations in other costs, and consists of the range in labor rates or wages. The second concerns the tendency for managerial wages to vary with plant volume or capacity. The third and last type of variation has to do with the use of part-time rather than full-time assistants. The effects of these three types of variation are noted below.

Managerial wages, including Social Security payments and allocated costs of vacations with pay, ranged from \$26 to \$35 per week for the eight sample plants on January 1, 1939. The wages for full-time assistants ranged from \$20 to \$26 per week at the same time. The average managerial wage was \$31 with a standard deviation of \$2.70, and the

average full-time assistant wage was \$23 with a standard deviation of \$2. There was no apparent tendency for the high-salaried managers to be associated with the high-paid assistants, so each may be considered as a separate and independent element. The effects of variations equal to the approximate ranges and standard deviations of wages for managers and assistants are found in table 41.

TABLE 41.—CHANGES IN PLANT COSTS PER HUNDREDWEIGHT THAT ACCOMPANY CHANGES IN WAGES, SIX HYPOTHETICAL PLANTS¹

Item	Daily hundredweight of milk					
	42	90	200	300	400	480
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Change in manager's wage:						
\$4.50 per week ²	0.0155	0.0072	0.0033	0.0022	0.0017	0.0013
\$2.70 per week ³.....	.0093	.0043	.0020	.0013	.0010	.0008
Change in assistant's wage:						
\$3.00 per week ².....	.0104	.0048	.0021	.0015	.0010	.0009
\$2.00 per week ³.....	.0069	.0032	.0014	.0010	.0007	.0006

¹ Represents addition to or subtraction from economy-of-scale curve.

² Approximately equal to the maximum variation from average wage.

³ Approximately equal to the standard deviation in wages.

Here again the modifications are greatest in the case of the smallest plant and decrease rapidly as the average size of plant increases. For the plant averaging 4,200 pounds, the maximum range in managerial and assistants' wages results in a maximum modification to the economy curve of \$0.0152 and \$0.0102 respectively, while a range equal to the standard deviation causes a change of \$0.0093 and \$0.0069. These changes are reduced to \$0.0013 and \$0.0009 for the maximum range in the largest plant and \$0.0008 and \$0.0006 per hundredweight for changes in wages equal to the standard deviation.

In considering labor rates, there appeared to be a tendency for the salary of the manager to increase as the size or capacity of the plant increased. But this relationship was of such slight statistical significance that it was disregarded and the average rate was applied to all plants. As accurately as could be determined, the regression took the form of a fixed cost of \$29 per week with increases of \$0.01 for each hundredweight per day in the peak volume.²⁵ If this description of the manager's salary had been used, costs evidently would be somewhat lower than those indicated for small plants and somewhat higher for the large plants. The differences in costs are of little significance for all except the smallest plant sizes, however, amounting to a reduction of nearly

²⁵ Coefficient of correlation of only 0.141 when corrected for parameters. This is partially the result of the small number of cases. With a larger sample and with detailed data as to the manager's experience. Tucker in an earlier study for the New York area (3) found a regression almost exactly equivalent to this, and a partial coefficient of correlation, holding years of experience constant, of 0.61.

\$0.005 for the plant with daily volumes of 4,200 pounds and reductions or additions of \$0.0013 or less for all other plants. These changes are indicated in the first part of table 42.

TABLE 42.—EFFECTS OF MANAGERIAL WAGES INCREASING WITH PLANT SIZE AND OF USING PART-TIME ASSISTANTS ON THE ECONOMY-OF-SCALE CURVE

Daily average hundredweight of milk	Modification for Manager's wage	Modification for part-time assistant's wage
	Dollars	Dollars
42	-0.0048	.....¹
90	— .0013	.....¹
200	+ .0006	-0.0038
300	+ .0010	— .0048
400	+ .0013	— .0041
480	+ .0013	— .0036

¹ These are one-man plants, and are not affected by changes in the wages of assistants.

Table 42 also gives the reductions in costs per hundredweight that would result from the practice of hiring part-time assistants instead of the full-time men specified in the original computations. It is possible in most plants to have one or more of the assistants hired only for the peak load hours of each day. In calculating the effects of this procedure, it has been assumed that the part-time assistants received \$15 per week, and that all helpers were hired on this basis. As the two smallest plants are normally operated by one man, the manager, this adjustment will not affect their costs. In the other plants, with one or two helpers either year-round or in the flush season, the maximum reduction in costs is \$0.0048 for the plant handling 30,000 pounds daily, while the smallest is \$0.0036 per hundredweight for the 48,000-pound plant.

Combined Effects of Variations in Eight Cost Elements

The independent effects of variations in eight cost rates have now been described—rates are for electrical power, coal, depreciation, interest, insurance, taxes, manager's wages, and the wages of plant assistants. Some of them may move together on occasion but they are essentially independent in character. It is conceivable that the rates for all eight items might be high or low for some plant location, or even that all of the rates would be at the maximum or the minimum level. This is not probable, however, and there will ordinarily be a combination of high and low rates applicable to any location.

If the several elements are taken to be completely independent it is possible to indicate the expected range around the economy-of-scale curve that will include two-thirds of the cases. This is based on the standard deviation for each element, or the effect of a variation equal to the standard deviation on unit costs. Such information is available

for power, coal, and labor rates, but not for the fixed cost rates. In making the following computations, it was assumed that the standard deviations for these fixed items is equal to 20 percent. In interpreting the indicated range around the economy curve, these qualifications must be remembered. The effects on unit costs of a variation equal to one standard deviation or of 20 percent are summarized in table 43 for the eight elements, and the computed range from the combined effects indicated.

TABLE 43.—EFFECTS OF A VARIATION IN RATES EQUAL TO ONE STANDARD DEVIATION ON COSTS PER HUNDREDWEIGHT FOR EIGHT COST ITEMS INDEPENDENTLY, AND THE ESTIMATED DEVIATION RESULTING FROM COMBINED EFFECTS

Item	Daily average hundredweight of milk					
	42	90	200	390	400	480
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Power	0.0030	0.0024	0.0018	0.0016	0.0016	0.0015
Coal .....	.0028	.0020	.0012	.0010	.0009	.0009
Depreciation ¹ .....	.0093	.0050	.0032	.0026	.0026	.0026
Interest ¹ .....	.0038	.0021	.0014	.0011	.0010	.0010
Insurance ¹ .....	.0010	.0006	.0004	.0003	.0003	.0003
Taxes ¹ .....	.0025	.0014	.0009	.0007	.0007	.0007
Manager's salary .....	.0093	.0043	.0020	.0013	.0010	.0008
Assistant's wage .....	.....²	.....²	.0014	.0010	.0007	.0006
Standard deviation of combined effect ³ .....	.0145	.0078	.0049	.0038	.0036	.0035

¹ Standard deviation assumed to be 20 percent of established rate.

² One-man plants.

³ Calculated as the square root of the sum of the squares of the independent effects.

