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AUTHOR CARL WILLIAM HALL

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AN OPERATIONAL ANALYSIS OF DAIRY PLANT EQUIPMENT

by

Carl William Hall

A THESIS

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Engineering

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Carl William Hall

candidate for the degree of

DOCTOR OF PHILOSOPHY

Final Examination: July 30, 1952, Agricultural Engineering Engineering Building, Room 218.

Dissertation: An Operational Analysis of Dairy Plant Equipment.

Outline of Studies:
Major subject: Agricultural Engineering
Minor subjects: Mathematics
Mechanical Engineering

Biographical Items:
Born, November 16, 1924, Tiffin, Ohio

Undergraduate Studies, Ohio State University, 1942-3, 1946-8, Columbus Ohio
Degrees: B. S. College of Agriculture
B. Agr. E., College of Engineering
(summa cum laude)

Graduate Studies
(1) University of Delaware, Newark, Delaware, 1948 -50.
Major: Mechanical Engineering
Minor: Mathematics
Degree: Master of Mechanical Engineering.

(2) Michigan State College, East Lansing, Michigan, 1950 - 1952.

Military Service: U. S. Army, 1943 to 1946, European combat service, Staff Sergeant, Infantry.

Experience:
Assistant Instructor, Ohio State University, Spring, 1948.
Instructor, University of Delaware, 1948-1950
Assistant Professor, University of Delaware, 1950-1951
Michigan State College, 1951-

Member of:
Tau Beta Pi, Engineering Honorary
Gamma Sigma Delta, Alpha Zeta: Agricultural Honoraries
American Society of Agricultural Engineers (ASAE)
Society of Automotive Engineers (SAE)

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ABSTRACT OF THESIS

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The dairy manufacturing industry has been forced to carefully analyze its procedures to assure a financial return. The competition is keen and the profit small. The analysis was made to aid the dairy industry in improving its operations.

A study was made of the costs of each operation in the process of bottling fluid milk. Plants were selected for study which were considered to have an efficient operation. Charts were prepared showing the relationship between the operational cost and capacity of equipment in 1952 for dairies with capacities from 20,000 to 100,000 pounds per day. The charts may aid the plant operator in selecting the most economical piece of equipment for an operation.

Each individual operation was studied to determine methods of decreasing the cost. Time studies were made to determine the time required by different operators on the same job. By comparing different operators the easiest and least time-consuming method for completing the work was recommended. The item of major cost in each operation was selected and suggestions made for decreasing the cost of the operation. In many cases equipment was either too large or too small to efficiently utilize labor, utilities, building space, or other equipment.

A check list was formulated which could be used by the manufacturers of dairy equipment, dairy plant planners, or dairy plant operators to analyze present or proposed operations.

Most of the equipment used in dairies is at least a year old. The cost of operation of the older pieces of equipment would not necessarily be the same as the costs figured for 1952. A series of charts were prepared which can be used by the plant operator to calculate the operational costs of his particular equipment. The data can be used as a guide for economically selecting new equipment.

After the equipment is selected, a satisfactory layout must be used. Tangible methods were illustrated to aid the planner in selecting the best arrangement by use of an operation schedule, utility and man analysis charts, and layout with block models.

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I. INTRODUCTION

In 1949 the total milk production by cows on farms in the United States was 119,136,000,000 pounds. Of this quantity 45,000,000,000 pounds of milk and cream were consumed in towns (1). The remainder of the milk was consumed on the farm and made into factory products. The Bureau of Census has reported a detailed breakdown of manufactured products, but has not summarized the quantities of fluid milk sold. The number of dairy plants processing fluid milk is reflected by the number of milk dealers in the United States. There were a total of 15,736 milk dealers, of which 5,655 milk dealers had over four routes (2). There are also the following:

5360 butter manufacturers;
3661 cheese manufacturers;
1561 condensed, evaporated, and dry milk manufacturers;
7122 ice cream manufacturers.

Michigan lies in the East North Central district of the United States for census purposes. This district produces 35,615,000,000 pounds, or twenty-nine per cent of the total milk production in the United States. Michigan ranks

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1. Dairy Industries Catalog, The Olsen Publishing Company, Milwaukee, Wisconsin, 1951, p. 46.

2. Ibid., p. 53.

seventh in the United States in the production of fluid milk, being preceded by Wisconsin, New York, California, Iowa, Minnesota, and Pennsylvania.(1)

From the previous data, 37.6 per cent of the milk produced on the farm is sold in the city. It can be assumed that practically all of this milk is pasteurized and processed because of the health regulations. Assuming that there is a dairy for each milk route, the average dairy handles 21,000 pounds of milk per day. Michigan ranks sixth in the number of milk dealers, being behind New York, Pennsylvania, California, Illinois, and Ohio (2).

The equipment required by the dairy industry is specialized, and manufactured by a group of approximately 37,000 people who are engaged in the manufacture of food processing equipment (3).

The dairy industry does not make an exorbitant profit. The competition is keen and the profit is small. According to the Pennsylvania Milk Commission, 565 companies made an average profit of three-fifths of a cent a quart after taxes, in 1949, and 127 companies showed a net loss for the year (4). A similar survey by the Indiana University

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1. See Appendix Table I
2. See Appendix Table II
3. ______________ 1947 Census of Manufacturers, Vol. II, U. S. Department of Commerce, Statistics by Industry, U. S. Printing Office, 1949.
4. Neeley, George E. "Problems in Milk Distribution," Talk presented before the National Association of Sanitary Milk Bottle Closure Manufacturers from an undated publication by the same title.

Bureau of Business Research on a nationwide basis covering 313 companies showed an average net profit of two-fifths of a cent per quart (1).

The fact that the mortality of dairies in the last fifteen years (1935-1950) has been about fifty per cent (1) illustrates the importance of analyzing the problems involved in the dairy plant.

Planning the many operations involved in a dairy plant is difficult because of the many variable involved. Once the equipment is installed in the plant, the main concern of the manager is to assign the proper amount of work to each employee. A better job is performed by workers who are responsible for a definite activity. In order to assign a fair share of work to an employee, standard times for each operation should be available to plan the work schedule.

Plant planners frequently encounter difficulty in placing equipment in a plant, either new or old. The efficiency of a plant can often be increased more by the proper arrangement of equipment than by improving the work methods. In order to provide an efficient plant layout, standard times for each operation should be available.

Engineers who design dairy plant equipment could do industry a service by designing simplified methods and motion

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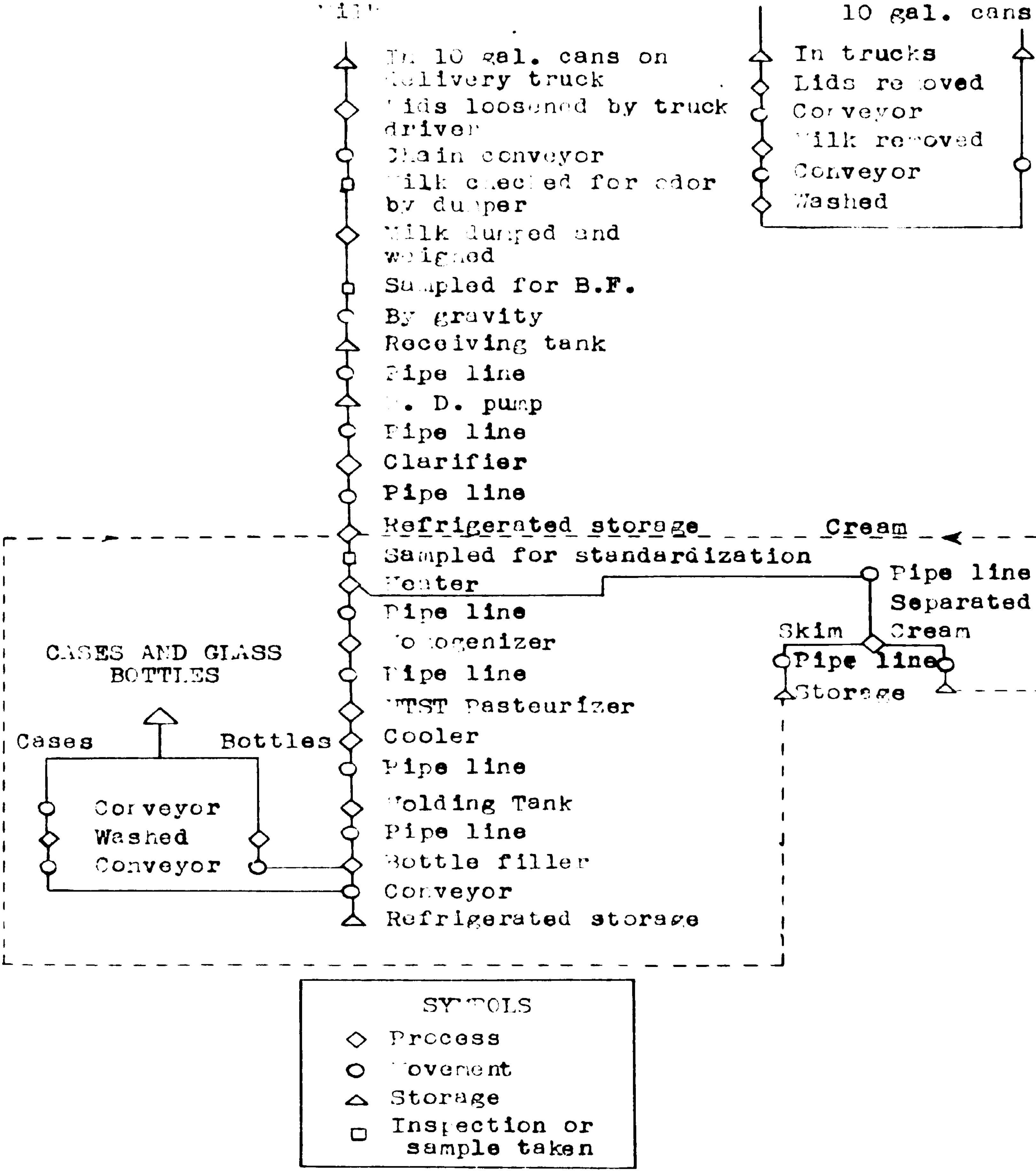
1. Neeley, George E. Loc. cit.

economy into the machinery. Many of the strained relations which often develop when management attempts to improve the workers methods could then be avoided. Thus, the operator and planner of dairy plants, and the designer of dairy plant equipment can benefit by a thorough analysis of the time and cost of each operation. After analyzing each operation, it is often found that steps in the operation, or the entire operation may be eliminated. Time studies also aid in locating the "bottlenecks" in a process, and permit a person to visualize the need for and the possibilities in developing new equipment.

Many processes may be carried out in a dairy plant. Examples of processes are bottling milk, producing ice cream, manufacturing cheese, and churning butter. Each of these processes consists of several operations. The receiving, processing, and bottling of milk will be the only process investigated in this dissertation. The various operations may be listed in order of occurrence for ease in visualizing the successive steps in processing milk. A chart illustrating these steps with appropriate symbols is called a flow process chart. Not all dairies are alike in their operations. A typical flow process chart for the processing of whole milk is shown in Fig. 1. The same information plotted on a floor plan gives a flow diagram.

One objective will be to obtain time values for various elements of work in each operation. The next step will in-

FIG. 1. Flow Process Chart for Milk Bottling



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volve obtaining time values for each of the operations as a whole. The time values can be obtained for different plant and equipment capacities to calculate part of the cost of the operation.

Standard times for each operation, together with the necessary time between operations, are established to assure management that the worker is doing his share, and to assure the worker that he is not doing more than his share. The standard time represents the time, in minutes, that a worker should require to perform a certain task, which includes allowances. The total allowance varies with the plant and the task, but is generally twenty per cent of the actual work time. Allowances are for rest to prevent fatigue and for personal items. It may be necessary to add additional time for condition factors as cold, heat, slippery floors, etc. The work time varies according to the pace of the worker, so while making a time study it is necessary to rate a worker's speed. This is a difficult task which requires experience. One method suggested by Carroll (1) is to define a normal pace as being equivalent to dealing 52 cards in four piles around a bridge table in 0.45 minutes.

By comparing the standard times for different pieces of equipment, a check list of desirable features can be formulated. Too often equipment is patterned from that of a competitor without formulating new approaches, and conse-

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1. Carroll, Phil, <u>How to Chart Timestudy Data</u>, McGraw-Hill Book Company, New York, 1950, p. 57.

quently void of new ideas. The time study results offer a new approach to designing equipment--an approach which should lead to improved equipment and methods. Of course, the equipment must first be designed to perform a function, but time study results should be an approach to improving a design.

The fact that standard times often benefit the worker as well as the company is often overlooked. An example is the result of a time study which showed that a man can shovel the maximum tonnage a day if he lifts 21.5 pounds on each shovel full (1). The worker would be less fatigued, in addition to accomplishing extra work, and possibly greater pay, if his shovel were designed to hold only the optimum weight.

Time study methods have previously been widely applied to industries with repetitive operations. The processing of bottled milk consists of continuous operations which do not readily lend themselves to time study methods. Chemical industries are similar to the dairy industry in this respect. Adapting time study methods to the dairy industry presents a challenge. Many operations are controlled by the capacity of the equipment in the dairy. It is important to secure values for the relationship between operating and rated capacity. One of the objectives in plant design is to minimize handling. The same objective can be sought in dairy plant design. Minimum handling would include minimum pipe length which is desirable from the standpoint of lower initial costs,

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1. Barnes, R. M., Motion and Time Study, Wiley and Sons, New York, 1948, p. 11.

reduced labor requirement, and in reduction of fat losses. The relationship of one operation to another is of prime importance in considering the handling problem.

The cost of an operation is a function of the floor area required, the cost of the equipment, the layout of the plant, labor required for the operation, and the services and utilities required in the form of electricity, steam, water, etc. A mathematical relationship among these various factors would be of benefit to the people connected with the dairy industry in order to determine the efficiency of operation. These costs could be expressed best in terms of the equipment cost and capacity, which are usually known to the dairy plant operator or engineer.

II. REVIEW OF LITERATURE

During the last few years the dairy industry has been forced to increase the efficiency of its operation in order to obtain a profit because labor costs have increased markedly and the public has demanded that prices for dairy products be held down. It is difficult to evaluate exactly the efficiency of a dairy plant by methods other than from the profit-loss column, which includes plant and delivery operations for most dairies.

The efficiency of an operation, as far as the plant is concerned, depends upon the labor costs, utility costs, building space requirement, equipment costs, and interest on investment. Each of these factors has been studied separately for each piece of equipment.

A. Labor

Time studies were first used in 1881 by F. W. Taylor at the Midvale Steel Company (1). Frank and Lillian Gilbreth are credited with originating motion study as we know it today (2).

Time and motion studies have been applied to industries other than the dairy industry for several years. These

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1. Barnes, op. cit., p. 7.
2. Ibid., p. 12-15.

industries were mainly of the repetitive type in which the machine operator worked continuously on one machine repeating the same task during short intervals. The chemical industry, which is very similar to the dairy industry, is made up of continuous operations. Time studies came into use in the chemical industry during the early part of the 1940's. Bjorksten (1) in 1943 pointed out many advantages to the chemical industries from the use of time and motion studies. Rossmore and Aries (2) pointed out that even though the cost of manufacturing for mechanical industries where time and motion studies are usually used included fifty per cent labor cost in comparison to twenty per cent labor cost for chemical industries, that the chemical industries could benefit greatly because of the following factors:

1. As an independent expense item, labor costs have a deciding effect on plant location and economics;

2. Many operations are mechanical;

3. Unit operations could be simplified, thus requiring less supervision and time;

4. Development of new types of equipment;

5. Use for arrangement or rearrangement of equipment.

Although time and motion study methods were developed many years ago, these methods have only been applied to the

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1. Bjorksten, J., "Time and Motion Studies for Chemists," Chemical and Engineering News, Volume 21 (1943), p. 1324.
2. Rossmore, F., and R. S. Aries, "Time and Motion Study in the Chemical Process Industries," Chemical and Engineering News, Volume 25 (1947), pp. 3142-3144.

dairy industry recently. The most recent study was made by Shiffermiller (1) in 1950. He found that the cleaning operations in a dairy required seventeen to twenty per cent of the total plant labor, and made recommendations for reducing the labor requirements for cleaning.

H. P. Hood and Sons Company has been adapting time and motion study analysis to the dairy industry since 1942, and they have been able to decrease their labor requirements considerably (2).

In spite of the fact that many plant executives feel that time study is not needed, Nadler (3) gives the following benefits of time study, which were taken from Mundel (4), even though the product is machine-controlled:

1. Improve schedules
2. Determine job requirements
3. Check work efficiency
4. Distribute work uniformly
5. Establish incentive
6. Determine best methods

In an Australian cheese factory, applying principles of motion study in wrapping, a fifty per cent decrease in labor was reported and the output was increased two hundred per

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1. Shiffermiller, William E., "A Time and Motion Analysis of Cleaning Operations in Milk Plants," Unpublished Thesis for Master of Science Degree, Michigan State College, 1950, p. 44.

2. Dunlop, H. G., "Work Simplification Pays Off," Food Industries, October 1949, pp. 1356-1359; November 1949, pp. 1548-1552.

3. Nadler, Gerald, "Time and Motion Study in Canning Plant," Food Industries, February 1950, pp. 236-237.

4. Mundel, M. E., Motion and Time Study, Prentice-Hall, Inc., New York, 1950.

cent according to Felling (1). Although not carried out, as yet, Morrison emphasizes the need for applying work simplification to the ice cream industry, in the face of rising labor costs (2). He points out that studies should be made with the idea of making the best use of present facilities. He also cautions against simplifying one operation at the expense of others.

Recent studies at Purdue showed that the average worker in the receiving room wasted forty-three per cent of his day (3). The time wasted ran as high as seventy-six per cent in some dairies (4). The job was analyzed by breaking it down into small parts, and plotting the time values of these parts by use of a multiman chart. By redistributing the work the labor requirements were reduced from 58.8 man-minutes to 37.4 man-minutes for receiving a 100-can truck load.

Van Pechman emphasized the importance of obtaining operating standards for teaching a job to an untrained person (5).

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1. Felling, R. C., "Changed Layout Saves $2500," Factory Management, February 1940, pp. 64-65.

2. Morrison, R. W., "Work Simplification in an Ice Cream Operation," Ice Cream Review, June 1951, pp. 152-153.

3. French, Charles E., "Work Simplification in the Dairy Plant," Cherry-Burrell Circle, March-April 1952, pp. 3-7.

4. French, Charles E., "Streamlining Receiving Operations," Food Engineering, January, 1952, p. 99.

5. Van Pechman, F., "Revision and Expansion of Operating Standards," Chemical and Engineering News, October 10, 1943, pp. 1621-1625.

United States Department of Agriculture studies of 115 dairy plants, handling an average of 62,000 pounds of milk, showed that 384 gallons of milk were received per man-hour when the milk was handled in cans from trucks (1). An average of 3.9 men spent 4.6 hours receiving the milk. In the same studies, dairies of the same size handled 1309 gallons of milk per man-hour when the milk was received from tank trucks or tank cars. In the latter case 1.5 men spent 4.4 hours receiving.

Much of the data reported on labor studies in dairy plants was secured during those years when the labor cost was not as great, comparatively speaking, as it is at the present time. Many textbooks have quoted the data of Tables I and II, which would not apply to present modern dairy plants, but which are useful for comparison. These data were obtained before the use of the short-time pasteurizing unit.

Table I. Relation Between the Size of Dairy and Labor Requirements for Pasteurizing and Cooling Milk and Cleaning Equipment in 112 Plants (2)

Milk pasteurized daily, gallons	(a)	(b)
3000 or less	246	3.7
3000 - 5000	341	5.0
5000 - 10,000	434	9.3
10,000 - 15,000	416	17.3
over 15,000	450	24.4

(a) Gallons of milk pasteurized and cooled per man-hour, including labor for cleaning
(b) Man-hours of labor required for cleaning pasteurizing equipment

1. Babcock, C. J., "Operation and Management of Milk Plants," United States Department of Agriculture, Washington, D. C., Circular No. 260, Revised, 1947, p. 8.
2. Clement, C. E., "Operation and Management of Milk Plants," United States Department of Agriculture, Washington,

Table II. Number of Men Employed in 194 City Milk Plants (1)

Size of Plant, gallons	Average number of employees inside plant	Milk handled per plant employee, gallons
2000 - 5000	15.3	216
5000 - 10,000	34.5	213
10,000 - 15,000	46	249
15,000 - 20,000	78.6	221
over 20,000	103	267

In 1933, Sommer listed the major processing expense as labor (2). From his figures, 40.5 per cent of the processing cost consisted of labor.

The use of permanent pipe lines offers great possibilities in decreasing the labor required for cleaning. Tests have shown that permanent glass lines can be cleaned effectively in place by recirculatory means (3).

B. Utilities

In order to calculate the utility cost, the quantity of the resource required can be calculated from the theoretical requirements and the efficiency of the equipment in using the utility. Data on utilities used by various pieces of equipment are rather limited. Chemical engineering texts and handbooks were consulted for U values, or heat transfer

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1. Clements, ibid., p. 38.
2. Sommer, Hugo E., Market Milk and Related Products, Second Edition, Olsen Publishing Company, 1946, p. 606.
3. Fleischman, F. F., Jr., J. C. White, and R. F. Holland, "Glass Lines: Do A-1 Job," Food Engineering, Vol. 22, 1950, pp. 1686-1690, 1821, 1823.

coefficients of standard pieces of equipment. Where data were not available for water to milk heat transfer, water to water data was available, and used in the calculations.

The information relating specifically to heat transfer in milk was published by Bowen (1) (2). An open-jacketed kettle had an efficiency of 89 per cent if the condensate was returned to the boiler, and 74 per cent if the condensate was discharged to an open drain (1). The U value of a jacketed kettle with a stirrer was 300 British Thermal Units per square feet-hour (2). This agrees with the data listed in Perry (3).

The coil vat, which has a heating surface of 65.5 square feet for 200 gallon capacity, had a U value of 176, and an efficiency of 75.6 per cent (4). However, in calculations a U of 200 is recommended (3).

C. Building

Much material has been written about the size and design of building which should be used for housing the dairy equipment. The size of building is usually designated by the number of square feet of floor area. Mitten made a survey

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1. Bowen, John, "Heat-Transfer in Dairy Machinery," Agricultural Engineering, Jan. 1930, pp. 30, 31.
2. Ibid., p. 27.
3. Perry, John H., Chemical Engineers' Handbook, McGraw-Hill, New York, 1950, p. 48.
4. Bowen, op. cit., Feb. 1930, pp. 71-74.

of twenty-eight milk plants to determine the space requirements of different dairies. He reported an average of one square foot of floor area per gallon for the large plants (over 100,000 pounds daily) and three square feet of floor area per gallon for the small plants (less than 20,000 pounds daily) (1). Mitten gives additional values for individual processing areas in the dairy.