These calculations indicate that two-thirds of the plant locations in New England can be expected to have plant costs that differ from those indicated by the economy-of-scale curve by less than \$0.015 per hundredweight in the very low-volume ranges, and that the standard deviation around the curve decreases rapidly as average volume increases, reaching \$0.0035 per hundredweight in the high-volume ranges. When it is realized that the eight elements included account for approximately 90 percent of total plant costs, excluding supervision and plant loss, it is apparent that variations in the cost rates applicable to different locations have a very minor effect on the economy curve in most cases. This is not a complete picture of variation around the basic curve, since it does not allow for deviations from the established physical relationships between volume and the several elements.

Effect of Seasonal Variation

It has been pointed out that milk production in northern New England is subject to a pronounced seasonal variation and that the seasonal index of fluid-milk receipts at all plants in Vermont in recent years has

ranged from a low of approximately 80 in the winter months to a high of 138 in June. The magnitude of this variation differs greatly from area to area in that State; it is smallest in the southeastern and largest in the northwestern part. Using the ratio of daily average receipts in high and low months to represent the fluctuation, the counties of Vermont range from Windsor County with a ratio of about 1.2 to Franklin County with a ratio of 2.3. The approximate index numbers of daily average fluid-milk receipts by months for these two counties are given in table 44, together with the index numbers of the seasonal fluctuation for the State as a whole. These are based on data for the period 1932-1937.

As the magnitude of the seasonal fluctuation in production will determine the season average volume handled by a plant of given

TABLE 44.—SEASONAL INDEX NUMBERS OF DAILY AVERAGE PLANT RECEIPTS OF FLUID MILK FOR VERMONT, AND THE APPROXIMATE INDEX NUMBERS FOR WINDSOR AND FRANKLIN COUNTIES
(1932-37 = 100)

Month	Index numbers of plant receipts		
	Vermont	Windsor County	Franklin County
January	82	95	71
February	84	95	75
March	95	99	92
April	107	102	111
May	125	108	140
June	138	112	160
July	116	105	126
August	100	100	100
September	98	99	97
October	94	98	90
November	81	94	70
December	80	94	68

capacity when volume is adjusted to capacity in the season of peak production, it will have a direct bearing on average costs per hundredweight of milk. Under average conditions, the year-round volume will be about 72 percent of plant capacity, while the fluctuations applicable to Windsor and Franklin Counties will permit average volumes of 89 and 62 percent of capacity respectively. Unit costs will be affected in two ways: (1) through the allocation of fixed costs to a smaller or larger volume, and (2) through changes in labor costs brought about by the need for assistants or helpers for a shorter or longer period during the year. The net effects on plant volumes and costs are shown in table 45 for the six theoretical plants.

Variations in seasonal fluctuation result in a range in costs for Plant U of \$0.074 per hundredweight and a range in average volume of 1,600

TABLE 45.—EFFECTS OF MAGNITUDE OF SEASONAL FLUCTUATION ON PLANT VOLUME AND COST PER HUNDREDWEIGHT OF MILK¹

Item	Plant					
	U	V	W	X	Y	Z
Capacity, cwts. per day	60	120	280	410	560	650
Vermont—average seasonal fluctuation:						
Daily average cwts.	42	90	200	300	400	480
Cost per cwt.	\$0.287	\$0.177	\$0.130	\$0.115	\$0.108	\$0.104
Windsor County—low-seasonal fluctuation:						
Daily average cwts.	53	107	249	356	498	578
Cost per cwt.	\$0.244	\$0.160	\$0.120	\$0.112	\$0.100	\$0.098
Franklin County—high-seasonal fluctuation:						
Daily average cwts.	37	74	174	254	347	403
Cost per cwt.	\$0.318	\$0.202	\$0.135	\$0.121	\$0.109	\$0.111

¹ In making the calculations for Windsor and Franklin Counties, the periods in which one or two assistants have been needed have been figured in full months. As a result of this discontinuity, the differences between the cost for the State and for either county deviate slightly from a smooth curve as size increases.

pounds per day. The cost range becomes smaller as size of plant increases and is only about 1 cent for the three largest plants. In all cases, a pronounced seasonal fluctuation reduces the daily average volume that can be handled by a given plant, and increases the average cost per hundredweight of milk, whereas relatively even production has the reverse effects.

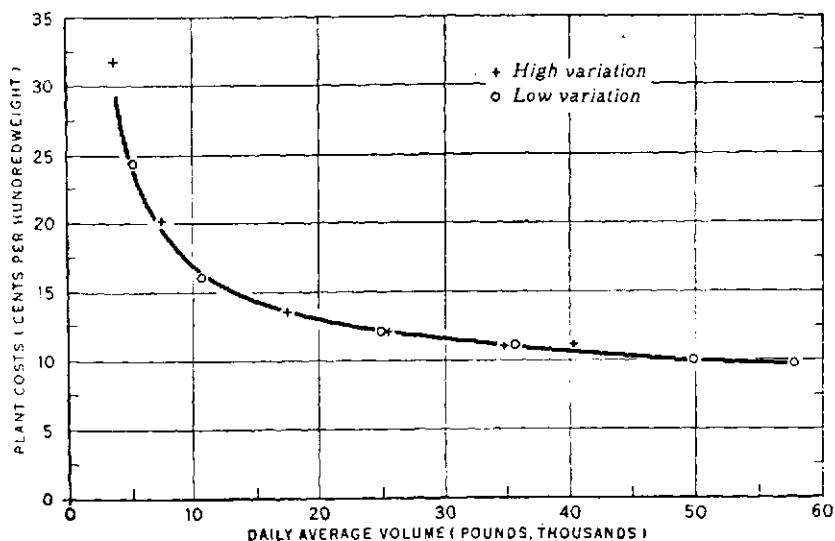


FIG. 13. The normal economy curve and average cost and volume situations under conditions of high- and low-seasonal fluctuations in plant receipts.

These cost changes do not represent modifications to the economy-of-scale curve directly, since the average volumes also change. Furthermore, the volume changes are inverse to the cost changes. As a result very little modification of the economy curve is necessary. This is illustrated by figure 13, in which the cost and volume situations for the extremes in seasonal fluctuation have been plotted with the basic economy curve. These points fall almost exactly on the economy curve, so it must be concluded that the basic curve showing the economy-of-scale relationship in terms of average volumes and average costs is not seriously distorted by variations in the seasonal fluctuations of the magnitude experienced in New England. The magnitude of the fluctuation will determine the average volume that can be handled by a plant of given capacity, but when this average volume is known the basic curve will indicate the average cost per hundredweight within a fraction of a cent. If the seasonal variation were unusually pronounced, however, there would be a tendency for the economy curve to be raised to higher average cost levels.