Ross has summarized the area requirements for the various operations for dairies of different capacities as shown in Table III.

Table III. Number of Square Feet in Various Work Rooms of Five Well-arranged Milk Plants (2)

Quantity bottled daily, gallons	Receiving room sq. ft.	Bottle washing room sq. ft.	Pasteurizing room sq. ft.	Bottling room sq. ft.	Milk Storage room sq. ft.	Glass bottle storage sq. ft.
1000	400	600	500	300	450	400
1500	--	700	500	375	550	--
3000	900	1050	1300	1200	1200	750
4000	460	1886	540	700	1426	540
6000	1200	1908	720	720	1110	720

A relationship between the total floor area of the plant and the area occupied by the equipment was presented

1. Mitten Horace L., "Functional Design of Fluid Milk Plants," Unpublished thesis for Master of Science degree, Michigan State College, 1948, p. 16.

2. Data taken from Ross, H. E., Care and Handling of Milk, Orange Judd Co., New York, 1939, p. 325. Ross obtained his data from United States Department of Agriculture, Washington, D. C., Bulletin 849, by Kelly.

by Grim (1). He suggests that the floor area required by the equipment should not exceed one-fifth of the total floor area.

The cost of the operation of the dairy plant depends partly on the investment in the building. Overbuilding has been the cause of several failures of dairy plants.

The building may be a one or multiple floor structure. Results from Babcock (2) show how the labor requirements increase as the number of floors increase. For one story buildings, 26.2 employees were required to handle 5,000 to 10,000 gallons of milk per day; for a two story building, 34.4 employees; and for three or more floors, 45 employees were required. It is recommended that all processing operations be done on one floor level. According to Witten (3), when handling 500 to 10,000 gallons per day, a plant having one story handled 361 gallons per employee; those with two stories handled 252 gallons per employee; and three stories, 235 gallons per employee.

Surveys by the United States Department of Agriculture agree closely with those reported from other sources. The average floor space for 24 plants processing over 20,000 pounds of milk was 2.84 square feet per gallon of milk (4).

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1. Grim, G. W., "Sanitary Construction in Dairy Buildings," Milk Plant Monthly, April, 1939, pp. 53-59.
2. Babcock, C. J., op. cit., p. 77.
3. Witten, Horace L., op. cit., p. 43.
4. Babcock, C. J., op. cit., p. 4.

The question of building for future expansion has always been a difficult problem to answer. The location of the plant and possible future markets are important factors to consider. Based on a survey of several plants, the safest approach for selecting the size of plant is to build the plant for the existing volume plus any foreseeable additional volume in the near future, and to arrange and locate the plant to permit expansion when necessary (1) (2). Flombergsson presented a diagramatic layout for dairy plants in Sweden which would allow for expansion about a central area (3).

D. Equipment

The over-all operational cost is affected by the cost of the equipment, the utilities and space required, and the labor required to operate it. Equipment manufacturers are faced with the task of developing machinery that will do better work at a lower cost. Commonly, the reduction of steam and water, electrical energy, and refrigeration are considered. However, the individual operation should be studied from the viewpoint of the person who is doing the work (4). The equipment should be designed to save the time and energy of the operator.

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1. Mitten, op. cit., p. 33.
2. ________ "Notes on Plant Layout," Cherry-Burrell Co., Chicago, Illinois, Mimeograph, November 2, 1949.
3. Flombergsson, F., "Discussion of General Principles for the Design of Dairies of Different Size and Production Capacity," Proceedings XII International Dairy Congress, Vol. 3, 1949, p. 573.
4. Barnes, R. M., op. cit., p. 72

It must be remembered that the cost of the equipment is usually not the most important factor, but rather how the unit fits into the economics of the system (1).

The usual practice in selection of equipment is to start planning with the bottle filler and work from there(2). An example by Thompson (1) lists the equipment for a 40-50 bottle per minute filling operation handling 600 gallon per hour in the following manner:

a. Number of vat pasteurizers -----------4
b. Size per unit --------------------------200 gal.
c. Preheating temperature ----------------130° F.
d. Clarifier or filter capacity------------5200 lb/hr.
e. Vat filling time ------------------------20 min.
f. Heating time in vats -------------------10 min.
g. Holding time in vats -------------------30 min.
h. Emptying time --------------------------20 min.

The development of the short-time pasteurizer has done much to make the straight-line flow more efficient as the milk is held for only fifteen seconds, and is forced to the next operation without a pump (3).

Because so much of the total plant labor is required for cleaning purposes, dairy equipment should be purchased after considering its ease of cleaning (4).

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1. Thompson, C. L., "Plant Operations and Efficiency," Milk Plant Monthly, May 1948, pp. 38-41.
2. Mitten, Horace L., "Milk Plant Layout," Milk Plant Monthly, March 1949, pp. 73-74.
3. MaGuire, Walter, "Plant Efficiencies Through Work Simplification," Milk Plant Monthly, Feb. 1947, p. 46.
4. Perkin, I. E., "Dairy Plant Housekeeping," Milk Plant Monthly, May 1949, p. 69.

E. Plant Layout

The layout of the equipment has a definite effect on the floor area and labor requirements.

The equipment may be laid out according to different flow arrangements, as L-shaped, U-shaped, and straight-line flow. The straight-line flow plan offers the following advantages (1):

a. Less confusion in working;
b. Gives workers feel of orderliness;
c. Less pipe running across flow lines;
d. Easier supervision.

In small and medium sized plants walking distance may be decreased by using the L-shaped flow pattern where workmen supervise several different pieces of equipment (2).

In laying out a milk plant, the historical developments and trends of the past can be used as a guide to planning the plants of tomorrow. Clement lists the following items for consideration when purchasing new equipment (3):

a. New equipment is more compact;
b. Milk handling equipment is faster, more automatic;
c. Fewer and simpler parts, designed for accessibility in cleaning;
d. Improvements in controls;
e. More effective utilization of alloys.

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1. Mitten, Horace L., "Functional Design of Fluid Milk Plant," Unpublished thesis for Master of Science degree, Michigan State College, 1948, pp. 56-57.
2. Loc. cit.
3. Clement, C. E., "Equipment for City Milk Plants," United States Department of Agriculture, Washington, D. C., Circular No. 99. Revised, June 1941, pp. 1-3.

Efficient layouts do not necessarily dictate that the products move in a straight-line, as a circle may be just as good if backtracking is eliminated (1).

One of the major objectives of plant layout is to utilize labor effectively. The following items have been suggested for reaching this objective (2):

a. Reduce manual handling to a minimum;
b. Minimize walking;
c. Balance machine cycles;
d. Provide for effective supervision.

An important function of plant layout is to plan for future expansion of the plant and for changes in equipment (3) (4). A statement which summarizes the ideas of several authors is written by Marks (5):

> "The ideal arrangement of equipment will permit the material to travel in the shortest path, yet coordinate manufacture with administration and inspection requirements."

The operation of a chemical plant more closely parallels the dairy plant than the mechanical industries. Perry (6) states that frequently the plant layout is so inefficient

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1. Caldwell, Eugene, "Check Layouts Before You Expand," Factory Management and Maintenance, July 1941, p. 57.
2. Apple, James, Materials Handling and Plant Layout, Ronald Press Company, New York, 1950, pp. 13-14.
3. Marks, Lionel, Mechanical Engineers' Handbook, McGraw-Hill Book Company, New York, 1941, p. 1559.
4. Apple, James, op. cit., p. 299.
5. Marks, Lionel S., loc. cit.
6. Perry, John, op. cit., p. 1835.

that as much as forty per cent of the workers time is spent needlessly. He lists four elements of task determination which should be studied to decrease the labor requirements:

a. Analysis of task elements;
b. Improvement of methods;
c. Stop watch readings;
d. Adjustment of stop watch reading for normal speed.

The plant should be properly lighted to aid the workmen in increasing the cleaning efficiency (1).

F. Materials Handling

Methods of handling the products in a plant are important factors to be considered in the design of the plant layout. It is difficult to divorce the two. Textbooks on the subject of plant layout devote at least half of their space to materials handling devices. The author can recall milk plants in which there were no conveyors, or chutes, and a minimum of piping and pumps. Much of the milk was handled in 10 gallon cans throughout the plant, and carried from one operation to the other. There are only a few plants of this type in use today.

In the dairy plant, with a glass bottle operation, the handling of the bottles should be held to a minimum to prevent breakage. The importance of this factor is shown in Table IV.

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1. Larkin, L. ., _op. cit._, p. 69.

Table IV. Effect of Transferring Bottles on Bottle Breakage (1)

Transfer of bottles	Plants	Bottles filled daily	Glass broken per 1000 bottles filled: Before washing	At discharge of washer	Total plant breakage
None	64	38,467	4.9	5.8	11.8
1	10	56,504	4.3	6.3	12.3
2	16	82,775	6.0	7.4	15.3
3	2	25,915	9.3	15.4	27.1

The pallet method of handling in the milk processing plant does not have wide acceptance as yet. The saving in labor requirements by use of palletized loads would be obtained mainly in loading and unloading the delivery trucks. Ordinarily, from seven to ten minutes are required for loading a delivery truck, in addition to about fifteen to twenty-five minutes for waiting. When using a palletized load with a fork-lift truck, two minutes are required for loading, and about five minutes for waiting (2) (3). There would be a saving of twenty to fifty minutes per day per delivery truck. A total labor saving up to about fifty per cent may be realized by using a fork-truck-pallet system. The cases can be stacked higher, thus increasing storage in cooler and bottle washing room if adequate head room is available.

1. Ross, H. E., Care and Handling of Milk, Orange Judd Company, New York, 1939, p. 322.
2. Heckendorn, L. F., "The Pallet System of Handling for the Milk Processing Plants," Milk Plant Monthly, June 1950, pp. 28-34.
3. Gemmill, Arthur, "They Call it the World's Most Modern Dairy," Food Engineering, July 1951, pp. 60-71.

Bottle breakage can be reduced thirty per cent by the pallet method of handling (1). A soft-drink manufacturer reduced the loading time eighty-two per cent by changing from manual to palletized truck handling (2).

The latest development in handling of milk from the farm is the use of bulk handling methods. The ten gallon cans are replaced by a tank truck. The milk is collected in holding tanks on the farm. The farm tank may be an insulated tank or a cold wall tank. When using the former, the milk is cooled over a surface cooler before it is placed in the tank. In the later type, the milk is cooled in the farm tank. Bulk handling of milk is being practiced in localities of the Western and Eastern states. A conventional milk truck normally hauls about 100 cans; the bulk tank on the truck which collects milk from the farm has a larger capacity, usually equivalent to 300 cans of milk. In the Los Angeles area the minimum pick-up that has proved economical is 250 gallons (3). An economical comparison of can and bulk handling is shown in Table V. In areas where the average producer sends less than 250 gallons to the dairy, skip-a-day pickup is practiced.

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1. Heckendorn, L. H., loc. cit.
2. ____________ "Trucks Loaded 50 Cases at a Time," Food Engineering, February 1949, pp. 173-175.
3. ____________ "Bulk Handling of Milk," Western Dairy Journal, June 1, 1952, p. 11.

The advantages to the dairy plant of bulk handling over the use of 10 gallon cans in the Los Angeles area are listed below (1):

a. Elimination of space required for receiving room and can storage at the dairy;
b. Elimination of raw milk cooling at the dairy, saving tons of refrigeration;
c. Elimination of can washing at the plant;
d. Sanitation at the farm is encouraged because of easier and faster job;
e. Elimination of milk can inspection and maintenance;
f. Sampling can be done at the farm;
g. Milk can be received faster (a 2,000 gallon tanker can be unloaded in 10 to 12 minutes);
h. Elimination of carrying inventory of new cans for producers;
i. Lower bacteria count because milk is cooled almost immediately and quality of milk is usually better.

This is illustrated in Table V.

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1. __________ "Bulk Handling of Milk," Western Dairy Journal, June 1, 1952, p. 11.

Table V. Unit Costs of Milk Collection in Cans and by Farm-Tank Tanker Systems (1)

	Can collection	Tanker collection
Truck fixed costs:		
Tractor and trailer for 350 cans	$2,733 per yr.	
Tractor and tanker for 3500 gal.		$2,775 per yr.
Truck operation cost	16.78¢ per mi.	16.22¢ per mi.
Driving time	2.727 min/mi	2.727 min/mi
Driver's time at ranch:		
Fixed, per ranch	2.12 min.	10.1 min.
Variable		
Handling cans	0.0457 min/gal	
Pumping milk		0.0167 min/gal
Plant time:		
Unloading cans	0.0237 min/gal	
Pumping milk		0.0167 min/gal
Receiving room:		
Per patron	0.261 min.	
Per gallon daily	0.0206 min/gal	
Washing tanker		25.3 min/trip

Table Continued

1. Perry, R. L., "Tank Truck Collection of Milk from Farms," Agricultural Engineering, September 1951, p. 480. Originally prepared by Giannini Foundation of Agricultural Economics, University of California, and reported in Mimeograph Report No. 91.

Table V Continued

	Can collection	Tanker collection
Can fixed and maintenance costs 10 yr. life, 2 cans per 10 gal peak capacity	0.0797¢/gal	
Farm tank fixed cost per year, based on 300 gal. insulated tank with pump (not cold wall)		$190 per yr.

G. Other Factors

A typical plant with a daily capacity of 26,000 pounds carried an investment of fifty dollars per gallon of daily capacity on a single-shift basis in 1948 (1).

Milk bottle breakage accounts for some of the plant costs. A milk bottle makes from 20 to 30 trips before being broken, and in 1933 tests one-third of the breakage occurred in the plant (2). In 1947, the average number of trips per bottle was 37. The decrease in breakage can be attributed to the fact that progress against breakage took place in the dairy plants (3).

It is difficult to evaluate many of the factors that enter into the selection and arrangement of equipment. One of these is the impression the plant has on the public. This includes display of machinery, arrangements for visitors, and cleanliness of the staff (4).

Often equipment arrangements cannot be carried out which are ideal from an engineering standpoint, because health regulations prohibit, often of necessity, the application of many engineering methods.

The shrinkage of milk is often used as an indication of the efficiency of an operation. In 1933 the shrinkage was

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1. Thompson, C. L., op. cit., p. 38.
2. Clement, C. E., loc. cit.
3. Babcock, C. J., op. cit., p. 29.
4. Dierckx, Leo, "Plans de Laiteries de Differentes Capacities et de Manufactures de divers Types du Meme Genre," Proceedings XII International Dairy Congress, Volume 3, 1949, p. 582.

reported as four per cent (1). Several plants now report a shrinkage of one per cent. Ross reported a shrinkage of 2.29 per cent in 1939 (2).

In 1933 the processing expenses (cost of putting the product in saleable form) consisted of 14.8 per cent of the total cost involved in the distribution of milk (3). A breakdown of the processing expenses is shown in Table VI.

Table VI. Costs Involved in Milk Processing (4)

	Per cent cost of total processing cost	Per cent cost of total expenses
Labor	41.0	6.06
Power and refrigeration	16.8	2.49
Repairs	5.05	0.75
Depreciation	7.23	1.07
Taxes and rent	2.70	0.40
Insurance	0.94	0.14
Automobile	1.62	0.24
Cartons, boxes	14.9	2.20
Bottle caps	2.76	0.41
Bottles	2.22	0.33
Supplies	3.37	0.50
Miscellaneous	1.41	0.21
Total	100.00	14.80

1. Clement, C. E., <u>loc. cit.</u>
2. Ross, H. A., <u>op. cit.</u>, p. 359.
3. Sommer, Hugo H., <u>Market Milk and Related Products</u>, Second Edition, Olsen Publishing Co., Milwaukee, 1946, p. 606.
4. Calculated from data presented in (3)

In 1943 a survey of 92 companies showed that the cost of producing a quart of milk in a paper container was 2.7 cents, and in the glass container, 3.58 cents, when produced in those containers only. When both glass and paper containers were used, there was a cost of 3.42 cents per quart for milk in glass and 4.025 cents per quart for milk in paper (1). At the present time many dairies charge one cent extra a quart for milk in a paper carton. Data are needed, based on present day prices, comparing the two operations with glass and paper.

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1. Bartlett, Roland W., The Milk Industry, Ronald Press Co., N. Y., 1946, p. 47.

III. OBJECTIVES

1. Develop mathematical relationships of the cost of each operation to enable the dairy plant operator to compare his costs to calculated costs of an efficient operation.

(a) Use to illustrate economic factors of equipment selection.

(b) Develop nomographs which plant personnel can use to determine quickly from equipment specifications, without an extensive mathematical background, the cost of a particular operation.

2. Determine standard times for various operations which can be used for arranging a work schedule.

3. Develop check lists which will enable equipment manufacturers to do a better job of design and will enable the plant operator to do a better job of equipment selection.

4. Show how the standard times may be used as an aid to dairy plant planning, incorporating

(a) Graphs and charts to compare different plans

(b) Plant layout to utilize space and arrangement of equipment for convenience of workers

(c) Proper placement of drains and water valves.

5. Discuss possibilities of improving equipment to conform to plant operations and plant workers.

IV. METHOD OF ANALYSIS

The method of obtaining the data for the operational costs will be discussed in this section. The operational costs consist of labor requirement, interest on investment, building requirement, and utilities. The actual calculations involved will be discussed in the next section.

Several companies plan their work schedule so that each individual worker has a clear, defined task to perform in a given time, with added allowances. The arrangement of the work with the aid of a work simplification plan has reduced the labor requirements as much as one-third (1). The technique of observing the path followed by each worker, timing his operations, and revising his work pattern, is called a multi-man analysis.

The next step in refining the operation is to time the separate parts of the operation, and to compare different workers and develop methods by which the labor requirements can be reduced, or made easier. This often entails an improved design of equipment. Certainly a worker would be more likely to accept work simplification methods, and develop techniques through his own initiative, if the equipment is

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1. French, Charles E., "Work Simplification in the Dairy Plant," Cherry-Burrell Circle, March-April 1952, pp. 3-7.

designed for his consideration. Cleaning dairy equipment is an outstanding example of an operation which should be simplified to make the worker's job easier.

Two methods of recording the time with a stop watch may be used. These are the continuous and snap-back methods. In the continuous method the stop watch runs continuously and readings are taken as desired at various intervals. In the snap-back method, the hand of the watch is snapped back to zero for each interval. The interval of time is called an element. The elements consist of work done in a time interval exceeding 0.03 minutes. Both methods were used at various times. With the continuous reading there is no danger of omitting part of the time, even though a small element may not be recorded. The continuous timing method gives the most satisfactory results on most operations (1). The snap-back method eliminates a lot of calculations, because the readings obtained are of an element of work, whereas the successive readings of the stop watch by the continuous method must be subtracted to obtain the elemental times.

Synthesized time standards are obtained by analyzing the data from several workers. The standards are established by taking time study data for several steps of an operation. The inefficient steps are eliminated, and the efficient steps combined to obtain an efficient method. This procedure was

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1. Morrow, Robert L., Time Study and Motion Economy, Ronald Press, N. Y., 1946, pp. 101-103.

used in this research for determining the time standard for can dumping, and sampling and weighing of milk in the receiving room. The synthetic time studies must have the following characteristics to be applicable to other situations (1),

- (a) Adequate written standard practice with well-defined element end points
- (b) Broken down into similar elements
- (c) Similar methods used
- (d) Similar equipment used
- (e) Homogeneous elements
- (f) Rated at a uniform rate of activity
- (g) Comparable allowances used.

The time studies were taken in several dairy plants to establish the length of time required for each operation. The time study data by Shiffermiller (2) was utilized on several operations. Several workers were observed, and the inefficient methods of carrying out the operation eliminated before using it as a basis for cost studies of the operation. It is often easy to note the better working techniques after observing in detail the worker's movements.

Possibilities for improvement in different plants were observed while making the studies and recorded in the check lists. No attempt was made to get the worker to adopt different methods.

An allowance of twenty per cent was made above the basic time at a normal pace. The allowance consists of five per cent for personal needs, five per cent for delays, and

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1. Mundel, M. E., <u>op. cit.</u>, p. 364.
2. <u>Loc. cit.</u>

ten per cent for fatigue. This agrees closely with the findings of a questionnaire answered by several companies (1).

The following items are commonly included in allowances (2)

(a) Delays during which the operator is idle because of machine breakdown.
(b) Preparing work essential to maintain flow of work.
(c) Maintenance and lubrication.
(d) Idle time during which operator is waiting for machine.
(e) Product ultimately rejected but on which normal work is done.
(f) Operator must work slowly because of slow flow of materials.
(g) Production reduced because of added manual work--as loosening can lids by dumper.
(h) Personal time.
(i) Fatigue.
(j) Incentive factors.

Data for the area requirements of the equipment were obtained from the catalogues of the companies manufacturing the dairy equipment. Several pieces of equipment of the same size were averaged together to obtain representative values of the building space required.

The cost prices of the equipment were obtained from the sales representatives of various manufacturers. The basic prices were obtained so that the costs would be as uniform as possible. The accessories commonly purchased with the equipment were added to the base prices. The same basis was used for comparing different pieces of equipment.

As discussed under the previous section, with regard to time studies, industries are usually grouped into either

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1. Morrow, Robert L., Op. cit., p. 81
2. Presgrave, Ralph, The Dynamics of Time Study, McGraw-Hill Book Company, N. Y., 1945, p. 195.

continuous or repetitive operations. The dairy industry would come under the former division. However, there are several operations in the milk plant which are repetitive for the worker. These are dumping, weighing, and sampling of milk, placing filled bottles into crates, placing bottles into the bottle washer, and stacking filled bottle crates in the storage room. The cleaning operation could be thought of as a repetitive operation when it is considered over a long period of time. Studies were made on both types of operations.

The question of selecting the operation which offers the most promise for further study frequently arises. Generally, the operations most promising for improvement are those which are costly, those which require considerable labor, and those which are repetitive in nature. An example of a farming operation vividly illustrates this item. An analysis of harvesting ensilage with a forage harvester showed that the amount of time used in unloading the ensilage was 0.65 man-hours per ton, which was longer than the time required for harvesting and hauling the hay (1). The time consuming operation was studied, and equipment developed, so that the unloading time was reduced to 0.09 man-hours per ton.

To facilitate plant layout and equipment arrangement, information was assembled which can be used to plan the

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1. Davidson, J. B., C. K. Shead, E. J. Collins, "Labor Duty in the Harvesting of Ensilage," Agricultural Engineering, September 1943, p. 293.

movements and work schedule of each worker. By charting the path of each worker, the efficiency of labor utilization can be ascertained. The equipment can then be moved to positions which may appear to be a more efficient layout. By applying the available information, a tangible means may be used for comparing equipment locations.