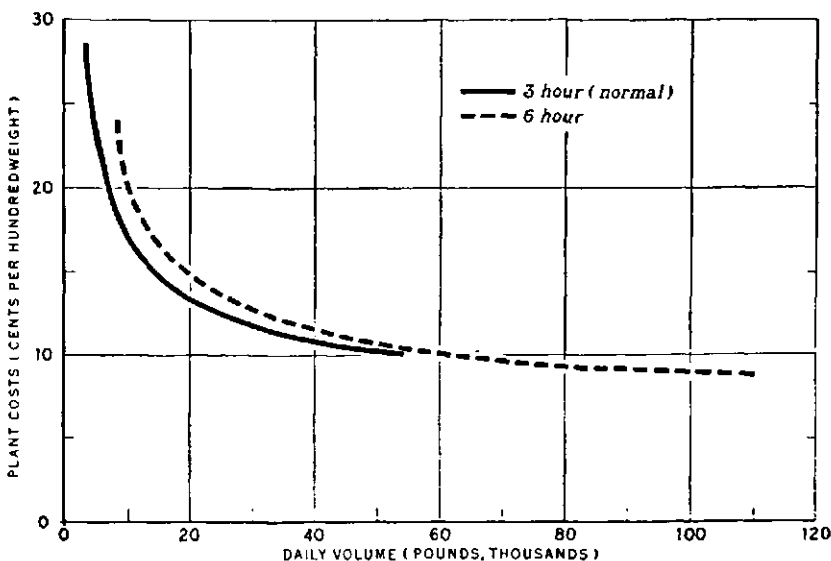
Changes in the Receiving Period

Most country receiving stations open early in the morning, receive milk for 2 to 4 hours, and ship to market in the late morning or early afternoon. Reports for 12 fluid milk plants scattered over New England indicate that the average receiving period is 3 hours, frequently from 6:00 to 9:00 a.m., Eastern Standard Time. Only 2 of the 12 plants normally received milk for a period that differed from the average by as much as 1 hour.

The receiving period is limited for three principal reasons: (1) The milk often must be ready for early shipment to market, (2) efficient operation demands that the receiving period be restricted so that the total hours of operation will be kept within reasonable limits, and (3) many of the State and municipal regulations specify that morning milk may be delivered to plants without farm cooling if delivered before 9:00 a.m. In preparing the estimates of plant capacity and plant costs, a receiving period of 3 hours has been assumed, as it is representative and is approximately the longest period that can be maintained between the time of milking and the 9 o'clock limit set by regulations. Since the maximum quantity of milk that can be received by a given plant in an hour is fairly well fixed, the establishment of a 3-hour period determines the daily capacity of the plant.

In a few instances, plants receive for longer periods or even receive in morning and evening periods. This extension of the receiving period

will increase the daily capacity and volume of a given plant and, as a result of the spreading of fixed costs, may be expected to lead to reduced unit costs. It seems reasonable to expect, therefore, that such changes will result in modifications to the economy-of-scale curve. The economy



U. S. DEPARTMENT OF AGRICULTURE

NEG. 33931

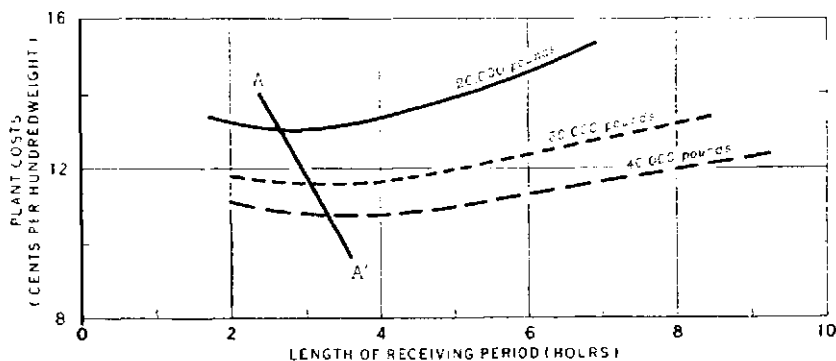
BUREAU OF AGRICULTURAL ECONOMICS

FIG. 14. Economy curves for three- and six-hour receiving periods.

curve applicable to 6-hour receiving periods is shown in figure 14, together with the normal curve. These curves indicate that costs will be lower under 3-hour operation within the volume range covered by the basic curve, but that possible volumes are doubled and that costs reach lower levels in these higher volume ranges with 6-hour operation. With 3-hour operation, for example, Plant Z can handle an average volume of 48,000 pounds at an average cost of \$0.104 per hundredweight. When the receiving period is increased to 6 hours, on the other hand, the plant could handle 96,000 pounds at a cost of approximately \$0.091 per hundredweight.

The curves in figure 15 show the relationships between costs and receiving hours for several volumes. As the receiving period is increased, the physical size of plant required to handle a given average volume decreases. These curves indicate the relative advantage of the normal 3-hour period and of longer and shorter periods. There is some indication that the optimum receiving period is longer than 3 hours for large volumes and shorter for small volumes. The approximate locus of the

least cost points is indicated by the line AA' in the figure. These least-cost points, however, represent costs that do not differ from those for 3-hour operation by as much as \$0.001. This means that the normal economy-of-scale curve could not be lowered appreciably by changes in the length of the receiving period, although increases in the period will permit volumes larger than those covered by the normal curve with costs lower than the lowest indicated by the normal curve. For average



U. S. DEPARTMENT OF AGRICULTURE

NEG 39832 BUREAU OF AGRICULTURAL ECONOMICS

FIG. 15. Effects of changes in the length of the receiving period on plant costs for daily average volumes of 20,000, 30,000, and 40,000 pounds. Line AA' represents the approximate locus of least-cost points.

volumes of less than 60,000 pounds, however, the normal or basic economy curve can be accepted as a practical representation of maximum efficiency from the standpoint of the length of the receiving period.

THE COMBINATION OF PLANT AND COLLECTION COSTS

The efficiency of the country phases of milk marketing depends not only on the organization of plants but on the organization of farm-collection routes and of plant-to-market transportation. The description of the economies of scale for country milk plants has indicated that marked savings may be achieved through the efficient operation of fairly large plants. Increasing the quantity of milk assembled at one point, however, necessitates an expansion in the milkshed or supply area for the plant. Additional milk must be collected from farms that are farther from the central point, and so the costs of collection will be increased. These increases in collection costs will offset, at least in part, the decreases in plant costs made possible through the expansion of volume and plant capacity. The most efficient organization for the whole country-marketing function will involve plants of such a size that the combined

costs of assembly, plant operation, and transportation to market are at a minimum.

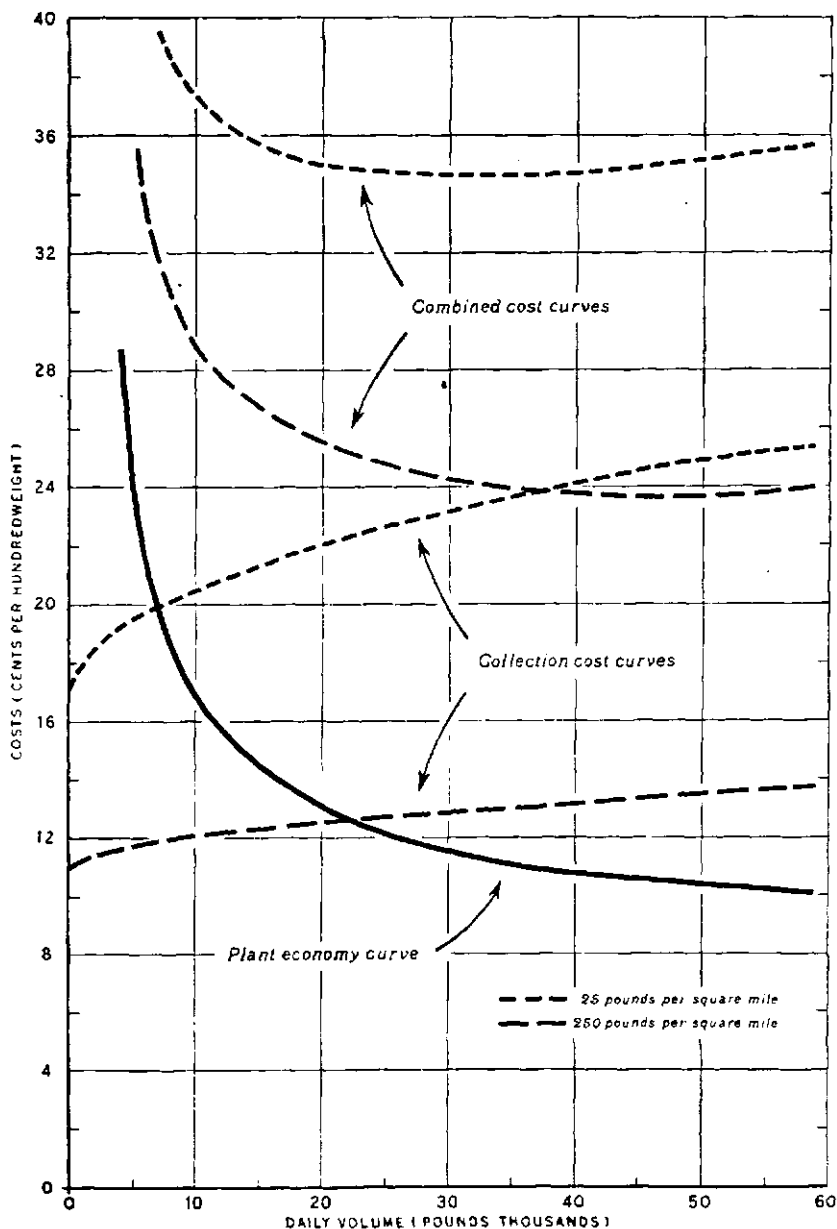


FIG. 16.—The combination of collection costs and plant costs to determine the most economical organizations for several density-of-production situations.

An investigation of all of these elements is beyond the scope of this bulletin, but it is possible to indicate briefly the nature of the results. Collection- or assembly-cost curves for several hypothetical situations have been combined with the plant-economy curve in figure 16. These curves are based on the costs of operating efficiently organized 4-ton collection truck routes under constant density of production conditions (13). Two density situations are illustrated, one with production of 25 pounds of milk per square mile and the other with 250 pounds per square mile. Regardless of the density and the size of truck, the average collection costs will tend to increase at a decreasing rate. The rate of increase will be most pronounced and the costs highest, however, for small trucks and low-density situations. When the assembly and the plant costs are combined, the total-cost curve declines sharply at first with the pronounced savings in plant operations but the increases in assembly costs eventually offset the decreases in plant costs, and total costs increase.

With production density of only 25 pounds per square mile, combined costs appear to reach a low point at an average volume of approximately 35,000 pounds. With this volume, efficient plant costs would be approximately \$0.110 and efficient collection costs would be about \$0.236, or combined costs would average about \$0.346. This volume would correspond to a milkshed extending more than 20 miles from the plant. With production density of 250 pounds per square mile, on the other hand, costs would be at a minimum with an average volume of about 45,000 pounds and plant, collection, and combined costs would be approximately \$0.105, \$0.133, and \$0.238 respectively. The milkshed in this case would have a radius of less than 8 miles. In both cases, it will be noted, the combined curves are quite flat near the least-cost volume so that there are wide ranges within which costs are only a fraction of a cent above the minimum.

These calculations have assumed that the density of production is constant as the radius of the milkshed increases. In actual situations it is common to find plants located near the center of fairly dense producing areas where density decreases as distance from the plant increases. This may take the form of the small and somewhat isolated valleys that are found in northern New England. The nature of the collection cost and so the combined-cost curves will then depend on the size of the adjacent productive area, the density of production, and the additional distance and cost involved in trucking milk from outside areas. If an area is isolated from other areas by 20 or 30 miles, it will probably be economically desirable to restrict plant volume to the milk produced in the ad-

jacent area. If additional producing areas can be reached with an extra haul of only a few miles, on the other hand, the effect on collection costs will not be great and it may be feasible to expand plant capacities and volumes.

Plant-to-market transportation may also be affected by the volume of milk available for shipment from a single plant. The familiar differences between less-than-carload, carload, and tank-car rates suggest that there are marked economies of large-scale shipment. Under New England tariff schedules, however, cars may be loaded at several points without extra charge and so the low rates are applicable to small as well as to large plants. Although particular conditions may result in advantageous volumes, there appears to be no consistent relationship between volumes and rates. Insofar as this is true, plant-to-market transportation costs will not influence the optimum organization of plants.

PLANT COSTS UNDER EFFICIENT ORGANIZATION

The examples have indicated the general way in which the optimum size of country milk plants may be determined. In actual application, the collection cost-volume relationship will be conditioned by such factors as the existing pattern of production and the existing road network, while the economies of scale in plant operation will be modified somewhat by local variations in the several cost elements. By determining the curves appropriate to particular locations and by including a complete area it would be possible to indicate the most economical organization of plants for the entire area. This optimum organization would evolve with changes in such factors as technology and demand and

TABLE 46.—THE DISTRIBUTION OF FLUID-MILK PLANTS BY ANNUAL VOLUME OF MILK RECEIVED, AND ESTIMATES OF THE PLANT OPERATING COSTS THAT WOULD HAVE CHARACTERIZED THE SYSTEM IF CAPACITIES HAD BEEN ADJUSTED TO PEAK VOLUMES.

Annual milk receipts	Fluid-milk plants ¹	Estimated cost per hundredweight ²
Million pounds	Number	Dollars
0.0- 3.9	9	0.225
4.0- 7.9	14	.140
8.0-11.9	15	.119
12.0-15.9	4	.109
16.0-19.9	3	.104
20.0-23.9	1	.102
Estimated average cost for all plants ³		.124

¹ All plants that received and shipped only fluid milk. New Hampshire and Vermont volume data are for 1937, Maine data for 1939.

² As indicated by the economy curve in figure 12.

³ Weighted by total volume in each class.

supply conditions. The evolution would probably be slow and that fact, coupled with the flat nature of the combined-cost curves, should make it possible to develop a practical solution that could be modified when and as required and that would have costs closely approximating the true minimum.