The efficiency of labor utilization is paramount in plant planning. However, a minimum floor area, and short utility lines are desirable.

A visual means of studying the plant layout is very helpful. Scale models were used in this study. A scale of 1/4 inch equal to one foot was selected for the models and floor plan because it is the standard scale usually used for plant layout (1). Block models were developed for each piece of equipment. In most plant planning, the worker stands in one place or works in a limited area during his work. Consequently, the flow of the product receives major attention. In a dairy plant, the worker must move from work area to work area; therefore, the path of the man must receive primary consideration, with the product receiving secondary consideration. In a dairy plant, the flow of the product will be considered indirectly in minimizing the labor requirements because the pipe line requires considerable cleaning time.

A grid is used as a background for the floor plan. The grid is laid off in one-fourth inch squares to aid the

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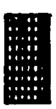
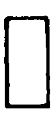
1. Apple, James, op. cit., p. 229.

observer in noting the distance between equipment and various operations. The distance between lines of the grid used for the floor is one foot.

In evaluating a plant layout, an activity chart was used. An activity chart provides a graphic method of illustrating the individual steps of the work performed by men and/or machines (1). The activity chart may be broken down into right and left hand movements, and may indicate the time and distance involved in each individual step. The symbols in Table VII are used to illustrate the individual steps.

Table VII. Symbols for Activity Chart (2)

Symbol	Name	Man Activity	Machine Activity
	Operation	Doing something at one place	Machine working
	Operation	Not used	Man operating machine
	Quantity determination	Person must determine quantity of item present	Not used
	Inspection	Inspection of product or container or equipment	Not used
	Delay	Idleness	Machine is idle

Each step in the present operation and proposed operation can be criticized with respect to the check lists

1. Mundel, M. E., op. cit., p. 171.
2. Adapted from Mundel, op. cit., p. 186.

provided. A new chart can then be developed for the proposed on the basis of the check list suggestions and rechecked.

The handling of the cans, milk, etc., in the plant should be studied to see if the cost can be reduced. The materials handling for different equipment locations can be analyzed by collecting the data to complete Table VIII.

Table VIII. Analysis of Handling of Products

Method	Distance in feet	Number of units moved	Number of persons	Time in hours

In order to utilize the data fully it is necessary to anticipate production, apply principles of efficient handling, and prescribe changes. Each of the following handling methods should be investigated for each of the items handled from the time of entry into the plant until they leave the plant:

(a) Manual
(b) Conveyors, chutes
(c) Pipe line
(d) Trucks and carts
(e) Trolley and monorail
(f) Pallets, lift trucks
(g) Elevators, hoists

V. CALCULATIONS

The method used for calculating the data included in Tables V to XXVII in the Appendix, and illustrated in numerous figures in the discussion of results, is discussed in this section. All equipment costs are based on 1952 prices. The figures presented in later sections on operational costs apply specifically to new equipment. When the new cost is less, the ensuing cost is less. The operational costs of used equipment can be calculated by use of the charts presented in the later section on equipment selection.

A. Fixed Costs

1. Taxes, insurance, and licenses. The taxes, insurance and license costs were figured at three per cent of the original cost of the equipment and building. In 1930 the federal and state taxes amounted to 0.5 per cent of the investment (1). A survey of ninety-two companies in 1943 showed the annual taxes, insurance, and license costs to be about one eighth of the building and equipment depreciation(2). This would amount to about one per cent annually of the first cost of the building and equipment. Taxes are often as high as five per cent of the investment (3). At the present time

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1. Eidman, F. L., Economic Control of Engineering and Manufacturing, McGraw-Hill Book Company, New York, 1931, p. 29.
2. Bartlett, Roland W., op. cit., p. 46.
3. Grant, Eugene L., Principles of Engineering Economy,

insurance rates are higher than those reported in previous surveys, and more money is required for licensing and inspection. With an increase in the rate of taxation, and recognizing that the tax evaluation is often one-half of the first cost, a value of three per cent of the original equipment and building cost was chosen.

2. Life of equipment. When calculating interest and depreciation it is necessary to estimate the life of the equipment. The calculations in this dissertation were based on Federal Tax Guide Reports (1), as shown in Table IX.

Table IX. Estimated Life of Dairy Equipment

Chain conveyor	15
Roller Conveyor	14
Can Dump	17
Weigh Can	12
Milk Scales	18
Straight-away Can Washer	17
Rotary Can Washer	12
Piston Milk Pump	15
Centrifugal Milk Pump	18
Sanitary Piping and Fittings	14
Clarifier	14
Surface Cooler	12
Internal Tube Cooler	18
Coil Vat	20
Storage Equipment for Receiving	18
Glass Lined Milk Storage	20
Coil Heaters	20
Forewarmer	12
Cream Separators	16
Homogenizer	17
Pasteurizer	15
Bottle Soaker Unit	15
Bottle Capper	17
Carton Machine	15
Ammonia Compression System	22
Brine System	15
Other Receiving Equipment	15
Milk Bottle Cases	4

1. Federal Tax Guide Reports, Commerce Clearing House, Inc., 1948, pp. 286-288.

3. Depreciation and interest. The annual depreciation of most equipment is figured by the straight-line method in which the salvage value of a piece of equipment is subtracted from the initial cost and the difference divided by the life of the equipment.

In figuring equipment costs the interest should be included because the money is being used. Otherwise, the money could be invested in stocks or bonds where it would be expected to give a financial return. The common method of calculating the annual interest cost is to multiply the interest rate times one-half of the original value of the investment, or times one-half of the difference between the original and salvage value of the equipment. The interest rate varies with the size and type of investment. The large investor expects about two per cent interest; whereas, the small investor expects about six per cent interest (1).

The straight-line method of depreciation is an approximate method, but the simplest. The annual cost of capital recovery which includes the depreciation and interest may be calculated by exact means (2). The exact capital recovery factor is $\left(\frac{i\ (i + 1)^n}{(1 + i)^n - 1} \right)$, in which n is the estimated life of the equipment in years, and i is the interest rate. By multiplying the first cost of the machine by the capital

1. Grant, Eugene L., Principles of Engineering Economy, Ronald Press, N. Y., 1950, pp. 71-84.
2. Ibid., pp. 86-87.

recovery factor, the annual payment necessary to pay for the equipment with interest is obtained, if there is no salvage value. Table X gives the capital recovery factors for four per cent interest. Values of the capital recovery factor for other rates of interest are available (1).

Table X. Capital Recovery Factor for Uniform Annual Depreciation and Interest for an Annuity whose Present Value is one with Four per cent Interest

n years	CRF	n years	CRF
1	1.0400	11	0.1141
2	0.5302	12	0.1066
3	0.3603	13	0.1001
4	0.2755	14	0.0947
5	0.2246	15	0.0899
6	0.1908	16	0.0858
7	0.1666	17	0.0822
8	0.1485	18	0.0790
9	0.1345	19	0.0761
10	0.1233	20	0.0736

Many of the pieces of dairy equipment have an appreciable salvage value because they contain valuable materials of construction such as stainless steel, copper, motors, and other accessory parts such as switches and control devices. A salvage value was selected for each piece of equipment, ranging from zero to ten per cent, depending on the item. When a salvage value is anticipated, the annual capital recovery is calculated as follows (2):

1. Ibid., pp. 596-613.
2. *Ibid.*, p. 89.

Capital Recovery = (First Cost - Salvage Value) (CRF)
+ (Salvage Value)(Interest Rate)

The difference between the straight-line and accurate method of calculating the depreciation and interest is not great for equipment with expected life of twenty years or less, considering the assumptions which are made for taxes, insurance, repairs, etc. For a large investment, over a long period, the difference is large, as is shown by Table XI. The straight-line method was used for the calculations in this research so that the results could be obtained as simply as possible and still be as accurate as the data on which the calculations are based. The methods used in the calculations have been kept as simple as possible so that they can be used by interested dairy personnel who might not have an extensive mathematical background.

The annual interest charge is the product of the interest rate and the average investment. The average investment is equal to one-half of the sum of the first cost and the salvage value. This method was used for the calculations in this dissertation. Another, slightly more accurate method for calculating the average interest is as follows (1):

$$\text{Average interest} = (\text{first cost} - \text{salvage value})\left(\frac{i}{2}\right)\left(\frac{n+1}{n}\right) + (\text{salvage value})\,(i)$$

1. *Ibid.*, p. 95.

Table XI. Annual Depreciation and Interest on an Investment of $1000 at 4 per cent Interest by
(a) straight-line depreciation plus average interest
(b) accurate method using Capital Recovery Factor

Years	(a)	(b)	per cent difference
5	220.00	224.60	2.0
10	120.00	123.30	2.7
20	70.00	73.60	4.9
30	53.40	57.80	7.7
40	45.00	50.50	11.0
50	40.00	46.60	14.0

4. Building costs. The cost of the building was calculated for each operation in the dairy. In a few cases, added building space is required to decrease the labor requirement, as exemplified by the storage tank design. The saving in labor was compared to the additional cost of providing more building space.

In 1930 building costs varied from $0.25 to $1.10 per cubic foot for brick construction, with the more expensive estimate for stores (1). In 1946 the cost of a mercantile building was estimated at $0.70 per cubic foot (2).

Most dairy plant equipment is located in processing rooms which have a height of twelve feet. The volume occupied by a piece of equipment was calculated on the basis of a room of twelve foot high (3), at $1.50 for each cubic foot, or $18.00 for each square foot. This estimate was

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1. Eidman, F. L., op. cit., p. 67.
2. Pulver, H. E., Construction Estimates and Costs, McGraw-Hill Book Company, N. Y. 1947, p. 483.
3. Mitten, Horace L., op. cit., p. 30.

obtained by calculating the cost of constructing a dairy with a capacity of 60,000 pounds per day. The estimate agrees closely with the value obtained by applying the 1930-1950 building indexes to the building costs of 1930 (1). Building depreciation is assumed to take place over a fifty year period (2). No salvage value is allowed for buildings because technological changes often decrease the value of a structure to such an extent that it is often a liability rather than an asset.

5. Repairs, maintenance, supplies. The repair, maintenance and supply cost was considered to be four per cent of the first cost of the equipment. It is true that the repair cost is expected to be low when the equipment is relatively new, and large after the equipment has been used. The repair cost will vary considerably with different pieces of dairy equipment. Data are not available for individual pieces of equipment. In boiler operation, one to two per cent of the original cost is required for repairs, maintenance, and supplies (3). However, this cost would be expected to be higher for dairy equipment which operates in moist conditions, constantly being assembled and disassembled, and requiring considerable soap solution for cleaning. The repair and maintenance supplies for the whole plant

1. See Appendix Table III for economic indexes.
2. Federal Tax Guide Reprt. op. cit., p. 274.
3. Perry, J. H., op. cit.

amounted to about one-half of the depreciation of the buildings and equipment in a survey of 92 companies in 1943 (1). On this basis, a value of four per cent of the original cost of the equipment approximates the normal plant charge for repairs and maintenance.

The expense for repairs would be expected to depend to some extent on use, and these costs might be included in the operating costs instead of fixed costs. In the case of farm tractors where the equipment is used a reasonable amount under average conditions, there is justification for including repairs as a fixed cost (2). The same assumptions can be made for dairy equipment which is used with more regularity and care than much farm machinery.

B. Operating Costs

The costs for electricity, water, steam, and refrigeration will vary considerably in each plant, depending on the quantity used, and the location and operation of the plant. The calculated values for the utilities were used throughout the calculations, so that all equipment would be on the same basis. These figures will give an accurate relationship for comparing equipment, but can only be used as an average value, or as a guide for figuring plant costs.

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1. Bartlett, Roland W. op. cit. p. 46.
2. Barger, E. L., W. M. Carleton, E. G. McKibben, Roy Bainer, Tractors and Their Power Units, John Wiley and Sons, New York, 1952, pp. 451-452.

1. Electricity. All electrical energy costs were figured at $0.0125 per kilowatt-hour. It was not possible to place meters on all the pieces of equipment employing electric motors. Data were taken from the manufacturer's specifications for the equipment, and converted to kilowatt-hour values based on motor power requirements of induction three-phase motors as established by Ibbetson (1), and the length of time the motor was in operation. No attempt was made to calculate power requirements for controls, the cost of which is small, and which is included under the cost of supplies.

2. Water. The commercial water rates as of April 1,1952 Lansing, Michigan, were used as the basis for the water costs,

25¢ per 100 cu. ft. for first 500 cu. ft.
12¢ per 100 cu. ft. for next 1500 cu. ft.
11¢ per 100 cu. ft. for next 3000 cu. ft.
9.5¢ per 100 cu. ft. for all over 5000 cu. ft.

A typical 25,000 pound per day dairy uses about 60,000 cu. ft. of water per month (2). Based on these values, the average cost of water in different sizes of plants is as follows:

20,000 lb. per day dairy, $0.10 per 100 cu. ft.
40,000 lb. per day dairy, $0.099 per 100 cu. ft.
60,000 lb. per day dairy, $0.098 per 100 cu. ft.
80,000 lb. per day dairy, $0.097 per 100 cu. ft.
100,000 lb. per day dairy, $0.096 per 100 cu. ft.

3. Steam. Most of the references available which give the cost of boiler operation were written at least twenty

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1. Ibbetson, W. S., Electrical Power Engineers' Handbook, Chemical Publishing Company of New York, Inc., N. Y. 1939, p. 134. (Appendix Table IV)

2. ________ "Operating Time Schedule," Planning Plants, Sales Engineering, Cherry-Burrell Corporation, Chicago,

years ago, or gave costs based on fuel costs only. Two methods were used for determining the steam cost, based on different references, and averaged to establish a reasonable cost for steam.

A plant investment of eight dollars per pound of steam making capacity per hour is required (1). On the basis of a 100 boiler horsepower (BHP) boiler, or 3,450 pounds of steam per hour, the investment would be $27,600. All fixed costs in a boiler plant are figured at twelve per cent of the investment (1), or $3312. The daily costs of operation of the boiler are as follows:

Fixed Costs	$9.10
Labor	10.90
Electricity	1.00
Water	2.00
Fuel	15.00
Total Daily Cost	$ 38.00

The total cost is calculated on the basis of providing 13,800,000 Btu. per day. The total cost would be $2.75 for 1000 Btu. or one pound of steam.

A cost of $2.25 per pound of steam was quoted by Gaffert (2) in 1946 for a high capacity boiler above 1000 boiler horsepower. Correcting this figure on the basis of the 1950 Economic Index for fuel and power cost (3), the

1. Perry, J. H., *op. cit.*, p. 1631.
2. Gaffert, Gustaf A., *Steam Power Stations*, McGraw-Hill Book Company, New York, 1946, p. 506.
3. ______ *The Economic Almanac, 1951-2*, The National Industry Conference Board, 247 Park Avenue, New York 12, New York, p. 110. (See Appendix Table III).

equivalent charge for one pound of steam in 1950 was $3.32. The average of these two values of $2.75 and $3.32 is $3.03 which was used for all steam cost calculations. A boiler efficiency of eighty per cent was assumed in determining fuel costs.

Unless other data were available for particular pieces of equipment eighty-three per cent of the heat output of the boiler was assumed to be converted into useful heating energy at the equipment. This assumed efficiency is not unreasonable when the condensate is returned to the boiler.

The cost of steam is considerable higher than that given by many references for plants with capacities above 10,000 pounds per hour capacity. Values between $0.40 and $0.70 per pound of steam are reported (1) (2).

The steam requirements for the various pieces of equipment were calculated from published data and manufacturer's recommendations. The time required to accomplish the heat transfer was evaluated from the U (3) values of the different pieces of equipment. The U values were used for comparing the heating times for the batch processes. For the continuous processes with low U values, such as heaters and coolers, the heating surfaces would have to be larger to give the same capacity as equipment with high U values. The larger heating surfaces would be reflected in higher initial costs.

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1. Perry, J. H., op. cit., p. 1633.
2. Reflected in data, Skrotzki, B. G., and W. A. Vopat, "Applied Energy Conversion," McGraw-Hill, N. Y., 1945, p. 347.
3. See Glossary for explanation of U factor.

4. Refrigeration cost. In 1943 the cost of operating a compressor was \$0.53 per ton-day (1), excluding cost of rental. The operating cost includes a labor cost of \$0.08 per ton-day, which will vary considerably with the size of the system. Corrected on the basis of the 1950 Economic Index (2) the labor charge is \$0.12 per ton per day in 1950.

An investment of \$1500 per ton is required for a refrigerating system (3). The annual fixed cost figured at nineteen per cent of the first cost (4) is \$285 per ton, or \$0.78 per ton per day. A total cost of \$1.35 per ton-day is gotten by adding \$0.78 for the fixed cost, \$0.45 for the operating cost (calculated by subtracting \$0.08 from \$0.53), and \$0.12 for the labor cost. This is equivalent to an hourly cost of \$0.056 per ton of refrigeration. The total cost will vary considerably with a change in plant size. Based on a comparison of operating costs for ice-making equipment of different sizes (5), Table XII gives the cost of operating the refrigeration systems of different sizes of dairy plants.

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1. McCoy, Daniel, Editor, Refrigerating Data Book, 3rd edition American Society of Refrigeration Engineers, 1951, p. 641.
2. The Economic Almanac, loc. cit.
3. Perry, J. H., op. cit. p. 1631
4. Moyer, J. A., Refrigeration, McGraw-Hill Book Company, New York, 1928, p. 255.
5. Motz, William H., Principles of Refrigeration, Nickerson and Collins Company, Chicago, Illinois, 1926, pp. 590-616.

Table XII. Cost of Operating Refrigeration Systems in Different Sizes of Dairies

Daily Capacity Pounds	Refrigeration Cost Dollars per Ton-hour
80,000	.0563
60,000	.0563
50,000	.0575
40,000	.0605
30,000	.0643
20,000	.0675
15,000	.0766
10,000	.0860

The most efficient method of refrigeration in a dairy is by means of an ice builder sweet water system. The initial cost of one small compressor and an ice builder tank is the same as the total cost of a larger direct expansion system (1). The total operating cost, however, of an ice builder system is much less than for the direct expansion system because the demand rate is much less. The energy charge is theoretically slightly more, but practically the energy charge is about the same because of the inefficiency of the compressor motor from starting and stopping caused by plant delays. The sweet water system was considered to operate at sixty per cent of the electrical cost as the direct expansion.

Water is often used to do part of the cooling in the plant. It is usually necessary to circulate from three to six times as much water or sweet water as milk to remove heat.

1. Kampman, W. J., "Principles of Mechanical Refrigeration," Mimeograph, University of Illinois Extension Course, 1949, p. 15.

The quantity of refrigeration required to accomplish the cooling in different types of cooler was calculated from the efficiency and the U values.

5. Labor costs. All labor costs were figured at $1.75 per hour. Any time a piece of equipment has a capacity that required the attention of a man, but only the actual physical labor of one-half a man in a later operation, the wasted or inefficiently used time was charged to the improperly sized machine. In conventional analysis, if the man is not kept busy, the implication is that he is not doing his share. Some of the evils of time study can be eliminated if the lack of work of the employee is attributed to the machine which he is attending. The fault then lies with the engineer for improperly designing the equipment. Penalizing the incorrectly sized machine aids in selecting the proper piece of equipment on the basis of the operational analysis.

Even though equipment may not be designed to utilize fully the worker's time and attention, an efficient plant operator will organize the work schedule to utilize labor fully. Such a procedure requires additional traveling between equipment for the worker, and is not efficient if it can be avoided. On the other equipment, such as a can washer which is too small, the worker could not possibly utilize a small fraction of the delay time when the equipment is slower than the worker.

The cleaning time of each piece of equipment includes the disassembly and assembly of the parts.

Dairy equipment which is normally thought of as being automatic in operation, as a heater, high-temperature short-time (HTST) pasteurizer, cooler, etc., had a supervisory labor charge added to the cost. The supervision labor was determined on the basis of a percentage of the total operating time of the equipment.

VI. DISCUSSION OF RESULTS

A. Receiving Room Operations

1. Dumping. The rate of dumping the ten gallon milk cans is the key to the various operations in the receiving room. The size of weigh can, receiving tank, and capacity of the can washer should be determined by the speed at which the operator can dump the milk cans.

In the one-man receiving operations one worker dumps the milk cans, weighs and records the weight of the milk, samples the milk, and releases the milk from the weigh can. The equipment in a one-man dumping operation is illustrated in Fig. 2.

Two different arrangements for the workers were used in the two-man receiving rooms. In one work arrangement, one worker dumped the milk cans, weighed and recorded the weights, and released the milk from the weigh can, while the other worker sampled the milk from the weigh can. In another work arrangement, one person dumped the milk while the other worker weighed, recorded the weight, sampled the milk, and released the milk from the weigh can.

Two different work arrangements were used in the three-man receiving rooms. In one work arrangement one person dumped, one person weighed, recorded, and released the milk from the weigh can, while the third person sampled. In another three-man work arrangement, one man loosened lids, one man dumped, and one man weighed, sampled, and released the milk from the weigh can.

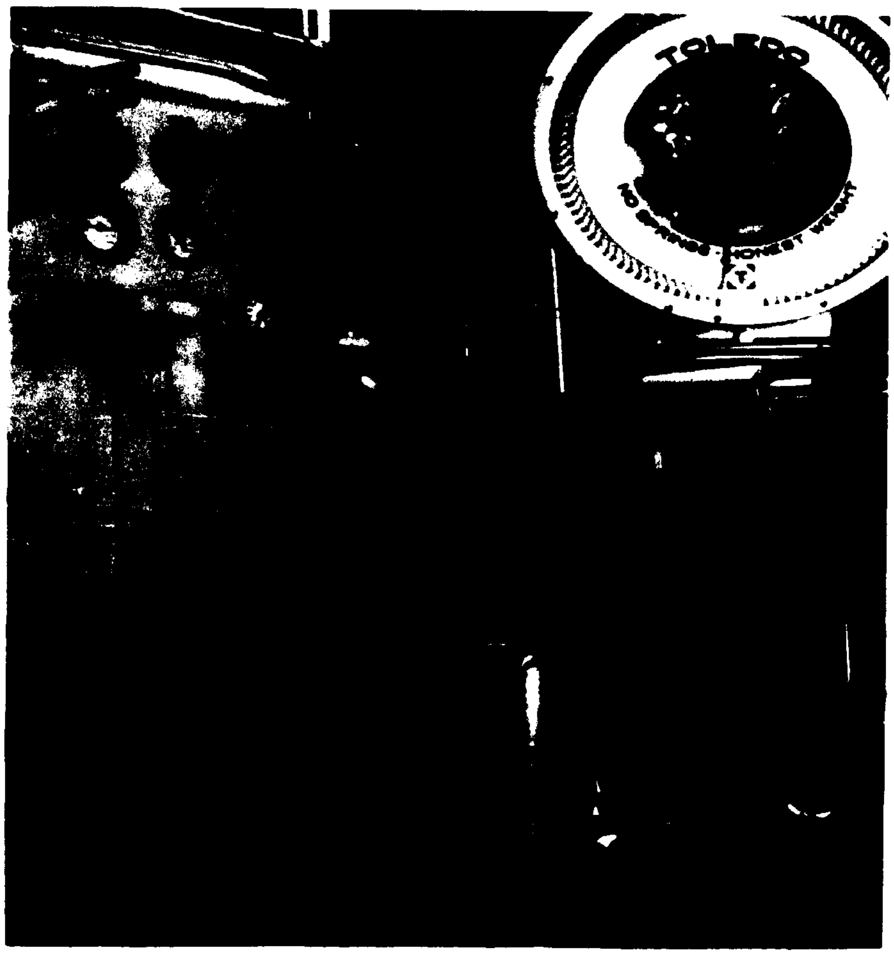


Fig. 2. Equipment in a Typical One-man Dumping Operation

The rate of dumping the cans is influenced by the number of cans per producer, particularly for the one-man operations and the multiple-man operations where there is a delay for weighing and sampling. The two- or three-man operation can only be justified if the subsequent processing operations are slowed down or stopped because of a slow rate of dumping, which might occur in a one-man operation.

The average of several hundred readings in various dairies is used for the basis of the standard time for receiving room operations in Table XIII.

Table XIII. Standard Time for Receiving Room Operations
(Dumper checks quality, unless otherwise specified)

	Mins.
A. For one-man operation	
Dumping time per can, 0.10 min.	
Weighing, recording weight, emptying weigh can,	0.13
Sampling time,	0.07
B. For two-man operation	
(1) One man dumping; one man weighing and sampling	
Dumping time per can,	0.091
Dumping delay time for weighing and sampling between producer lots	0.06
(2) One man dumping and weighing; one man sampling	
Dumping time per can,	0.10
Weighing time for dumper,	0.13
C. For three-man operation	
(1) One man dumping, one man weighing, one man sampling	
Dumping time per can	0.091
Delay for draining weigh can between producers lots,	0.02 to 0.06
(2) One man loosening lids and checking for quality, one man dumping, and one man weighing and sampling, same as B (1) above	

The time for weighing may be decreased from 0.13 to 0.095 minutes by using a print-weigh device on the scales. At 1952 prices, with labor at $1.75 per hour, approximately 4.8 years would be required for a 40,000 pound per day dairy to pay for the added cost of a print-weigh device. The possibilities of decreasing weighing errors and the ease to the weigher should be considered in addition to the time saving when considering the purchase of a print-weigh device.

For the maximum dumping rates to be attained, the milk cans must be available to the dumper. The trucker cannot be expected to unload cans steadily and loosen lids to supply the dumper with cans at a rate exceeding seven cans per minute. In order for the faster operations to be successful, the truckers must help each other in unloading the trucks and loosening the lids. In a three-man receiving operation where a worker is inside the plant loosening lids and checking odors, as outlined in C (2) of Table XIII, the worker's productiveness would be increased if he were placed outside the receiving room and assigned the task of setting the cans on the milk can conveyor, loosening lids, and checking for odors. Improving the receiving room operation, where the worker is actually idled, while being envied by his co-workers, may result in unsatisfactory labor relations. In such a case, changes should be planned, but not carried out, until an appropriate time.

The dumping procedure has much to do with the rate of emptying the cans, recording weights and sampling, particularly for a one-man operation. The ease of carrying on the work and preventing milk loss by providing adequate time for drip are important.

There was no correlation between the rate of dumping the cans and the amount of milk in the cans. It was found that there was an average of 60 pounds of milk in a can, except during the spring months when the weight of milk per can was 72 pounds.

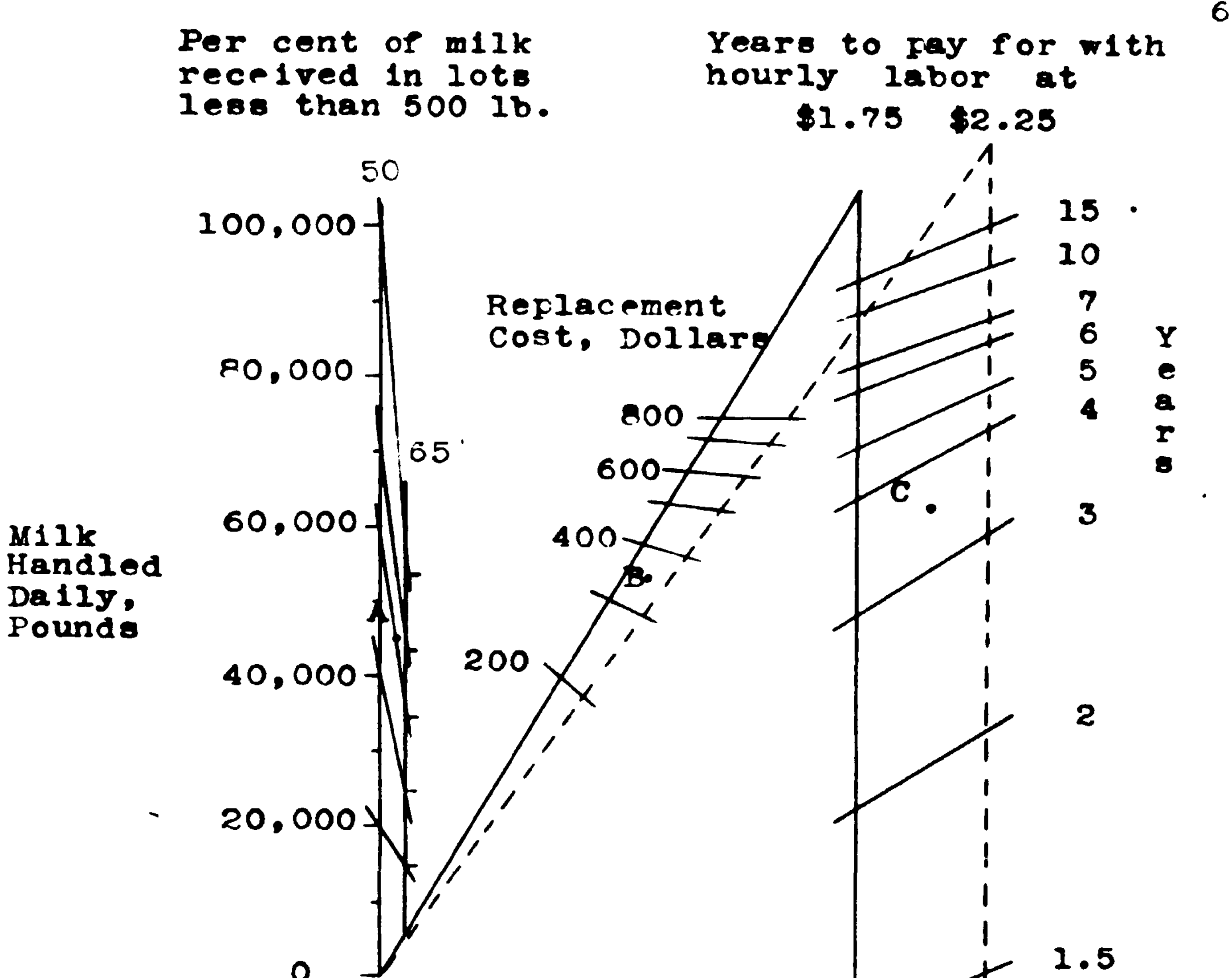
If the arrangements in the dairy are such that the trucker does not loosen the lids, the dumper should loosen a series of can lids around the conveyor, dump the cans, and repeat, rather than loosen the lids individually as the cans come to the dump rail. The time required to loosen only one lid is 0.07 minutes; whereas, the average time required to loosen each lid while walking around the conveyor where several lids are loosened is 0.02 minutes.

2. Weigh can and receiving tank. Weigh cans are normally manufactured in 500, 750, and 1000 pound sizes. Similarly, the weigh can may be supported by a 500, 750, or 1000 pound scales, predominately of the Toledo scale type. The 750 or 1000 pound scales may be used for the 500 or 750 pound weigh cans.

A question is frequently raised by dairy plant operators as to how large a weigh can should be used, or the practicability of replacing a 500 pound with a 750 pound weigh can, or larger.

The size of weigh can should be determined according to the amount of milk handled daily and the number of large producers. If all the milk producers shipped less than 500 pounds there would be no advantage in using a weigh can larger than 500 pounds. As the per cent of producers over 500 pounds increases, and as the number of pounds of milk handled daily increases, the value of the labor saved through dumping, increases. Fig. 3 relates the size of dairy in pounds per day, per cent of producers less than 500 pounds, and the cost of replacing (including installation) the 500 pound weigh can with the 750 pound weigh can to the years required to pay for the added cost by the labor saved. This chart may be used for selection of a new weigh can on the same basis. Fig. 3 may be used for a one-, two-, or three-man operation. Although the actual length of time saved between weighings is less for a two-man operation there are two or three men involved in the time saving, making the total saving practically the same as in the one-man operation.

In the one-man receiving room, there is sufficient time for the weigh can to drain while the operator is recording the weight of the milk. In the two- and three-man operations, the speed of dumping is controlled by the time required to drain the weigh can. It is necessary for the person weighing



Example: A dairy receiving 60,000 lb. of milk daily with 60 per cent of the milk in less than 500 lb. lots. The replacement cost for a 750 lb. weigh can is $350. Labor is $2.00 an hour.

Solution: Locate A as shown above, determined by size of dairy and size of shippers. Locate B, which is determined by the replacement and labor cost. Along line AB locate C at the appropriate hourly labor charge, and read 3.6 yr. to pay for the 750 lb. weigh can.

Interpretation: Even though the normal life of a weigh can is 12 yr. the dairy should plan to pay for the new equipment by the labor saving within 6 yr. to avoid the possibility of loss through obsolescence.

FIG. 3. CHART FOR DETERMINING YEARS REQUIRED TO OFFSET ADDITIONAL COST OF 750 LB. WEIGH CAN IN COMPARISON WITH A 500 LB. WEIGH CAN BY LABOR SAVED.

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the milk to observe the milk draining out of the weigh can or to observe the hand on the scales before closing the valve after each weighing.

In all the plants studied, the milk was released from the weigh can through a valve controlled by a manual or air operated hand lever. The lever was again manipulated to close the valve. The speed of the operation could be increased and the work of the operator lightened with a foot operated air valve.

The time for draining the weigh can varied considerably as shown by Fig. 5. This variation could be eliminated by a self-closing valve. The average saving in time would be 0.02 minutes per weighing on one-half of the weighings. A 100,000 pound per day dairy would have an average of 330 weighings per day. The yearly saving would amount to (3.3 minutes per day) x (365 days per year) x (3 men) x (1 hour per 60 minutes) or 60 hours. At 1952 prices, three years would be required to pay for the additional cost ($315) of the self-closing feature of an air-operated valve.

Sampling is usually done manually with a small hand dipper, but can be done with a vacuum sampler. There should be no obstructions to sampling. (See Fig. 4). The sampling time was found to be 0.07 minutes by either method. The vacuum sampler is often given credit for quicker sampling than the manual dipper method. In fact, because of poor techniques, the vacuum sampler often requires as much as 0.05

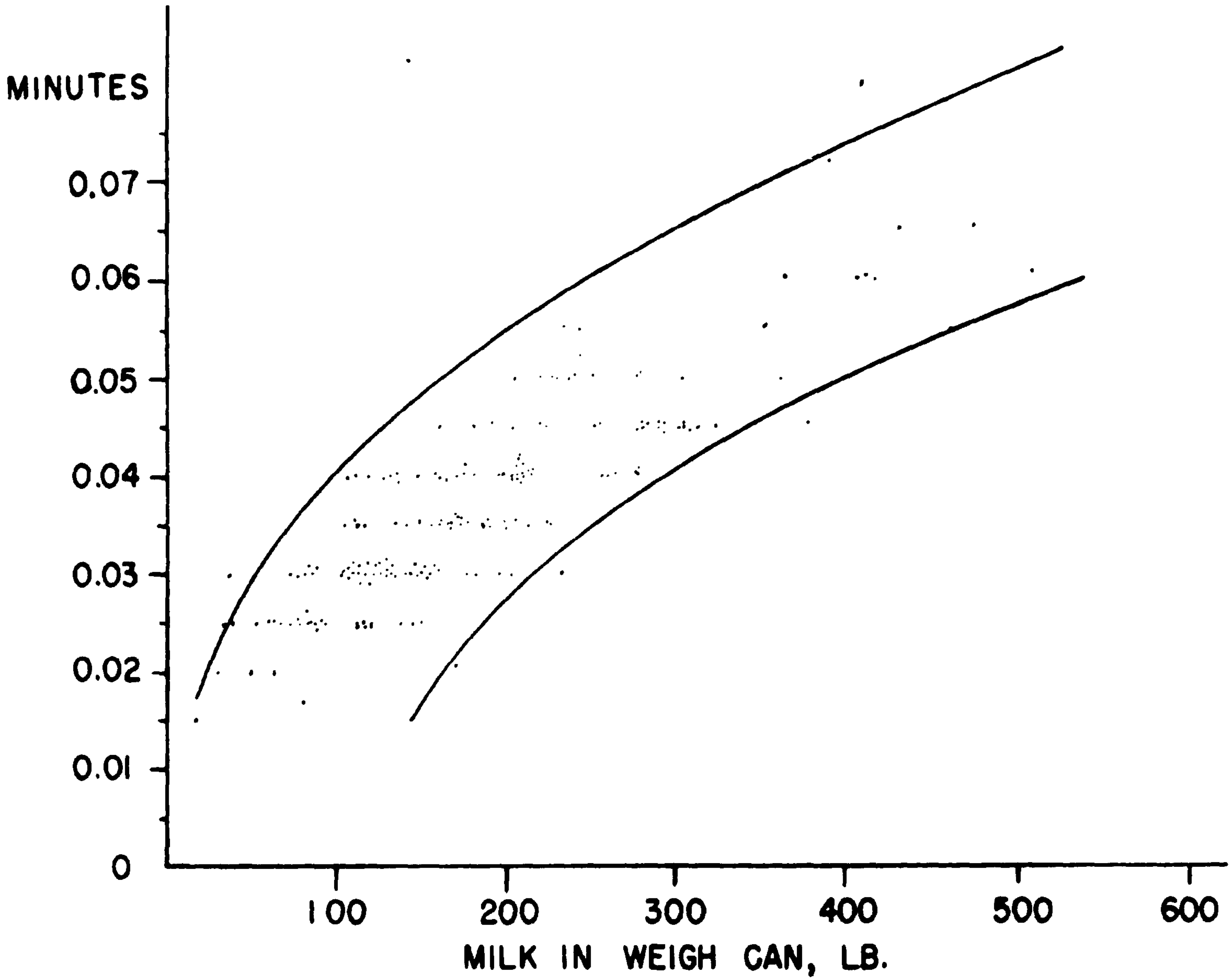

FIG. 5. TIME OPERATOR PERMITTED 750 LB. WEIGH CAN WITH 14 INCH DIAMETER OUTLET VALVE TO DRAIN

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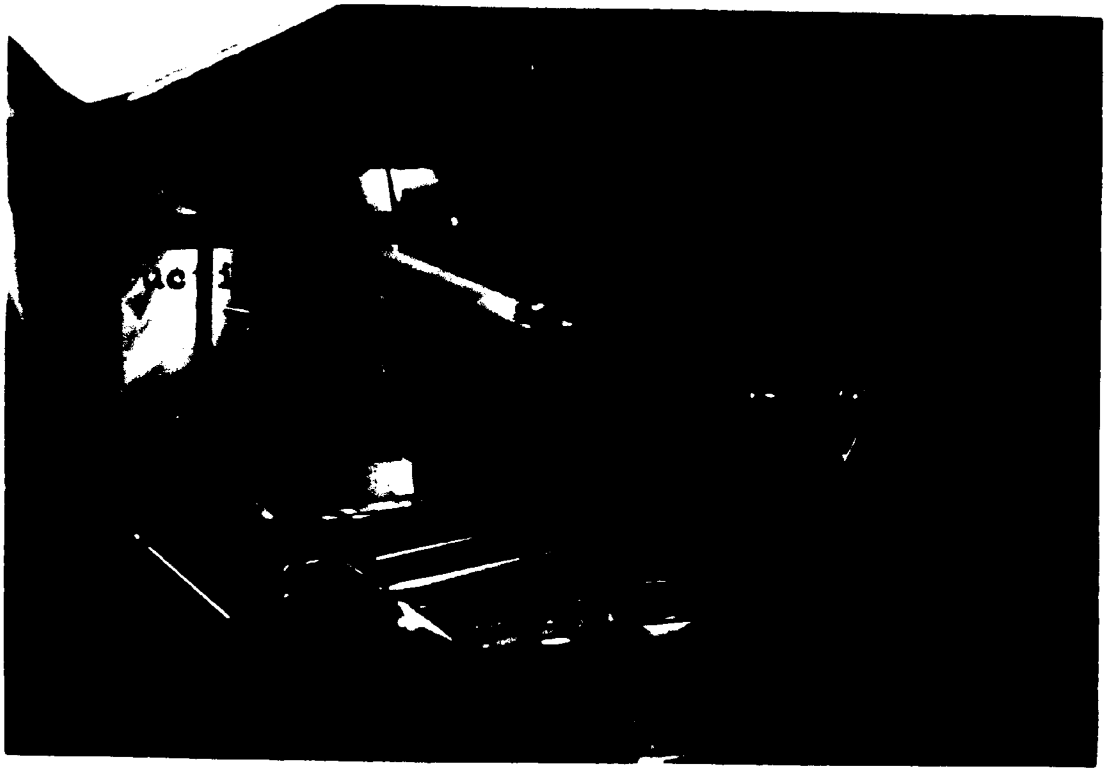

Fig. 4. Obstruction to Convenient Sampling

minutes longer for sampling than the manual dipper method. It isn't necessary to justify the additional cost of the vacuum sampler by a saving in labor, however, because the operator's work is lightened. There is still a question by some plant operators regarding the accuracy of sampling. The sample is always taken from the same position in the weigh tank with a vacuum sampler. The position of sampling is claimed by some plant operators to favor a high test for the small producer, and a low test for the large producer because of the tendency of the fat particles to rise to the top of the milk. This undesirable feature could be eliminated by fastening the sampling tube to a float which would move up and down with the milk.

On the other hand, the reliability of vacuum sampling has been established by tests of various other dairies. The results of a large Indiana Dairy Plant, in 1948, are shown in Table XIV. Although this data was furnished by the manufacturer of the vacuum sampler, the data may be obtained from the dairy.

Table XIV. Comparison of Vacuum and Hand Sampling (1)

Tests obtained by	
Vacuum sampler	Hand sampler
4.2	4.1
4.2	4.2
4.1	4.1
4.5	4.5
4.4	3.9
4.0	4.0
6.4	6.3
4.4	4.3
3.8	3.9
3.9	4.0
4.3	4.3
3.8	3.8
4.5	4.5
3.5	3.4
4.0	3.9
4.0	4.0
4.3	4.3
4.1	4.1
3.9	3.9
4.2	4.2
4.8	4.7
4.4	4.4

1. Information supplied by the Lathrop-Paulson Company in private correspondence of May 8, 1952.

The size of the receiving tank should be large enough to permit continuous dumping without delay, which is usually from two to three times as large as the weigh can. Although usually not attained in a plant for a period of over 15 minutes, the maximum rate of dumping for an average of 5 cans per producer is (7.1 cans per minute) x (60 pounds per can)= 426 pounds per minute, or 25,560 pounds per hour. Because of the many variables involved, it is difficult to determine the smallest size of receiving tank needed. In the plants studied, the 1500 pound receiving tank was large enough for the 750 pound weigh can, and the 1000 pound receiving tank was large enough for the 500 pound weigh can.

The receiving room should be well-lighted to add to the comfort of the workmen. A well-lighted room is usually kept clean and neat. An example of a properly lighted receiving room by natural and artificial light is shown in Fig. 6.

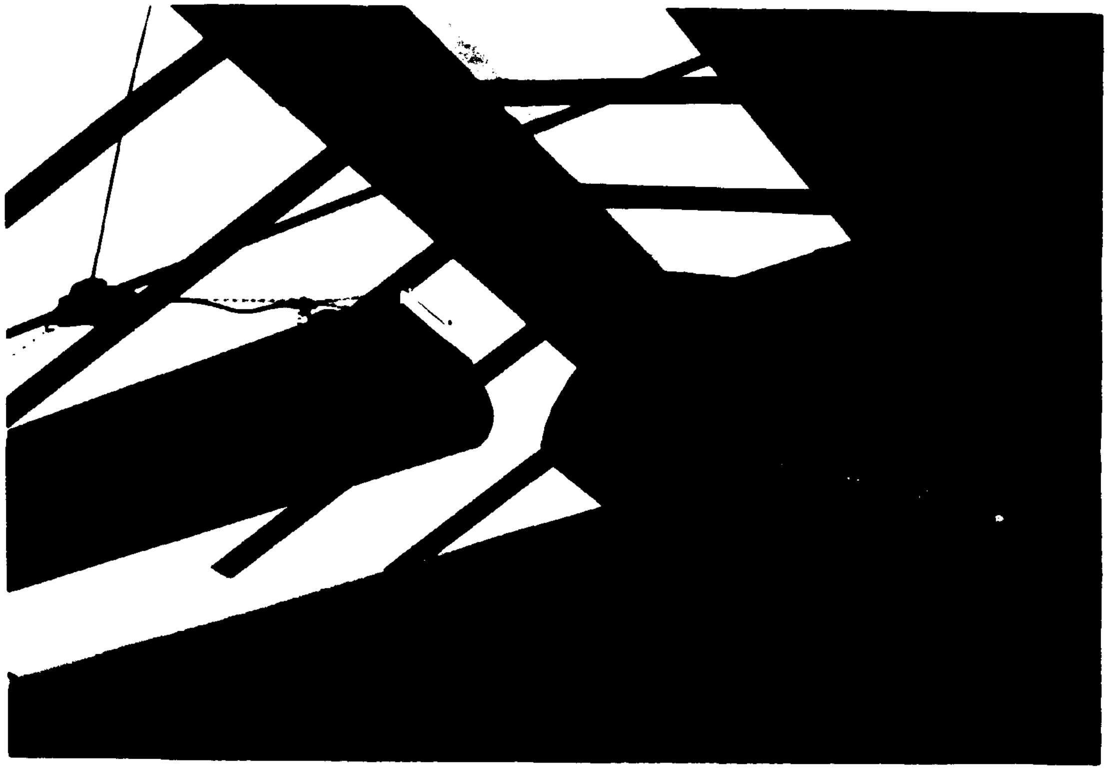

Fig. 6. A Properly Lighted Receiving Room With Natural and Artificial Light

The cost of operation of the conveyor, weigh can receiving tank, scales, and dumping accessories is shown in Fig. 7. The cost of operation includes the cost of labor for cleaning the equipment and for dumping the milk. Fig. 8 shows the unit cost per 100 pounds of milk for the operation. The data for the total and unit cost of the various operations are included in the appendix.