The previous examples suggest that country milk plant costs under an efficient organization would average less than \$0.11 per hundredweight. It is not possible here to develop a more definite estimate, but some indication of the probable costs may be obtained from the existing plant organization. Table 46 summarizes the volume distribution of the fluid-milk plants operating in the three States of northern New England in recent years. Average volumes varied from less than 2 million to more than 20 million pounds of milk annually. Using these volumes and assuming that plant capacities were adjusted to volume in the peak season, costs per hundredweight would have amounted to approximately \$0.23 for the smallest plants and \$0.10 for the largest, and the weighted average for the entire group would have been about \$0.124. These costs have been derived from the plant-economy curve and are summarized in the last column of table 46. The estimates are much lower than present costs, of course, because of existing excess capacity. At the same time they are undoubtedly higher than the costs that would characterize an efficient system, since complete reorganization would eliminate existing plant duplication and would consolidate some of the small and uneconomical plants.

COUNTRY PLANT ALLOWANCES

It is difficult to discuss milk-plant efficiency and costs without some reference to the charges that are made for milk-plant services, especially when there is reason to suppose that these allowances have been important in the development of the present situation. For many years charges or allowances have been established as flat rates applicable to all plants. Before the advent of Federal control, the plant allowance in the Boston milkshed was established by mutual agreement at approximately \$0.23 per hundredweight for all milk handled at country plants. Under Federal control the allowances were set at \$0.20 for class I and \$0.26 for class II milk until August, 1941, when the class II allowance was reduced slightly. Comparison of these allowances with the economy-of-scale curve indicates that they are in excess of efficient operating costs for all except the very smallest plants. This means that plants could be built or maintained with the expectation of high profits. A plant handling

60,000 pounds of milk daily in the peak production season, for example, could be operated at an average cost of less than \$0.11 per hundredweight and would earn annual profits of more than \$14,000 on a total investment of approximately \$30,000. Such returns would attract capital into the industry in excess of actual needs and the ultimate result could only be too many plants and relatively large amounts of unutilized capacity. The elimination of "price" competition through the fixed allowances thus not only permitted but encouraged inefficiency and high costs.

The theory of the allowances seems to have been that charges should be established at a uniform rate high enough to insure the continual supply of the necessary services. As such it has sufficient superficial resemblance to the competitive theory of supply and demand to appear reasonable. As a matter of fact it is fallacious when applied to the problem of country plants. There is no single market for country-plant services where buyers and sellers of the service assemble and through their actions determine price. There are practically as many markets as there are plant locations. In each of these markets there are elements of spatial monopoly as well as a limited number of "sellers" or plant operators. In this situation decreasing plant costs with an expanding scale of operation, at least within the range pertinent to the local area, must lead either to a considerable degree of local monopoly or to duopoly or oligopoly with costs above the monopoly level. Finally, as mentioned before, the fixed and uniform allowances have reduced the possibility of "price" competition. The market for country plant services, then, is inherently non-competitive in nature and the addition of relatively high and inflexible prices or charges has moved it even further from the field of competition. It is not surprising, therefore, that inefficiencies have not been eliminated automatically through the workings of competitive forces.

Powerful competitive forces leading towards improved efficiency would result, however, from a system of graduated allowances based on the economies of scale. These allowances could be established according to the volume handled by each plant and would differ from plant to plant and from month to month in each plant as volume changed. As the allowance would cover the costs for only those plants in which capacity and volume were well adjusted to each other, such plants would be the only ones to survive over a period of time. In addition, the graduated allowance would pass the benefits of large-scale operation back to the farmers and they would be able to balance off the costs of plant operation and the costs of milk collection to determine the organization that

would be most profitable to them as individuals. A producer who has been delivering his milk to a small plant would be anxious to shift to a larger plant if the differences in the allowances were larger than his increase in the costs of collection or hauling. As producers shifted from small to large plants, the discrepancies between volumes and allowances would be increased and the economic compulsion to shift would thereby be intensified. This would lead to the rapid abandonment of uneconomic plants and the more complete utilization of those remaining.

Although these adjustments would greatly improve the efficiency of the country-plant system, several factors would prevent the evolution from reaching the optimum organization. The collection system would be unaffected and presumably would be characterized by charges that did not reflect costs accurately. As a result, the balancing off of plant allowances and collection charges could not represent the minimum cost combination. Even if collection routes were efficiently organized and charges were made in accordance with costs, the process by producers of balancing off their individual costs of collection against the varying allowances would lead to a final adjustment with plants somewhat smaller than the optimum, as the optimum would be based on the average or composite costs of collection for the entire group and not the individual costs for the marginal producers. Finally, the adjustments would be hindered by existing producer-plant relationships and a lack of mobility, or lack of ability to shift in response to economic forces.

In addition to improved efficiency and lower costs, on the other hand, the graduated allowances would be flexible enough to permit the existence of high-cost plants in localities where conditions make such plants the best solution. There would be no tendency to subsidize such localities and to keep them in production, but neither would they be forced out by a flat allowance at a level too low to cover the necessary costs. Similarly, it would be possible for producers to maintain plants that were inefficient from the economic viewpoint but which yielded non-economic returns to producers in the form of pride in a local establishment or in the associations connected with a particular plant. In this case the price paid for these returns in the form of higher costs would be clearly apparent and the producers concerned would know the alternatives and be able to make informed decisions. As freedom of choice is prized by Americans in general and New England farmers in particular, this may be one of the most favorable attributes of a graduated station allowance based on the costs of efficient operation.

It is not to be supposed that the inauguration of such a scheme would be without difficulties. Graduated allowances could be handled by the existing control agencies, but they would undoubtedly complicate the administration and enforcement of the State and Federal programs. If put into effect, they would probably be challenged in the courts. Aside from the legal problem, there appears to be little justification for a program placing all of the burden of improved efficiency on present operators of plants, especially when it is realized that the existing system evolved in response to forces largely beyond their control. A more reasonable program would call for a sharing of this expense by producers and consumers.

It should be possible to solve these difficulties, however, and to devise a system that would lead to real efficiency. The graduated allowance would be a long step in this direction and would probably be as flexible and automatic as any effective system could be.

SUMMARY AND CONCLUSIONS

From the analyses presented it is apparent that there are pronounced economies of scale in the operation of country milk plants. With average daily volumes of 4,000 or 5,000 pounds the most efficient plants will have costs of nearly \$0.30 per hundredweight. With volumes of 20,000 pounds, however, the average costs with efficient operation will be only \$0.13, while further increases in capacity and volume to 50,000 will result in average costs approaching \$0.10 per hundredweight of milk. The exact level of the economy curve appropriate to any specific location will depend on the seasonal variation in production and on the particular cost rates applicable to the locality, but in most cases it will not differ greatly from the level given by the generalized or average curve.

Because of such inefficiencies as excess capacity, many plants operating in northern New England have average costs higher than those indicated by the economy curve. If the whole-milk receiving and shipping plants in the area were operated without appreciable amounts of excess capacity the average costs of operation probably would be between \$0.12 and \$0.13 per hundredweight of milk. The elimination of plant duplication and uneconomical plants would reduce costs to even lower levels. These savings could be passed back to producers through some system such as graduated plant charges or allowances based on the economy curve, and farm incomes in these States could thereby be increased approximately \$500,000 annually. This saving, based on the total volume of fluid milk shipped from the area, is large enough to completely

amortize the existing investments in milk shipping stations in the area in several years.