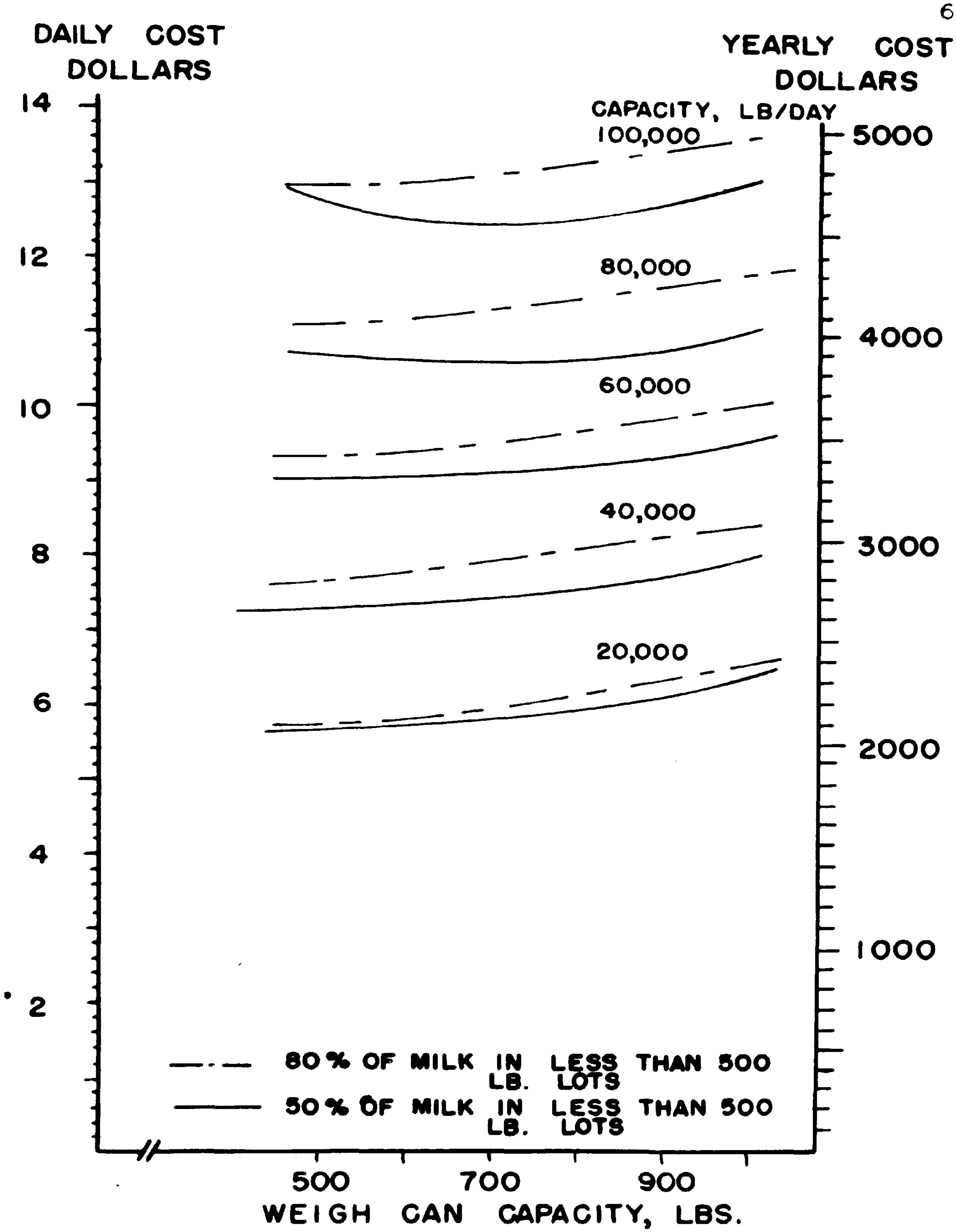

FIG. 7. TOTAL COST OF OPERATION OF CONVEYOR, DUMPING ACCESSORIES, WEIGH CAN, SCALES, AND RECEIVING TANK

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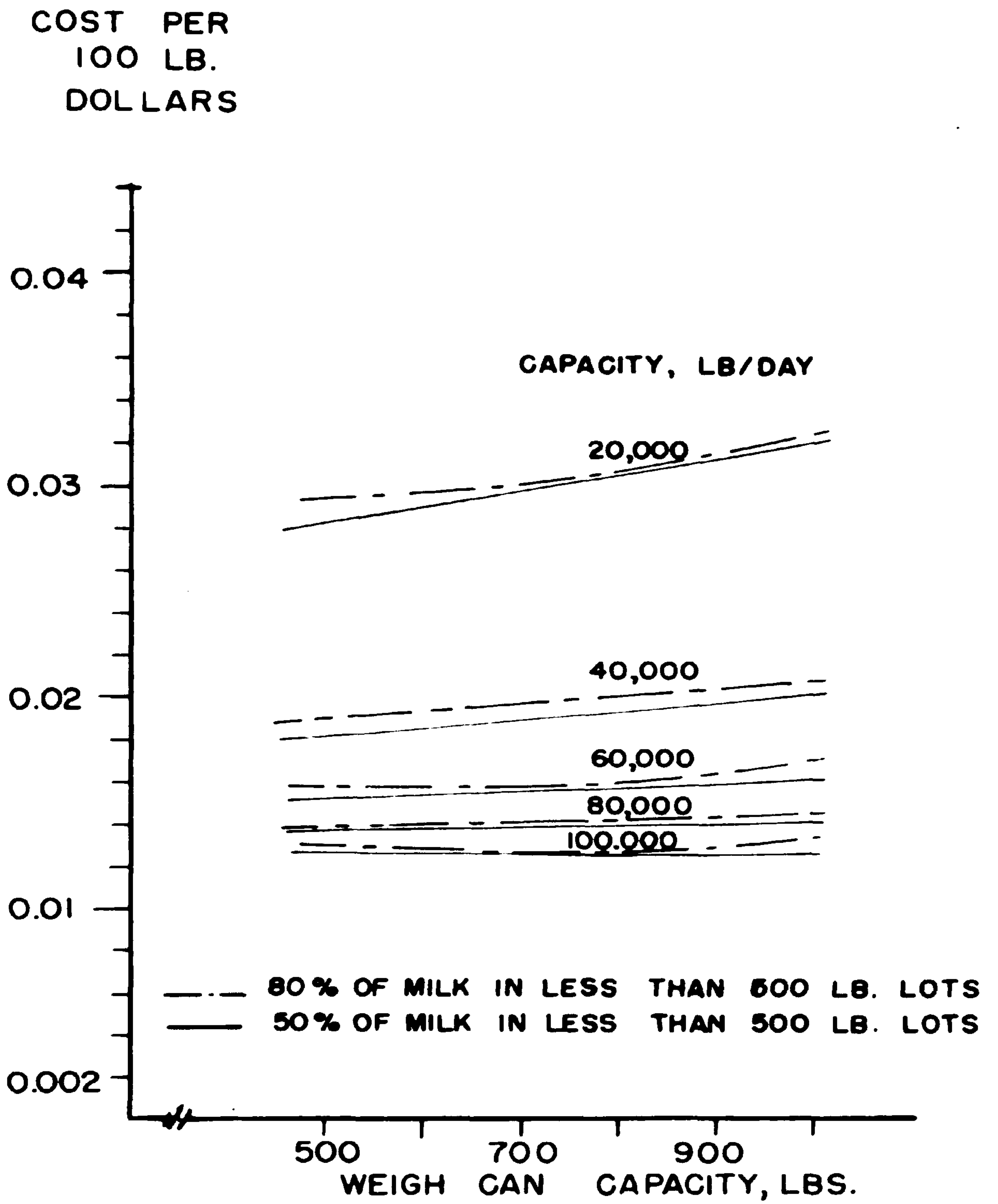

FIG. 8. UNIT COST OF OPERATION OF CONVEYOR, DUMPING ACCESSORIES, WEIGH CAN, SCALES, AND RECEIVING TANK

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3. Straight-away can washer. The capacity of the can washers varied greatly in different dairies, ranging from 6 to 14 can per minute capacities in the plants studied. The size of can washer which should be installed is limited by the rate at which the cans can be dumped at the weigh can. The one-man operation was much more efficient than the two- or three-man operation for receiving. One man can easily handle up to 80,000 pounds of milk per day. Even though more labor, usually expressed in man-minutes per 100 cans, is required for larger receiving stations, it may be imperative to speed up the receiving operation so that the processing which follows the receiving of the milk is not slowed down.

The rate of dumping, where the cans from the truck and the weigh can are not the limiting factors, is shown in Tables XV and XVI, and Fig. 9.

Table XV. Rate of Dumping, CPM, for (a) Manual weighing (b) Vacuum or hand sampling

Number of workers	Dairy (1)	Average number of cans per minute for 2.5 can producer	5 can producer	7.5 can producer	10 can producer	Worker's tasks (2)
1	A	5.2	7.1	7.6	8.2	A
2	F	6.5	7.9	8.5	8.9	B(2)
2	E	8.7	9.7	10.00	10.3	B(1)
3	H	8.9	10.0	10.5	10.9	C(1)
3	G	8.7	9.7	10.0	10.3	C(2)

(1) See Appendix for typical layouts of dairy equipment concerned, excluding equipment sizes.

(2) See Table XIII for description of tasks of workers in different layout arrangements.

Table XVI. Rate of Dumping, CPM, for (a) Print-weigh
(b) Vacuum or hand sampling

Number of workers	Dairy (1)	Average number of cans per minute for 2.5 can producer	5 can producer	7.5 producer	10 can producer	Worker's tasks (2)
1	A	6.6	7.9	8.4	8.8	A
2	F	7.2	8.4	8.8	9.2	B(2)
2	E	8.7	9.7	10.0	10.3	B(1)
3	H	8.9	10.0	10.5	10.9	C(1)
3	G	8.7	9.7	10.0	10.3	C(2)

See previous table for description of (1) and (2)

The size of can washer must be larger than the dumping rates shown in Tables XV and XVI. While the sampling, weighing, and recording is being carried out, there are no cans fed into the washer for a one-man operation. The can washer is not used to capacity during the weighing and sampling operation for two- or three-man operations. Table XVII gives the size of can washer necessary to permit desirable dumping rates. It is necessary to select a can washer with an operating capacity equal to or larger than the dumping rate of the worker.

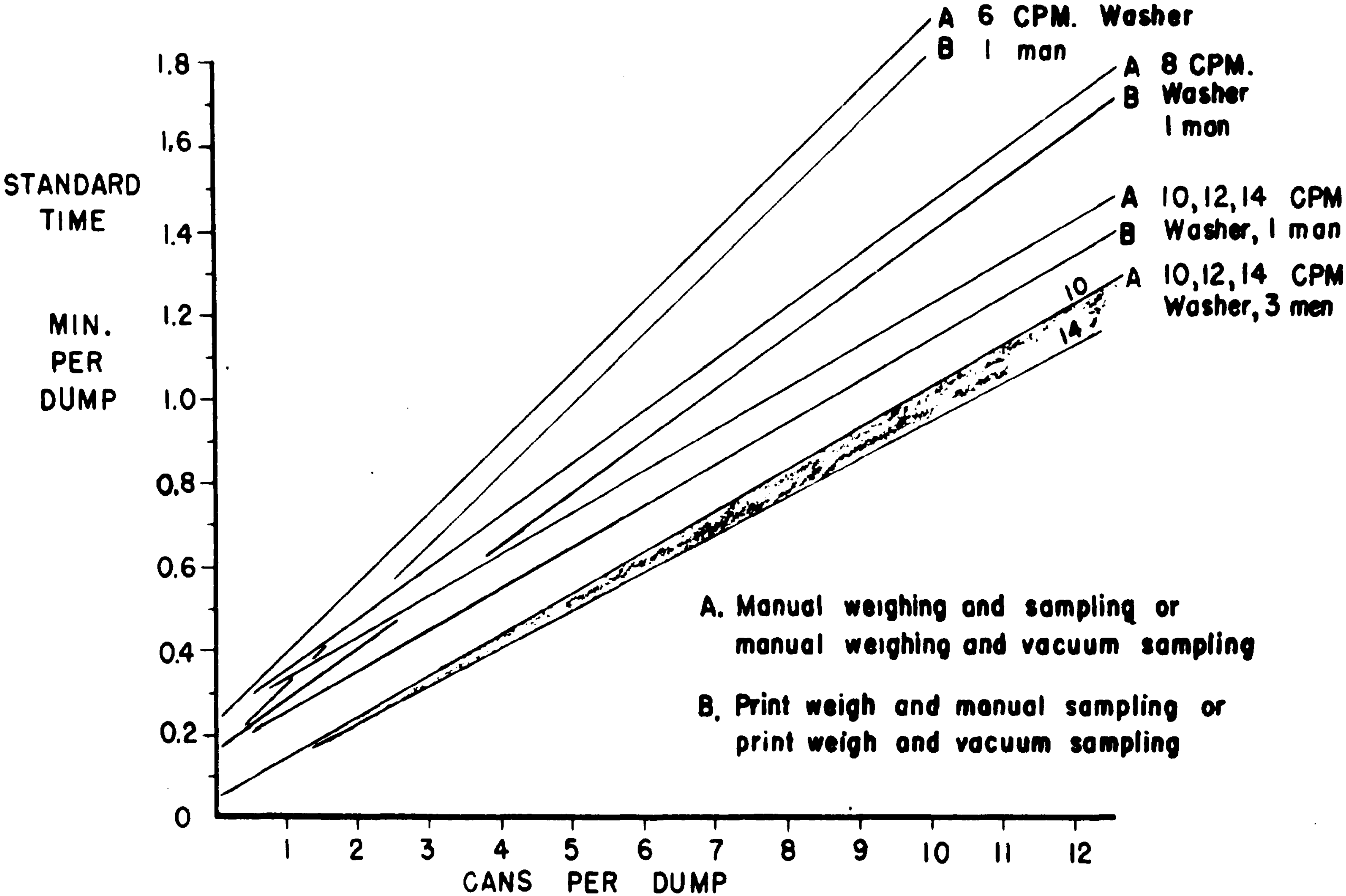

FIG. 9. STANDARD TIME FOR EMPTYING, SAMPLING, AND WEIGHING OF MILK

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Table XVII. Dumping Rates Obtainable with Different Sizes of Can Washers in CPM, Manual Operation, Five Cans per Producer

Can washer size CPM	One-man operation	Two-man operation	Three-man operation
6	5.5(1)	5.6	5.8
8	6.1	7.3	7.7
10	7.1	8.9	9.5
12	7.1	9.7	10.3
14	7.1	9.7	10.3

The size of can washer can be selected on the basis of the data in Tables XV and XVI which give the standard rate of dumping the cans. From these data it is evident that the eight or ten-can-per-minute washer will suffice for a typical one man operation in Michigan. A can washer larger than ten cans per minute cannot be justified and would be an uneconomical investment. A six-can-per-minute washer would be too slow to utilize fully the working ability of one man. A twelve-can-per-minute washer would be recommended for a two- or three-man operation.

In order to select an economical can washer, see Fig. 10 and 11. The size of dairy is considered in determining the correct selection. The labor requirement charged against the can washer includes preparing the unit for operation, cleaning the area between loads, and the daily cleaning of

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1. The calculated value is 5.0 CPM. However, one operator was able to obtain 5.5 CPM by moving a can into the washer with an extra movement of his arm between the time of sampling and the time of recording the weight.

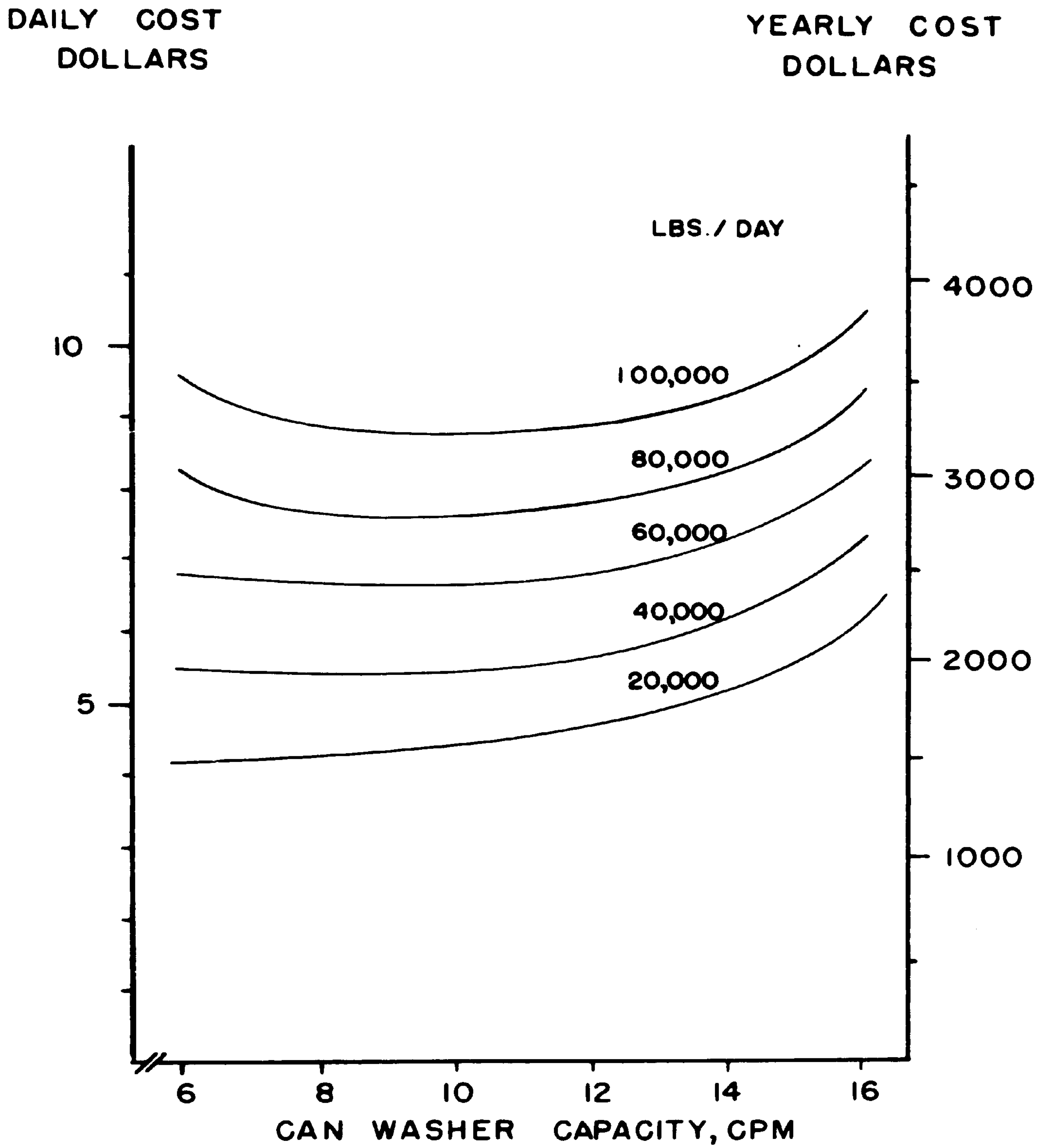

FIG. 10. TOTAL COST OF OPERATION OF STRAIGHT-AWAY CAN WASHER

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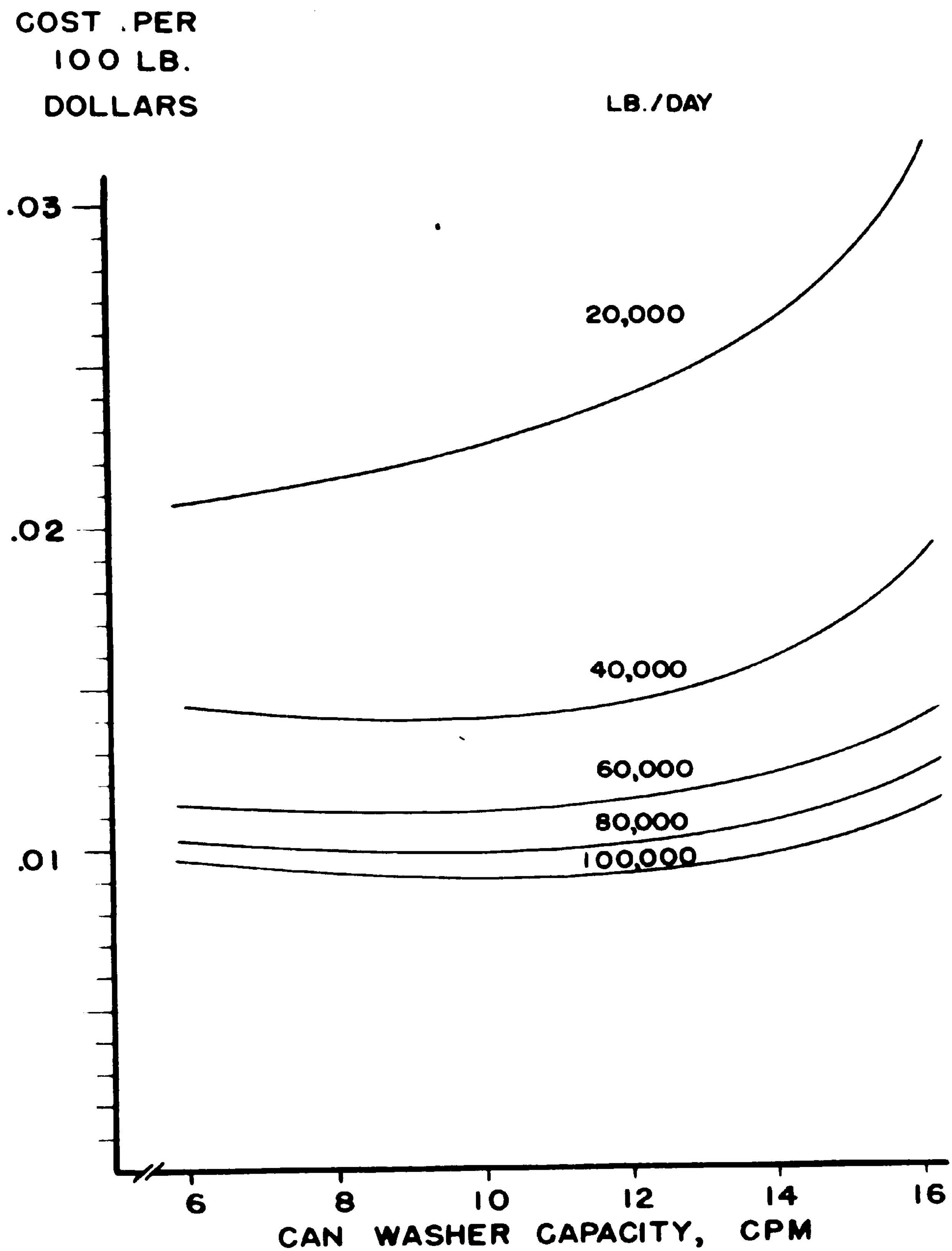

FIG. 11. UNIT COST OF OPERATION OF STRAIGHT-AWAY CAN WASHER

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the can washer. In addition, if the can washer does not move the cans through as rapidly as the worker can dump them, a charge is made against the washer. For example, assume the worker can dump 7.1 cans per minute in a particular dairy. The six-can-per-minute washer will permit one to dump 5.5 cans per minute. In this example, the difference in time required for dumping the milk at 7.1 and 5.5 cans per minute was charged against the washer.

4. Rotary can washer. The rotary can washer is usually recommended for plants which handle less than 20,000 pounds of milk per day. The rotary can washer is built in three and six-can-per-minute capacities. The rotary can washer does not permit as efficient utilization of labor as the straightaway washer, but has a much lower initial cost.

One of the major dairy machinery companies claims that the three-can-per-minute rotary washer is as large a unit as one man can operate. This is undoubtedly true in some dairy plant layouts. In an efficiently arranged layout, with conveyors going to and from the can washer, tests showed that one man can conveniently handle 5.85 cans per minute, or practically 6 cans per minute.

The entire cost of the receiving operation with the rotary washer can be calculated from Figs. 7 and 12. The data for both of these figures include charges for one man.

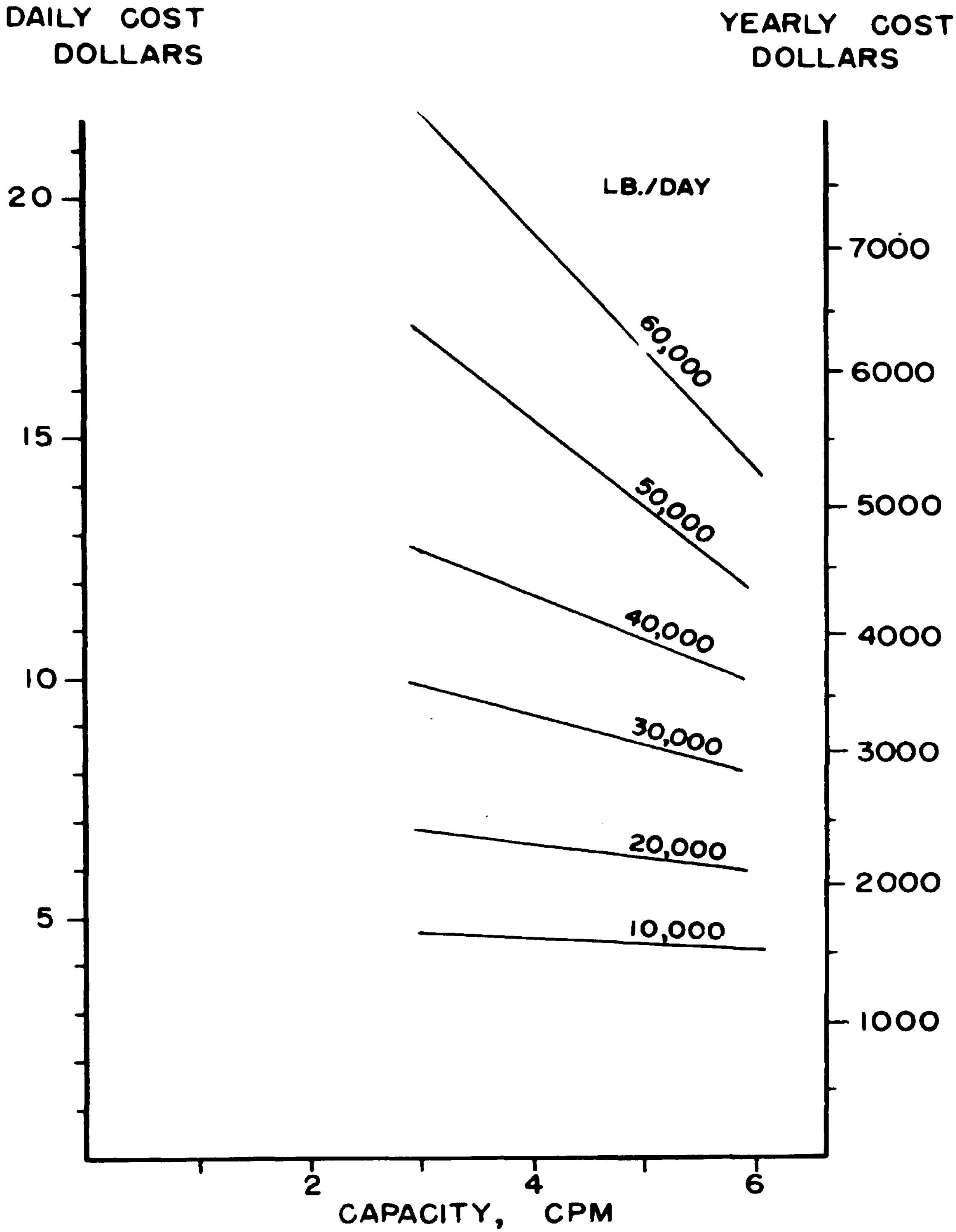

FIG. 12. TOTAL COST OF OPERATION OF ROTARY CAN WASHER

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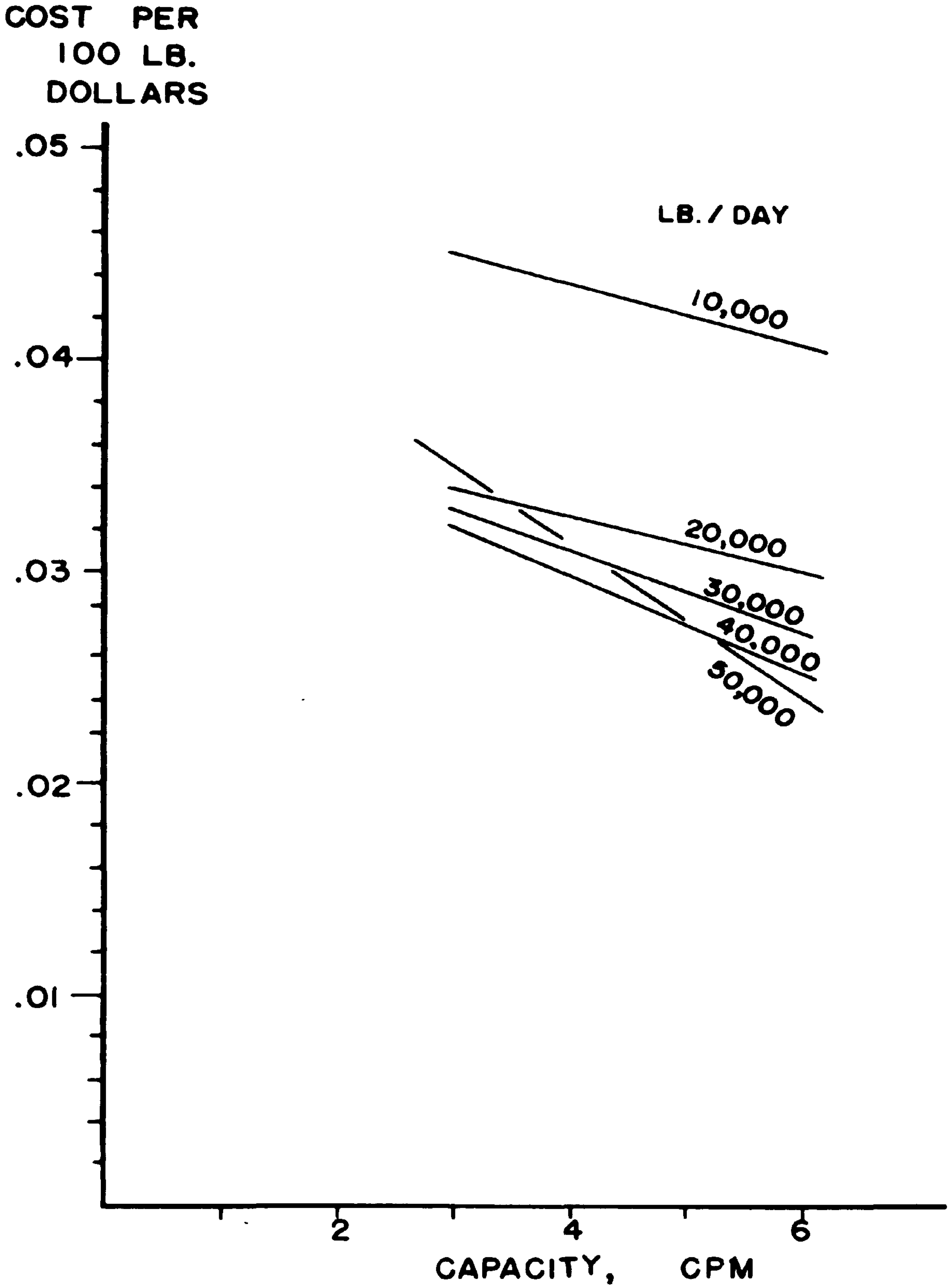

FIG. 13. UNIT COST OF OPERATION OF ROTARY CAN WASHER

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For the rotary washer to be used efficiently, and the dumping to be carried out rapidly, a minimum of two men are needed in the receiving room for a rotary can washer.

The entire cost of operation for the two types of washers which includes all costs, can be compared for different sizes of dairies and different sizes of equipment, to use as a guide in selecting the proper can washer.

5. Conveyor. The design of the conveyor equipment will often limit the efficiency of the other operations in the receiving room.

In most plants where both gravity and power conveyors were used, the cans would lodge at the junction of the two conveyors. The conveyor should be located on the same level or slightly above the truck bed to facilitate unloading. The incoming conveyor should be close to the empty can conveyor at the dump position, if the dumper is checking for quality, so that a short reject line is required (See Appendix, Fig. 3).

In some plants considerable difficulty was encountered from the cans pinching at the dump. The least difficulty was observed when the cans were dumped at a right angle to the conveyor. When the cans were dumped in the direction of conveyor travel, the cans would pinch into the dump. The better arrangement of the two possibilities is shown in Fig. 14 and Appendix, Fig. 3, 4, 5, 6, 8.

The length of the conveyor varied greatly in different plants. An analysis of the optimum length of conveyor was carried out and is summarized in Fig. 15. The results are based on receiving a 100 can truck load, with the trucker unloading cans and loosening lids at the rate of seven cans per minute. Two minutes were allowed to move the truck to the empty can conveyor from the unloading position. A conveyor speed of fifteen cans per minute was assumed. The time for emptying the can for different incoming conveyor lengths from zero to ninety feet for different dumping rates was calculated and plotted. The total length of conveyor was obtained by adding the incoming conveyor length to the empty can conveyor length necessary so that the dumping rate was not slowed down because of an accumulation of empty cans on the conveyor. The empty can conveyor includes the length of the washer.

For a dumping rate of six cans per minute, the dumping time is the same, regardless of the length of incoming conveyor. Whenever the dumping rate is slower than the speed at which the trucker can unload, there is no advantage to a long incoming conveyor.

A very interesting and important relationship exists between the conveyor length and the dumping time at dumping rates which are above the rate at which cans are placed on the conveyor. For example, for a dumping rate of eight cans per minute, the dumping time is reduced from 14.3 to 12.5 minutes as the conveyor length is increased from zero to thirty feet in length. When the incoming conveyor is thirty feet in length, a total conveyor length of 130 feet is required. As the length of the incoming conveyor is increased from thirty to ninety feet, the time required for dumping does not change, but the total length of conveyor required decreases from 130 feet to 118 feet. As the length of incoming conveyor increased, the number of cans remaining for the trucker to unload from the truck decreased. Thus, the trucker could unload the cans, move the truck to the empty can conveyor, and remove cans from the empty can conveyor sooner than if a short incoming conveyor is used. The total conveyor length is decreased as the length of the incoming conveyor is increased beyond thirty feet for a dumping rate of eight cans per minute.

In a large operation, with more than one man in the receiving room, where the trucks arrive at the plant on a schedule so as to prevent receiving room delays, the trucker can unload the cans without loosening lids, at a rate of ten cans per minute. Another trucker can loosen the lids. A rate of ten cans per minute is fast enough to keep the dumper supplied with cans in most operations. If the truckers cannot help each other, a double incoming conveyor could be constructed with a Y-feed at the dump. Two trucks could be unloading at the same time, although the dumper would take only one load at a time. Such a procedure would require long incoming conveyors.

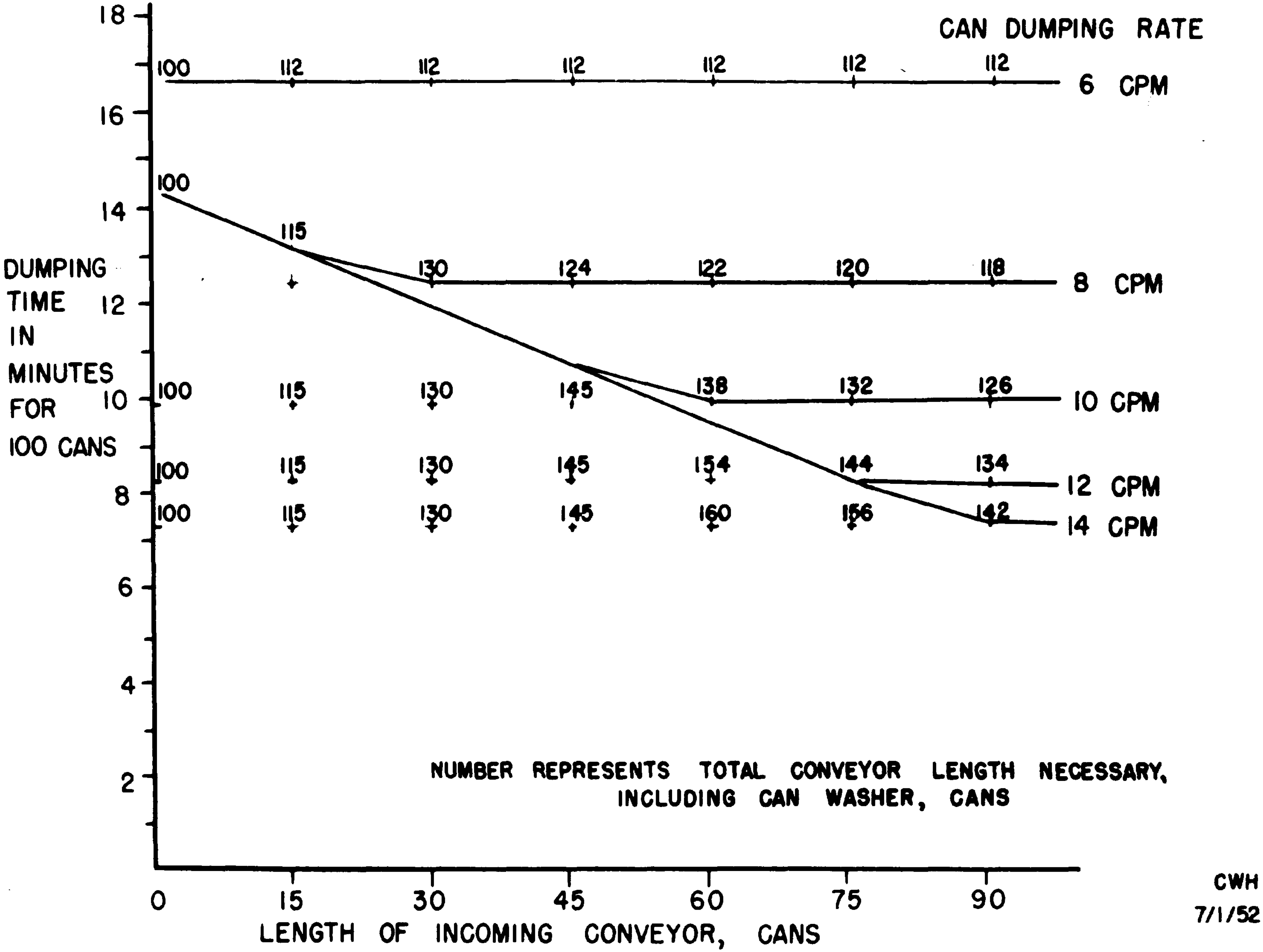

FIG. 15. RELATIONSHIP OF DUMPING TIME AND CONVEYOR LENGTH FOR DIFFERENT LENGTHS OF INCOMING CONVEYOR AND DIFFERENT

Fig. 14. Cans Dumped at Right Angles to the Conveyor

Long empty can conveyors often require the truck driver to wait for an excessive length of time for the empty cans for small loads. This is often of particular importance in the spring of the year when the truck driver may have half-loads because of highway load regulations. Long conveyors, as shown in Fig. 16, may require eight minutes for the cans to travel its length. To speed can delivery to the truck, the truck drivers would often lift the cans over one of the conveyor loops, so that the can would travel only one-half of the empty can conveyor length. A cross-over could be designed into the system to facilitate the movement of the cans.

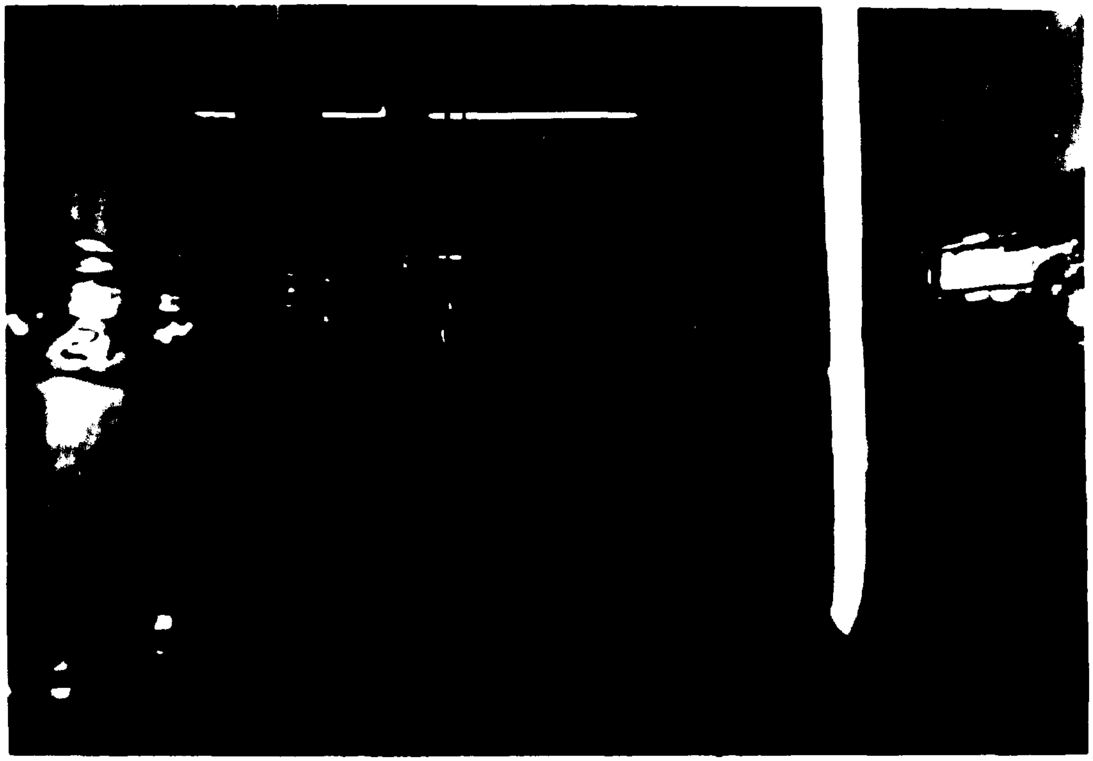

Fig. 16. Long Empty Can Conveyor (130 ft.)

6. Over-all efficiency of receiving room. The over-all labor efficiency in the receiving room can be expressed in terms of the man-minutes required to handle 100 cans, which represents an average truckers load. The results of several dairies which were studied are listed in Table XVIII with the theoretical expected labor requirements for the number of men being employed for the operation.

Table XVIII. Over-all Labor Efficiency of Receiving Rooms (Manual weighing and recording)

Number workers	Dairy (1)	Actual performance man-min / 100 cans	Cans per minute obtained	Size of can washer, CPM	Goal for 5 can producers, man-min / 100 cans	Workers tasks (2)	Major causes for delays
1	A	17.9	5.6	10	14.1	A	a
1	B	16.6	6.0	12	14.1	A	b
1	C	21.8	4.6	8	14.1	A	c
1	D	18.2	5.5	6	14.1	A	d
2	E	30.4	6.6	7	20.6	B(1)	e
2	F	35.0	5.7	13	20.6	B(2)	f
3	G	34.2	8.8	14	30.0	C(2)	g
3	H	31.2	9.6	13	30.0	C(1)	h
3	I	78.6		3	51.2		i
4	J(3)	58.8				(4)	j

a Low capacity clarifier, cans not supplied to dumper rapidly enough, can washer lid discharge not functioning properly
b. Can washer lid feed not functioning properly, cans pinched when dumping
c. Vacuum sampler used inefficiently
d Small can washer
e Cans supplied to washer too slow, small can washer
f Same person dumping and weighing; sampler should weigh
g Cans supplied to washer too slowly for multiple-man receiving room, man loosening lids not fully occupied
h Cans supplied to dumper too slowly
i Not a continuous operation, small rotary can washer
j Grader not fully occupied

1. See Appendix Fig. 1 to 9 for typical layouts of dairy equipment.
2. See Table XIII for description of worker's tasks
3. French, Charles E., op. cit., p. 6.
4. One grader, 1 dumper, 1 weight recorder, 1 sampler.

B. Processing Room Operations

Many different selections and arrangements of equipment are possible in the processing room. The charts included in this section should aid in selecting the most economical combination of equipment with the correct capacity to carry out the desired operations. Suggestions are included for improving the design of the equipment. Check lists give particular items which should be given attention in plant layout and operation.

The equipment from the storage tanks back to the receiving tank should be selected on the basis of the speed of the receiving operation. The equipment from the storage tanks to bottler should be selected on the basis of the speed of bottling or processing which will completely utilize the abilities of the workers.

The time required for cleaning, including the time for disassembly and assembly, various items of dairy machinery is shown in Fig. 52.

1. Clarifier. The clarifier may be placed between the receiving tank and the storage tank (See Fig. 1) so that the sediment is removed from the cold milk as it is brought into the plant. The clarifier is usually placed in or near the receiving room (See Fig. 19).