The need for increased marketing efficiency in the present period of national emergency goes beyond any statement of dollar savings. It is imperative that resources be conserved and diverted into the war effort. The consolidation of milk plants will result in material reductions in the amounts of power, fuel, and labor required to maintain these essential services. Plant operators will find it increasingly difficult to obtain some of these resources. Plant and equipment repairs and replacements will have to be cut to a minimum. In short, the revision of the country phases of milk marketing is not only desirable from the longtime standpoint of society but it is immediately important as a contribution to the war program and as a means of enabling the industry to continue the flow of milk from producer to consumer without interruption.

Although important changes have taken place in the organization of the country phases of milk marketing during the last few years, uncontrolled and automatic evolution cannot be expected to result in a system closely approximating the optimum. If the potential gains from increased marketing efficiency are to be obtained it will be necessary to have an active program of reorganization. Such a program should involve farm collection and plant-to-market transportation as well as fluid-milk plant operation, while in localities distant from markets it will be necessary to consider more complex types of country plants. The complete reorganization is beyond the scope of the study here reported, but a system of milk-plant charges graduated in accordance with the economies of scale would help bring about improved efficiency in the marketing of milk.

LITERATURE CITED

- (1) Bressler, R. G., Jr. 1942. *Dairy Plant Operation in Northern New England*. New England Research Council Mimeograph.
- (2) Schoenfeld, W. A. 1927. *Some Economic Aspects of the Marketing of Milk and Cream in New England*. United States Department of Agriculture Circular No. 16.
- (3) Tucker, C. K. 1929. *The Cost of Handling Fluid Milk and Cream in Country Plants*. Cornell University Agricultural Experiment Station Bulletin 473.
- (4) Camburn, O. M. 1929. *Milk Receiving Station Operation in Vermont*. Vermont Agricultural Experiment Station Bulletin 303.
- (5) Rittenhouse, C. F. and Co. 1936. *Summary Report on Cost of Distributing Milk in the Boston Market*. Massachusetts Milk Control Board Publication.
- (6) Clement, C. E. 1937. *Country Milk-receiving and Cooling Stations*. United States Department of Agriculture Circular No. 432.
- (7) Federal Trade Commission. 1936. *Distribution and Sale of Milk and Milk Products—Boston, Baltimore, Cincinnati, and St. Louis*. United States House of Representatives Document No. 501.
- (8) Pollard, A. J. 1938. *Transportation of Milk and Cream to Boston*. Vermont Agricultural Experiment Station Bulletin 437.

- (9) Sonley, L. T. 1940. *Cost of Transporting Milk and Cream to Boston*. Vermont Agricultural Experiment Station Bulletin 462.
- (10) Viner, J. 1931. "Cost Curves and Supply Curves," *Zeitschrift für National-ökonomie*, III.
- (11) Bowen, J. T. 1932. *Refrigeration in the Handling, Processing, and Storing of Milk and Milk Products*. United States Department of Agriculture Miscellaneous Publication 138.
- (12) Federal Power Commission, 1939. *Typical Net Monthly Bills for Electric Service—Maine, New Hampshire, Vermont*. Publications of the Federal Power Commission.
- (13) Bressler, R. G., Jr., and Hammerberg, D. O. 1942. *Efficiency of Milk Marketing in Connecticut*. 3. *Economics of the Assembly of Milk*. Storrs (Connecticut) Agricultural Experiment Station Bulletin 239.

APPENDIX

BUILDINGS AND EQUIPMENT FOR SIX THEORETICAL PLANTS

Floor Plans.—The floor plans for the six theoretical milk plants discussed in this bulletin are shown in figure 17. The plans are based on actual plants in New Hampshire and Vermont, although changes have been made to eliminate space not essential to the proposed type of operation. The plants range in annual volume from 1.5 to 17.5 million pounds of fluid milk. From the standpoint of floor area they range from 620 to 1,540 square feet.

The plans provide space for the storage of coal, although some operating plants store their coal outside. To achieve comparability between the several plant sizes, the space allocated for the storage of coal was made roughly proportional to the size of the boiler.

Long and narrow plants are somewhat more expensive to build than plants of similar floor area but with width and length nearly equal. But as the long, narrow type is well adapted to fluid-milk operations, the floor plans for the theoretical plants have widths of about 20 feet and lengths varying from 33 to 77 feet. The discrepancy in cost of construction would be most pronounced in the case of Plant Z, but estimates for a square plant of similar floor area indicate that the investment in buildings would be lowered less than 4 percent.

Method of Estimating Construction Costs.—The costs of constructing modern plants of the size and type indicated were estimated for these six plants. The estimates for frame buildings are largely the work of C. W. Dingman of the Springfield Bank for Cooperatives, while supplementary data for tile plants were obtained from other sources. The data were based on an assumption that no unusual difficulties would be encountered with respect to terrain or labor and materials. Cost rates were selected as representative of recent years and do not consider the effects of the present emergency conditions, as these are thought to be abnormal and not indicative of the long-run situation. The construction costs have been prepared by following practices commonly used by