The largest clarifier generally used in the dairy plant has a capacity of 20,000 pounds per hour. The capacity of the clarifier is regulated by the positive displacement pump placed after the receiving tank and just before the clarifier.

The optimum dumping rate for a one-man manual receiving operation is 7.1 cans per minute for an average of five cans per producer. With an average of sixty pounds of milk per can, dumping at a rate of 7.1 CPM, a 25,560 pound per hour clarifier would be required. The rate of dumping in some plants is definitely slowed down because the capacity of the clarifier is too small. This is not a serious matter from a labor standpoint, in a dairy of small or medium size handling less than 80,000 pounds per day. More important than the labor requirement is that there is more milk lost from running the receiving tank over because of the small clarifier, as it takes only thirty-five pounds of unprocessed milk to pay for an hour of labor. The value of the unprocessed milk is often overlooked by the worker and management.

In a three-man receiving operation the optimum rate of dumping is 10.0 CPM, which is equivalent to 36,000 pounds per hour. In plants with two- or three-man receiving room operation, where the raw milk is clarified, it is necessary to replace the conventional 1500 pound receiving tank with a 1000 gallon receiving tank located on a floor below the receiving room. The clarifier receives the milk from the receiving tank and can keep within 8000 pounds of the dumping by clarifying milk during delays while waiting for farm truck deliveries. A larger clarifier could be used, which would eliminate the necessity of using a storage tank as a receiving tank.

The clarifier may also be placed before or after the homogenizer, as the milk leaves the storage on the way to be pasteurized.

The total and unit cost of operation of a clarifier are shown in Figs. 17 and 18. The cost includes supervision amounting to one-tenth of the operation time.

As long as a preceding or following operation is not hindered, the small clarifier with a capacity of 5000 pounds per hour is the most economical for dairies handling up to 50,000 pounds per day. The medium sized clarifier, with a capacity of 12,000 pounds per hour, is the most economical for dairies with a daily capacity of from 50,000 to 90,000 pounds. For large dairies, with a capacity above 90,000 pounds per day, the 20,000 pound per hour clarifier is most economical.

If a 20,000 pound per hour clarifier is used in a one-man receiving room, the clarifier would have to be penalized for delaying that operation. The results of calculations including the penalty for delaying the receiving operation are shown in Appendix Table X, which illustrates the importance of considering the other operations when planning. The total cost is smaller for the larger machine because the cost of the labor saved is more than enough to pay for the added initial and operating costs. The total cost would be smaller for a clarifier with a capacity up to about 25,000 pounds per hour, depending upon the cost of a larger clarifier.

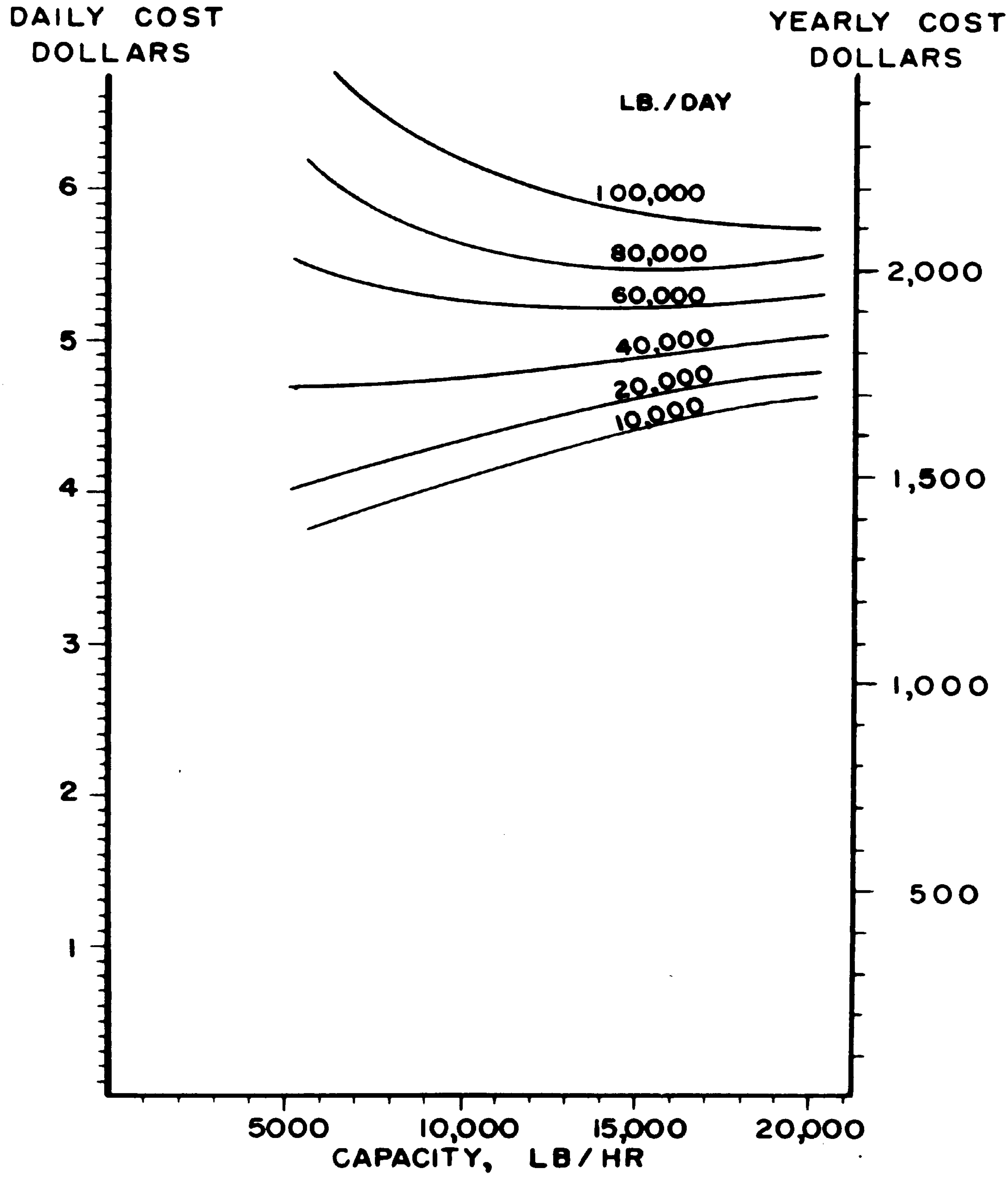

FIG. 17. TOTAL COST OF OPERATION OF CLARIFIER

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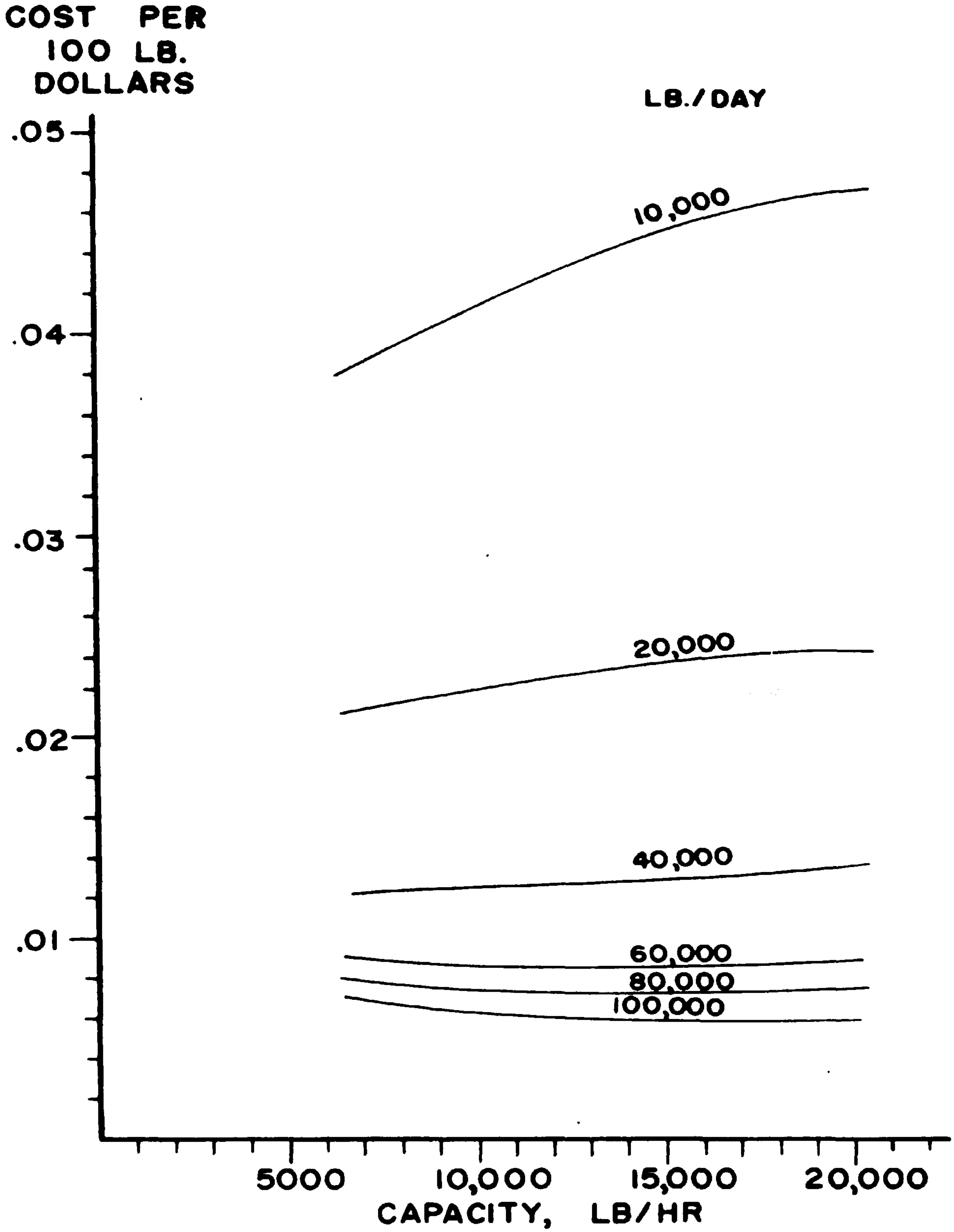

FIG. 18. UNIT COST OF OPERATION OF CLARIFIER

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A standardizing clarifier will be of great value in increasing the efficiency of the receiving operation when the milk is collected in a tank truck. It cannot be used for the present ten gallon can receiving room operations, because all of the milk fed into the unit must have the same test.

Fig. 19. Equipment Located in the Receiving Room

2. Filter. The cost of filtering can be compared to that of clarifying without regard to the amount of sediment removed. The capacities of the filters normally go up to 30,000 pounds per hour, and would not retard the one-man receiving operation.

Figs. 20 and 21 show the total and unit cost of filtering milk, which includes a charge for a motor and positive pump.

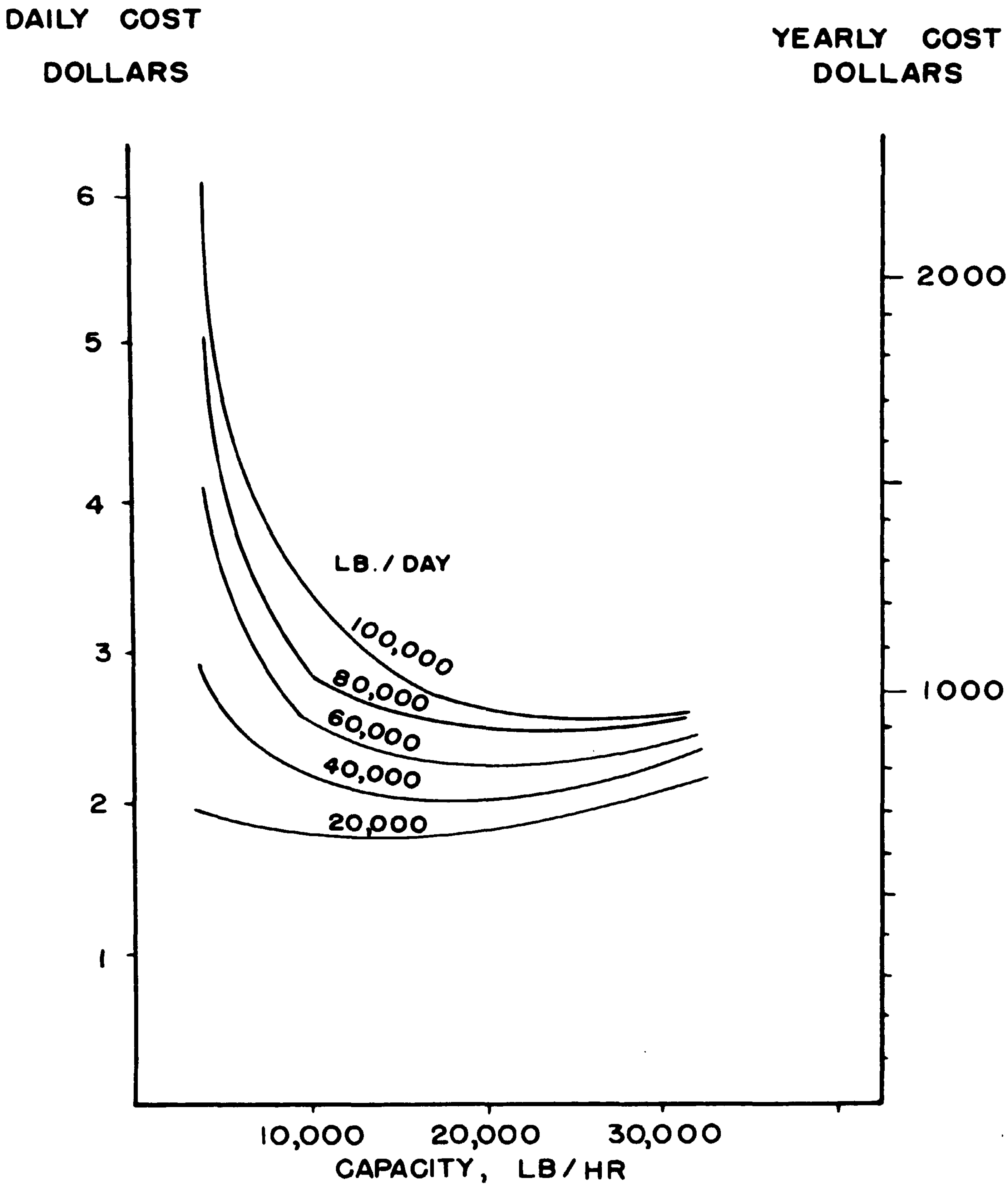

FIG. 20. TOTAL COST OF OPERATION OF FILTER

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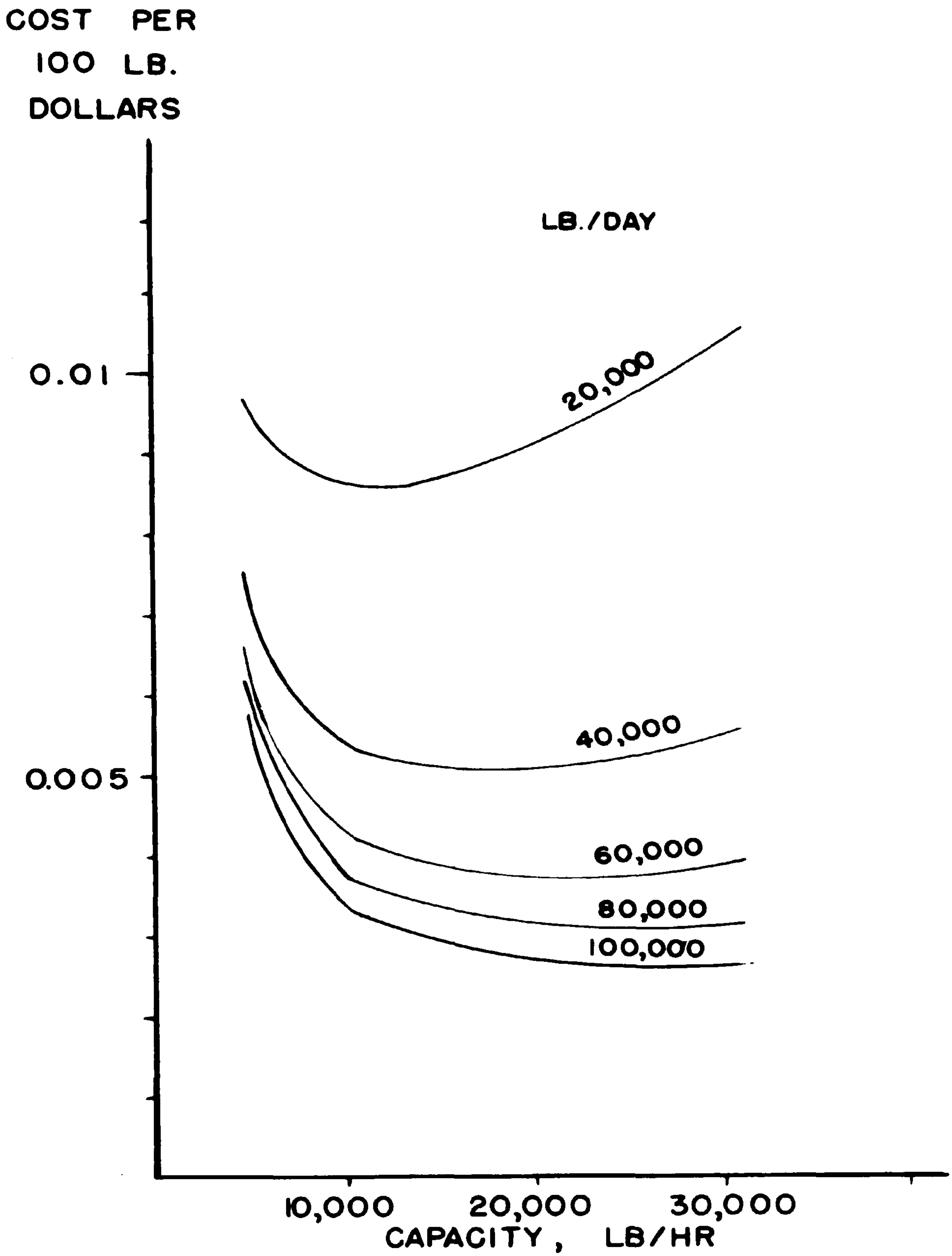

FIG. 21. UNIT COST OF OPERATION OF FILTER

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Filtering is about one-half as expensive as clarifying because a filter costs about one-sixth as much as a clarifier, with the daily fixed costs being two dollars less, and the labor required to clean a filter being about one-fifth as great as for a clarifier. The cost is not the only factor to be considered.

The milk should be filtered while cold so that none of the sediment dissolves in the milk. Cream must be filtered hot (170° F.) to prevent the filter from clogging (1).

3. <u>Raw milk plate cooler</u>. When an insulated tank is used for storage, without refrigeration, the milk is cooled before it is placed in the storage tank. A plate cooler is usually used for this cooling. A plate cooler is compact, has high efficiency, and because the number of plates can be easily changed has great flexibility. The cooling is usually done with sweet water because of its economy. It is usually not necessary to cool more than ten degrees F.

The cleaning time used for the calculations is based on an entirely manual cleaning operation, that is, without using circulating methods. Manual cleaning is required once a week when the cleaning is done daily with circulatory methods (2). The plates of the cooler have about one-third the area as the HTST pasteurizing plates. The time required for cleaning a cooler plate is 0.28 minutes.

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1. Farrall, A. W., Dairy Engineering, John Wiley and Sons, New York, 1942, pp. 325-326.

2. The Michigan Milk Ordinance, Bureau of Dairying, Lansing, Michigan, 1945, does not permit recirculatory cleaning. On p. 17 is stated, "Equipment shall be disassembled and washed after each operation and - - -."

The total and unit cost of operation of the raw milk cooler for a one-man continuous receiving operation are shown in Figs. 22 and 23. There is little difference in the total cost for either a 10,000 or 20,000 pounds per hour plate cooler for a 20,000 pound dairy. For dairies with capacities above 20,000 pounds per day, up to 100,000 pounds per day, the 20,000 pound per hour cooler is the most economical for a one-man receiving operation, in spite of the fact that the dumper is slowed down slightly.

4. Storage tank. There are three general types of storage tanks: the insulated, the cold wall, and the insulated with expansion coils placed in the milk. The storage tanks can also be divided into vertical and horizontal tanks, usually cylindrical in shape. The total and unit cost of operation of the three types of horizontal storages are shown in Figs. 24 and 25.

There is little difference in the total cost of operation between the cold wall refrigerated tank and the storage tank with expansion (DX) coils. If sweet water is used in the cold wall tank, the total cost of operation is reduced sixteen per cent.

The cost of using the insulated tank and the cooler may be added together to compare their cost of operation with the refrigerated tank.