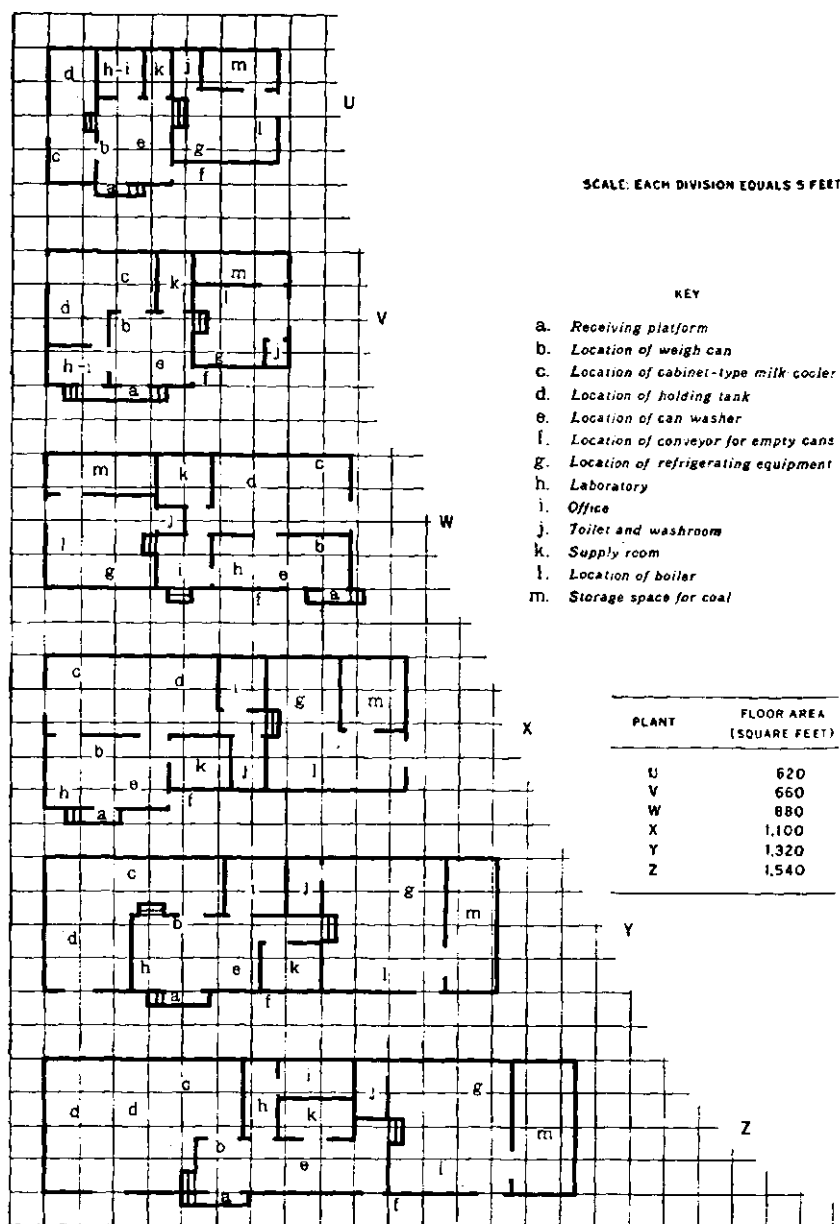


FIG. 17. Floor plans for six theoretical plants.

contractors in preparing bids. An allowance of 20 percent has been included to cover the returns to the contractor as well as any items that have been omitted as a result of the general nature of the specifications.

The general specifications for the plants stipulate that foundation walls should be of 8-inch concrete, extending 3 feet below the ground level and 1 foot above. Floors are to be of 4-inch concrete on 18-inch gravel or cinder fill. Walls above the foundation are of frame or hollow-tile construction. Frame walls use 2-inch by 4-inch studs spaced 18 inches apart, with the exterior finished with paper and novelty siding, and the interior of matched boards. Ceilings are of matched boards on 2-inch by 6-inch joists. Roofs are of asbestos-type shingles laid on roofers and 2-inch by 6-inch rafters. All interior walls are finished except those in boiler rooms and storage rooms for coal. All sash are of double-hung wood construction.

Details of the estimates for construction costs are given in the following pages for Plant Z. Similar detailed estimates have been made for Plants U and X, whereas the costs for Plants V, W, and Y were based on the unit costs as ascertained from the detailed estimates. Plant Z is designed to handle a daily peak load of 65,000 pounds of milk in a 3-hour receiving period. It is 20 feet wide and 77 feet long, with a floor area of 1,540 square feet and a cubic content of 22,300 cubic feet. Details are presented for frame construction only, the estimates for tile construction having been obtained in essentially the same way, with the substitution of tile costs for the corresponding lumber costs in the present estimates. The estimates are based on the following unit costs for materials and installation:

Excavation	\$ 1.00	per cubic yard
Backfill .....	.75	per cubic yard
Gravel fill	1.50	per cubic yard
Concrete		
Walls	8.00	per cubic yard
Floors	11.00	per cubic yard
Forms for concrete .....	.14	per square foot
Lumber:		
2 inches by 4 inches and 2 inches by 6 inches.....	6.00	per 100 board feet
Roofers	5.00	per 100 square feet
Matched boards	7.00	per 100 square feet
Novelty siding	10.00	per 100 square feet
Paper	1.00	per 100 square feet
Roofing	10.00	per 100 square feet
Tile	4.65	per square yard

Construction Costs for Plant Z²⁶

Excavation		\$250
Trench	194 feet by 3 feet by 3 feet = 1,746 cubic feet	
General	77 feet by 20 feet by 1.5 feet = 2,310 cubic feet	
Backfill	194 feet by 3 feet by 2 feet = 1,164 cubic feet	
Gravel fill	8 feet by 28 feet by 2.5 feet = 560 cubic feet	
	12 feet by 16 feet by 2.5 feet = 480 cubic feet	
	3 feet by 5 feet by 2.5 feet = 38 cubic feet	
	2 feet by 9 feet by 2.5 feet = 45 cubic feet	

Total gravel fill = 1,123 cubic feet

²⁶ Estimates have been rounded off.

Concrete			\$ 880
Footings	194 feet by 2 feet by .5 feet =	194 cubic feet	
Walls	194 feet by .67 feet by 4 feet =	518 cubic feet	
	96 feet by .67 feet by 4 feet =	256 cubic feet	
Platforms and steps		135 cubic feet	
		Total = 1,103 cubic feet	
Floors	77 feet by 20 feet by .33 feet =	508 cubic feet	
Forms:			
Walls	2 (194 feet by 4 feet) =	1,552 square feet	
	2 (96 feet by 4 feet) =	768 square feet	
Platform and steps		128 square feet	
		Total forms = 2,448 square feet	
Lumber and Paper			\$1,220
Sills and plates	630 feet by 2 inches by 4 inches =	420 board feet	
Studs	2,020 feet by 2 inches by 4 inches =	1,347 board feet	
Joists and rafters	2,530 feet by 2 inches by 6 inches =	2,530 board feet	
		Total = 4,297 board feet	
Roofers $\frac{7}{8}$ inches	194 feet by 10.5 feet =	2,037 square feet	
	154 feet by 13 feet =	2,002 square feet	
	20 percent allowance =	808 square feet	
		Total = 4,847 square feet	
Walls	194 feet by 10½ feet =	2,037 square feet	
Ceilings	77 feet by 20 feet =	1,540 square feet	
Partitions	226 feet by 8 feet =	1,808 square feet	
	20 percent allowance =	1,077 square feet	
		Total = 6,462 square feet	
Paper		2,030 square feet	
Novelty siding		2,030 square feet	
	20 percent allowance =	420 square feet	
		Total = 2,450 square feet	
Roofing (2,010 square feet)			\$ 200
Doors and windows			500
Painting			450
Plumbing and wiring (not including boiler)			1,400
Total			\$4,900
Allowance of 20 percent			980
Estimated construction cost			\$5,880

Equipment Costs.—The following pages give the lists of equipment and the estimated costs, including delivery and installation, of equipment for the six theoretical plants. The estimates were prepared from material submitted by several creamery-equipment companies as well as from the actual reported costs for several new plants now in operation. As in the case of construction costs, equipment prices do not include the effects of present emergency conditions. Because of the difficulties involved in list prices and actual prices, however, the estimates for some items may be somewhat inflated.

The equipment listed represents the principal items for plants designed to ship fluid milk in tank cars or tank trucks. Tank storage space has been provided in each plant equal to the daily average volume. Therefore, in using these plants it will be necessary to have tank trucks or cars at the plants before the receiving period is completed, during the flush season. This system is commonly used by many of the present plants. As a matter of fact, it is possible that the present plans call for more tank storage than is necessary or customary. It does provide a uniform relationship between volume and tank capacity, however, and so guarantees that the several plants will be comparable.

The refrigerating systems for all plants include ammonia compressors, sweet water coolers, and cabinet-type milk coolers. Sufficient capacity has been allowed to handle the daily peak load in a 3-hour receiving period. The calculations have assumed that, as the milk received at the plant consists of uncooled morning milk and farm-cooled evening milk, it will have an average temperature of 70° F. and will be cooled to an average temperature of 40° F.

The boiler horsepower for each plant has been determined by the can-washer requirements, since the washer represents the peak load. Can-washer capacities have been determined by the maximum volumes received in a 3-hour period and an assumption of 60 pounds of milk per can received.

PLANT U

Average volume—4,200 pounds per day
Peak volume—6,000 pounds
Number of producers—20

Receiving equipment	\$ 1,400
500-pound weigh can	
600-pound receiving vat	
500-pound dial scales, suspended	
Can-washing equipment	770
Hand-turned rotary washer, 1½ cans per minute	
Roller can conveyor, 20 feet	
Cooling equipment	2,800
Five-ton ammonia compressor with motor, condenser, pumps, etc.	
Five-ton sweet water cooler	
Cabinet-type milk cooler, capacity 2,000 pounds of milk per hour	
Storage equipment	1,450
500-gallon storage tank	
30 feet of sanitary piping	
Two milk pumps and motors, five gallons per minute	
Sanitary fittings, etc.	
Boiler equipment	550
Seven HP horizontal boiler	
30 feet of stack	
Boiler accessories	

Other equipment	830
Centrifuge	
Glassware for 20 patrons	
Water pump	
Miscellaneous equipment	
Estimated total cost installed for all equipment.....	<u>\$ 7,800</u>

PLANT V

Average volume—9,000 pounds per day

Peak volume—12,000 pounds

Number of producers—40

Receiving equipment	\$ 1,400
500-pound weigh can	
600-pound receiving vat	
500-pound dial scales, suspended	
Can-washing equipment	770
Hand-turned rotary washer, 1½ cans per minute	
Roller can conveyor, 20 feet	
Cooling equipment	3,475
11-ton ammonia compressor with motor, condenser, pumps, etc.	
11-ton sweet water cooler	
Cabinet-type milk cooler, capacity 4,500 pounds per hour	
Storage equipment	1,750
1,000-gallon storage tank	
30 feet of sanitary piping	
Two milk pumps and motors, 10 gallons per minute	
Sanitary fittings	
Boiler equipment	630
10 HP horizontal boiler	
30 feet of stack	
Boiler accessories	
Other equipment	1,175
Centrifuge and glassware for 40 patrons	
Thermometers, etc.	
Water pump	
Miscellaneous equipment	
Estimated total cost installed for all equipment	<u>\$ 9,200</u>

PLANT W

Average volume—20,000 pounds per day

Peak volume—28,000 pounds

Number of producers—85

Receiving equipment	\$ 1,550
700-pound weigh can	
800-pound receiving vat	
1,000-pound dial scales, suspended	
Can-washing equipment	1,280
Rotary can washer, 3 cans per minute	
Roller can conveyor, 20 feet	
Cooling equipment	5,735
25-ton ammonia compressor with motor, condenser, pumps, etc.	
25-ton sweet water cooler	
Cabinet-type milk cooler, capacity 10,000 pounds per hour	

Storage equipment	2,600
2,500-gallon storage tank	
40 feet of sanitary piping	
Two milk pumps, 25 gallons per minute	
Boiler equipment	730
15 HP Scotch marine boiler	
40 feet of stack	
Boiler accessories	
Other equipment	1,605
Centrifuge and glassware, 85 patrons	
Thermometers, etc.	
Water pump	
Miscellaneous equipment	
Estimated total cost installed for all equipment	<u>\$13,500</u>

PLANT X

Average volume—30,000 pounds per day

Peak volume—41,000 pounds

Number of producers—125

Receiving equipment	\$ 1,550
700-pound weigh can	
800-pound receiving vat	
1,000-pound dial scales, suspended	
Can-washing equipment	1,400
Rotary washer, four cans per minute	
Roller-type can conveyor, 35 feet	
Cooling equipment	7,015
35-ton ammonia compressor with motor, condenser, pumps, etc.	
35-ton sweet water cooler	
Cabinet-type milk cooler, capacity 14,000 pounds per hour	
Storage equipment	3,400
4,000-gallon storage tank	
40 feet of sanitary piping	
Two milk pumps, 35 gallons per minute	
Boiler equipment	820
20 HP Scotch marine boiler	
40 feet of stack	
Boiler accessories	
Other equipment	1,985
Centrifuge and glassware, 125 patrons	
Thermometers, etc.	
Water pump	
Miscellaneous equipment	
Estimated total cost installed for all equipment	<u>\$16,170</u>

PLANT Y

Average volume—40,000 pounds per day

Peak volume—56,000 pounds

Number of producers—170

Receiving equipment	\$ 2,100
750-pound weigh can with vacuum-operated dump valve	
2,000-pound receiving vat	
1,000-pound dial scales, suspended	

ECONOMIES OF SCALE

Can-washing equipment	2,100
Rotary washer, seven cans per minute with automatic can remover and lid placer	
Roller-type can conveyor, 40 feet	
Cooling equipment	8,805
45-ton ammonia compressor with motor, condenser, pumps, etc.	
45-ton sweet water cooler	
Cabinet-type milk cooler, capacity 18,000 pounds per hour	
Storage equipment	5,200
5,000-gallon storage tank	
50 feet of sanitary piping	
Two milk pumps, 45 gallons per minute	
Boiler equipment	970
30 HP Scotch marine boiler	
50 feet of stack	
Boiler accessories	
Other equipment	2,075
Centrifuge and glassware, 170 patrons	
Thermometers, etc.	
Water pump	
Miscellaneous equipment	
Estimated total cost installed for all equipment.....	\$21,250

PLANT Z

Average volume—48,000 pounds per day
 Peak volume—65,000 pounds
 Number of producers—200

Receiving equipment	\$ 2,100
750-pound weigh can with vacuum operated dump valve	
2,000-pound receiving vat	
1,000-pound dial scales, suspended	
Can-washing equipment	\$ 3,600
Fully automatic straightaway washer, 10 cans per minute	
Roller-type conveyor, 45 feet	
Cooling equipment	\$10,500
55-ton ammonia compressor with motor, condenser, pumps, etc.	
55-ton sweet water cooler	
Cabinet-type milk cooler, capacity 22,000 pounds per hour	
Storage equipment	6,000
Two 3,000-gallon storage tanks	
50 feet of sanitary piping	
Two milk pumps, 55 gallons per minute	
Boiler equipment	1,130
40 HP Scotch marine boiler	
50 feet of stack	
Boiler accessories	
Other equipment	2,330
Centrifuge and glassware, 200 patrons	
Thermometers, etc.	
Water pump	
Miscellaneous equipment	
Estimated total cost installed for all equipment	\$25,660