The time required to clean the storage tanks was given special attention. The time of cleaning storage tanks is

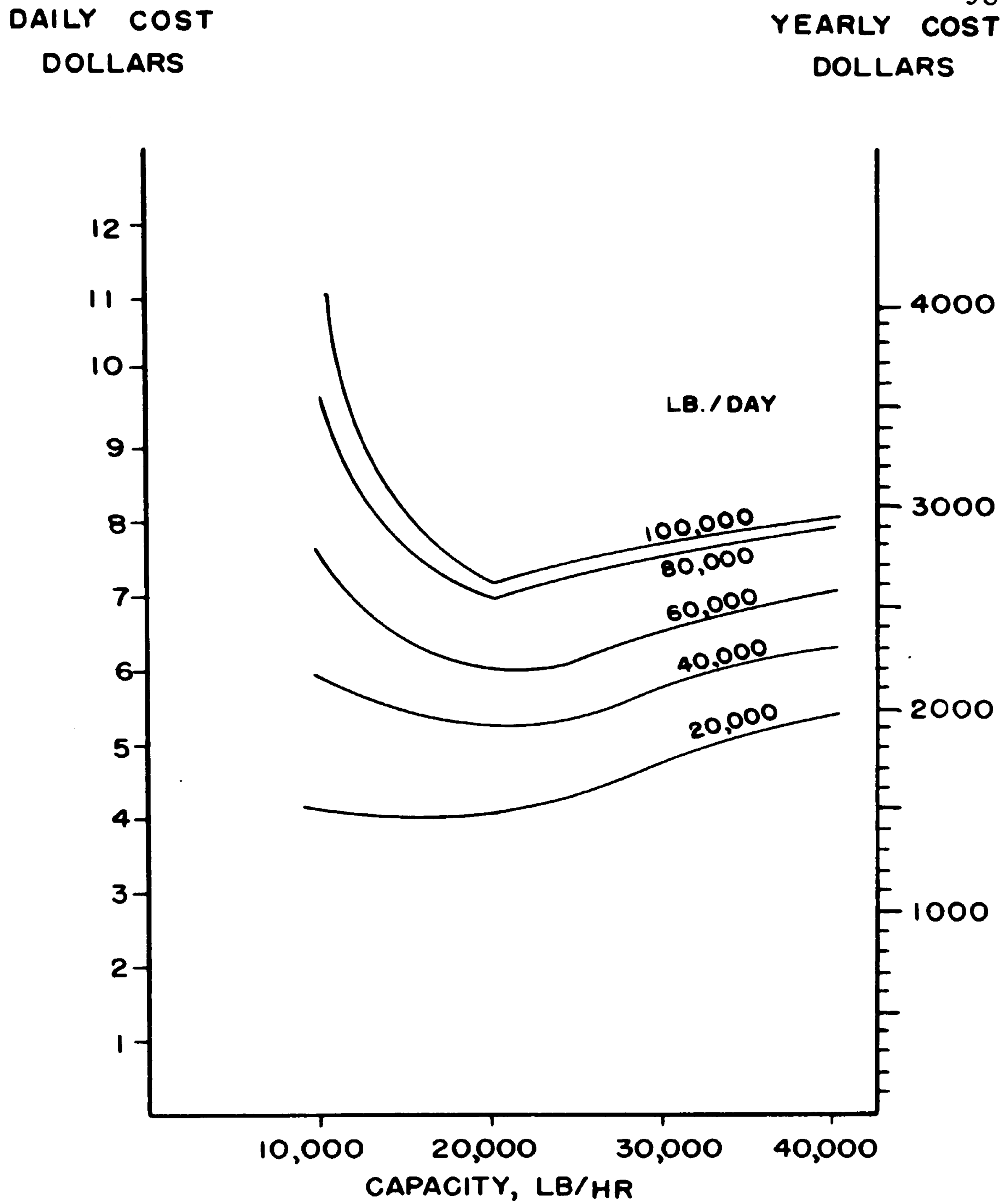

FIG. 22. TOTAL COST OF OPERATION OF RAW MILK PLATE COOLER

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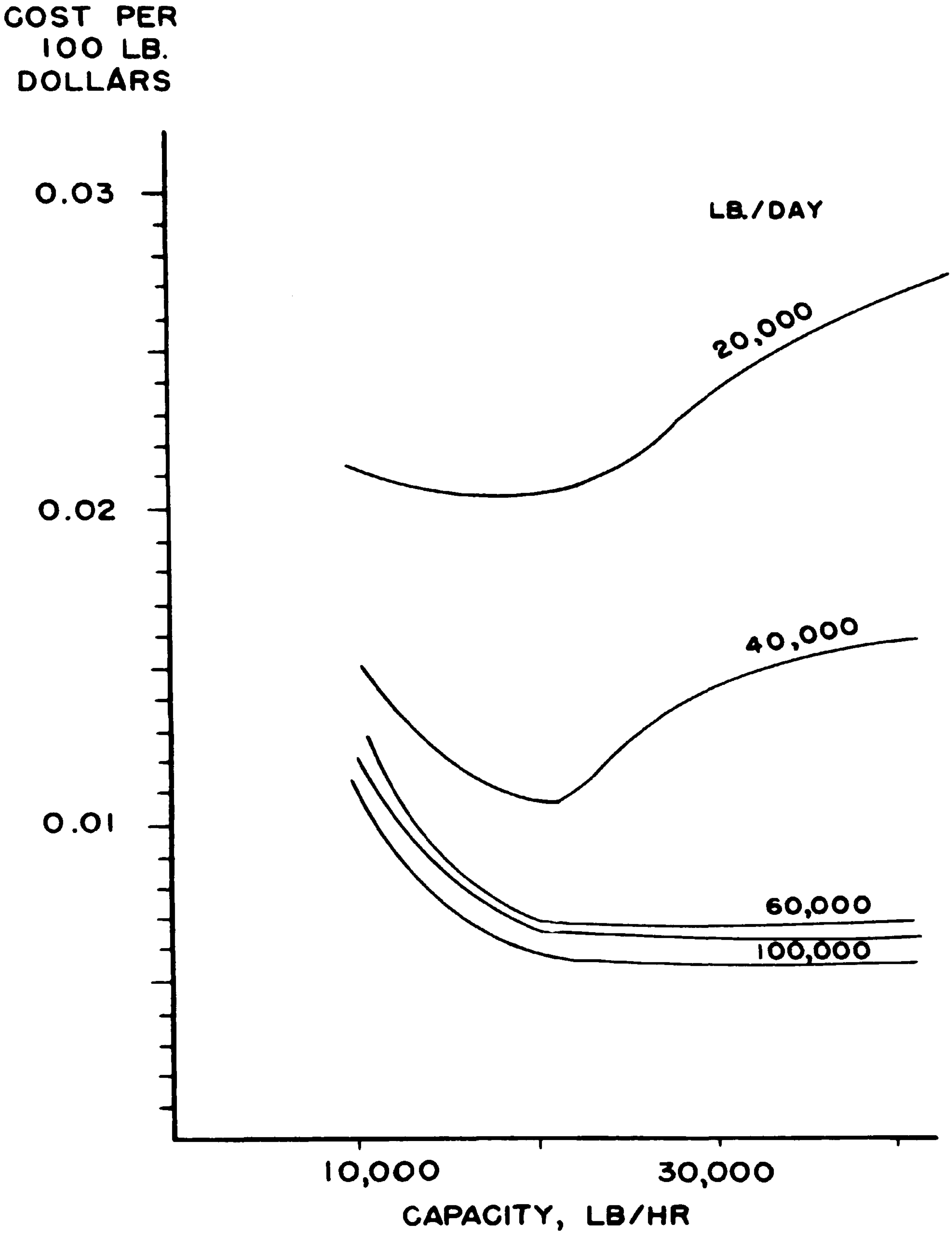

FIG. 23. UNIT COST OF OPERATION OF RAW MILK PLATE COOLER

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shown in Fig. 26. The small 600 gallon storage tank required more time for cleaning than the 1000 gallon tank. This difference is atbributed to the difference in diameter, which affects the ease of cleaning. The 3000 gallon storage tanks are manufactured in 84 inch and 96 inch diameters, and these two tanks sell for the same price. All the tanks above 3000 gallons have a diameter of 96 inches. The 84-inch diameter 3000-gallon tank required five minutes less to clean per day than the 96-inch diameter tank. These figures would certainly not apply to all workmen, regardless of height, who clean the tanks, but it represents an average time required of workers who were between 5 ft. 8 in. and 6 ft. tall.

The saving in cleaning labor for the 84-inch diameter tanks must be balanced against the additional building space required in comparison to the 96-inch diameter tank. The annual and life saving of the 84-inch diameter tank as compared to the 96-inch diameter tank are shown in Table XIX.

Table XIX. Saving in Operational Cost of 84-inch Diameter Compared With a 96-Inch Diameter Horizontal Milk Storage Tank. (See Appendix Table V for a complete analysis.)
Note: None of the storage tanks above 3000 gallons are made in 84-inch diameter at the present time.

Capacity 84 in. dia. (gallons)	Annual Saving Dollars	Life (18 yr.) Saving Dollars
3000	62.00	1116
4000	25.52	459
5000	- 7.30	- 131
6000	-25.50	- 459

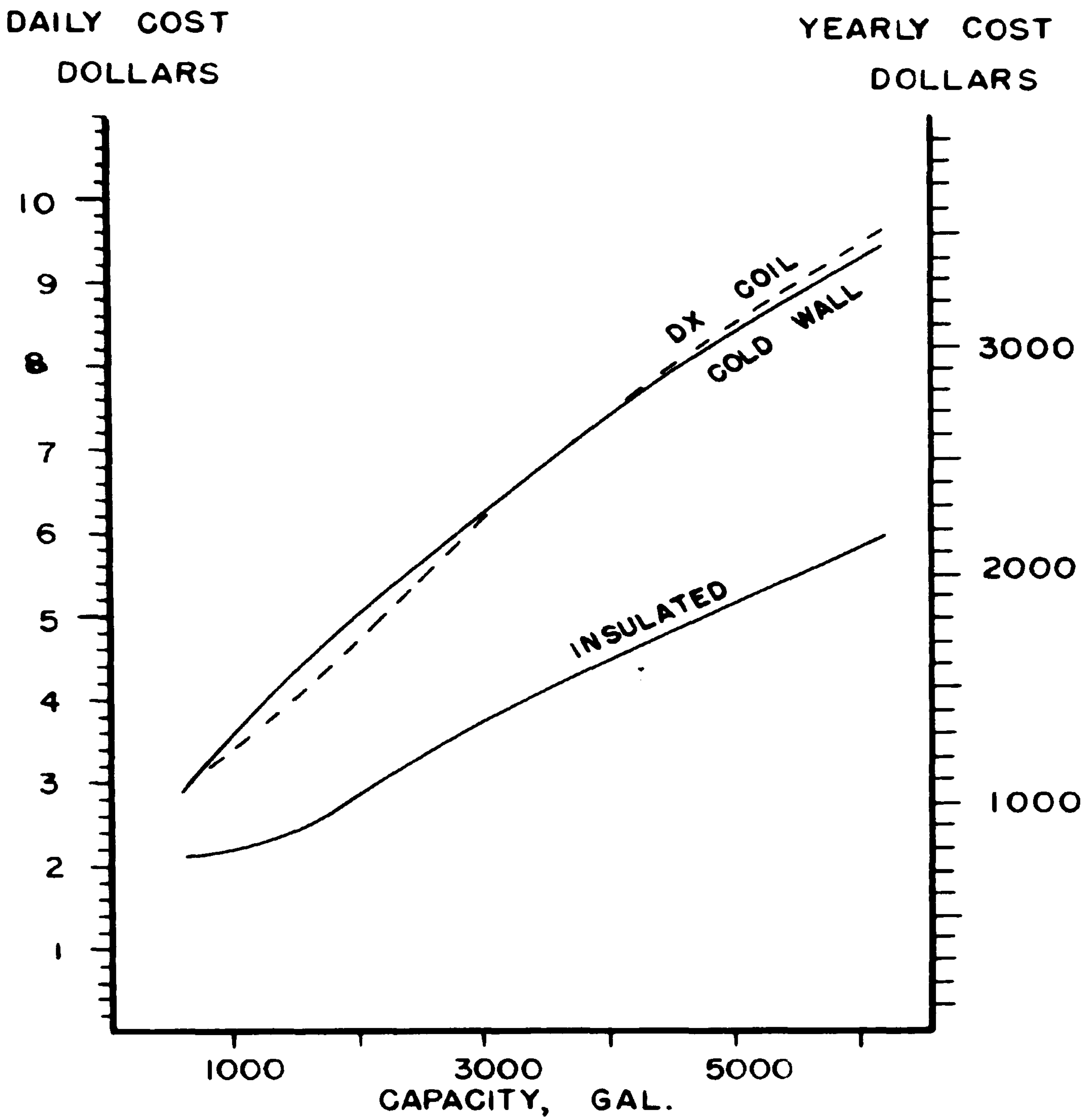

FIG. 24. TOTAL COST OF OPERATION OF HORIZONTAL STORAGE TANK

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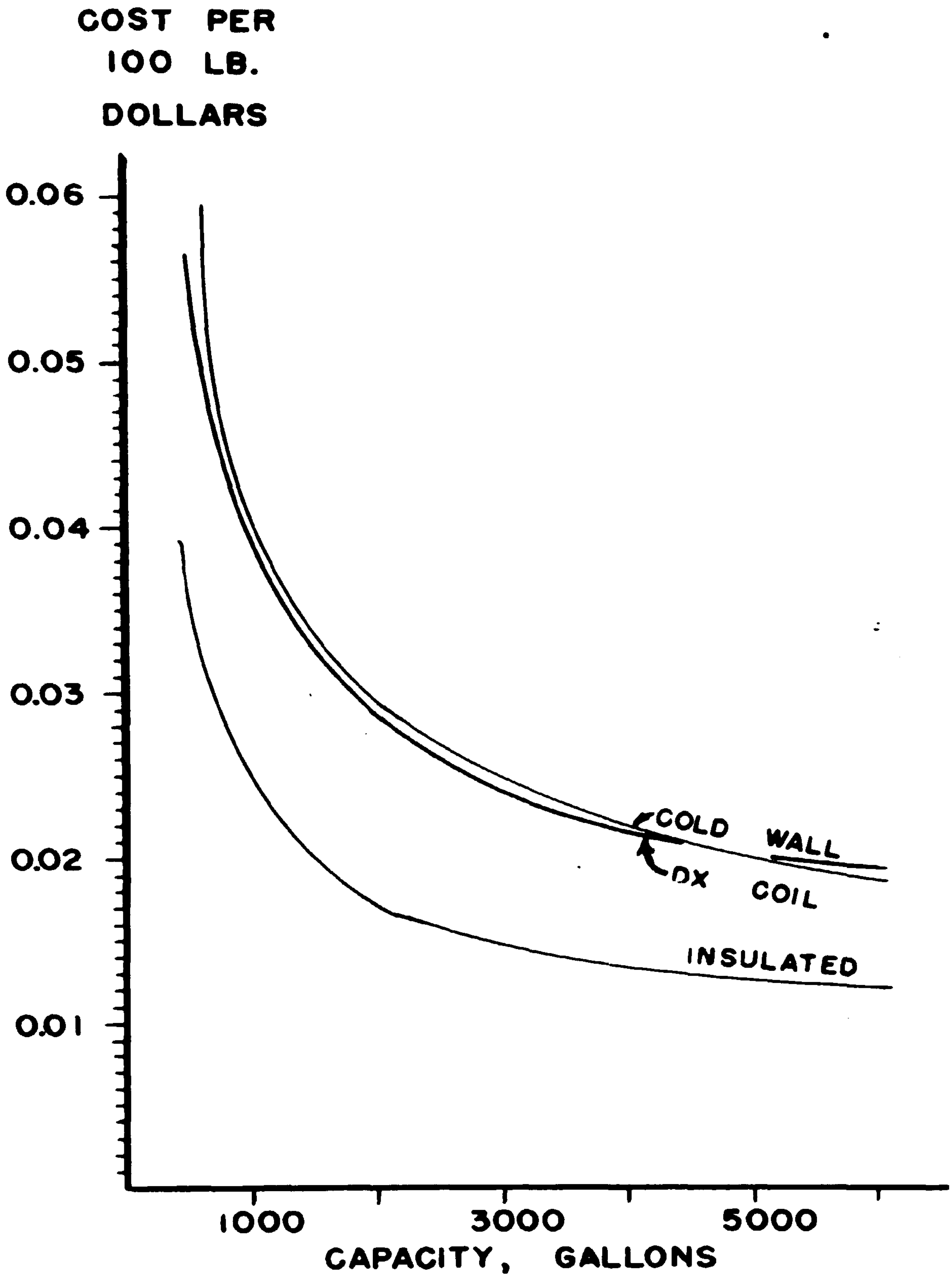

FIG. 25. UNIT COST OF OPERATION OF HORIZONTAL STORAGE TANK
ONE FILLING DAILY

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The dairy plant operator can justify the saving in labor, even though more floor area is required for tanks up to and including 4000 gallon capacity. For tanks with a capacity above 4000 gallon the added area required for the 84-inch diameter tank is more costly than the labor saving at 1952 prices.

It may not be necessary to change the tank diameters in order to save cleaning labor. The times used in Fig. 26 were taken from operators using their own and not improved methods. By using a cleaning brush with a long handle, and improving the technique of cleaning, it might be possible to clean the large diameter tanks as rapidly as the small diameter tanks.

The storage tanks with direct expansion coils required from seven to ten minutes more time per day for cleaning. The additional labor cost is offset by a smaller refrigeration cost in comparison to the cold wall tank. However, the ease and comfort of cleaning, and the possibility of contamination, if improperly cleaned, are factors which should be considered.

The vertical cylindrical storage tank offers a possibility of saving floor area. The number of dairy plants using vertical storage tanks with capacities over 2000 gallon is limited. The daily cleaning saving for the vertical tank, for either bottom or top opening, was four minutes. The daily total fixed cost for a 2000 gallon vertical storage

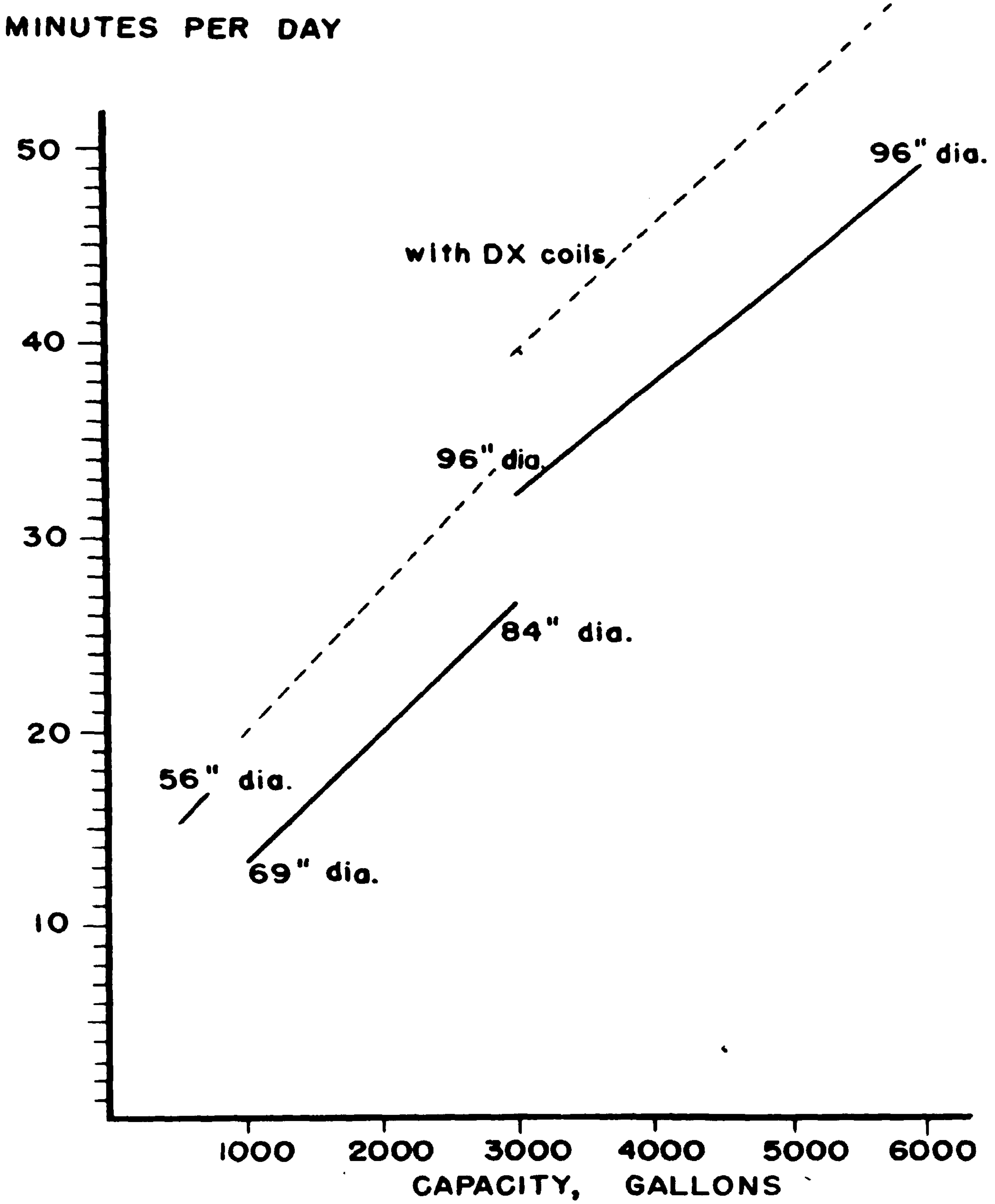

FIG. 26. TIME REQUIRED TO CLEAN HORIZONTAL STORAGE TANK

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tank is $1.92 as compared to $2.05 for the horizontal tank. The total daily saving of the 2000 gallon vertical tank is $0.25, which amounts to a yearly saving of ninety-one dollars. In plants where both horizontal and vertical storages of 2000 gallon capacity were used, the workers favored the vertical storage. The room ceiling height must be considered for the large vertical storages. About two minutes more were required for cleaning the 1000 gallon with an outside finish of stainless steel in comparison to the enamel finish.

The use of air for mixing the milk in storage tanks offers a method of decreasing the energy requirements for mixing and for shortening the time required for agitation. When using mechanical agitation, twenty minutes is usually required to agitate a tank of milk with a two horsepower

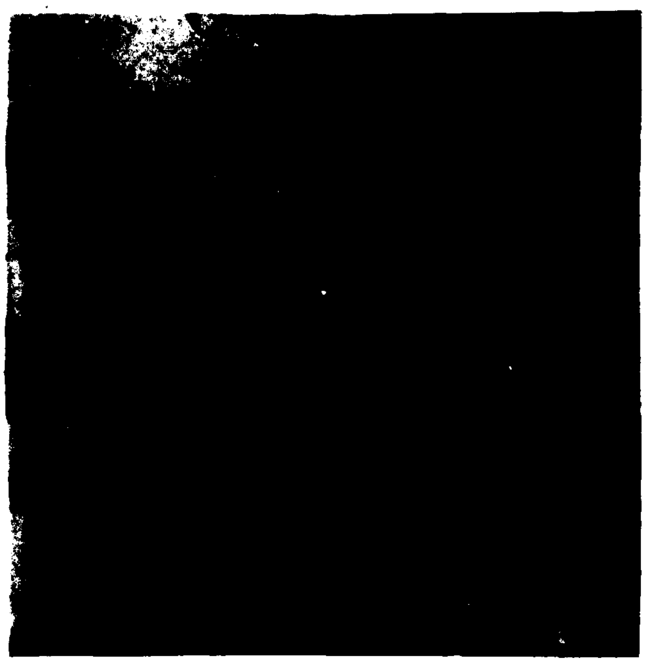

Fig. 27. A Cut-away View Showing Air Agitation in a Storage Tank (1)

1. Stork, Ralph E., "Air Agitation of Milk," Milk

motor. With air agitation (See Fig. 27) it takes about three minutes and requires one-half horsepower motor (1).

5. Internal tube heater. Milk may be standardized for butterfat by mixing the correct proportion of low and high test raw milk. A more common method, when permitted by law (2) is to separate the cream from the skim milk and make the milk at the correct test by adding cream or skim milk.

For separation, milk is usually heated to 90° F. (3). If the milk is to be vat pasteurized, it may be heated to 140° F.

The internal tube heater is generally used for heating the milk before separation. The total and unit costs are shown in Figs. 28 and 29, and are based on heating the milk from 40° to 90° F. A steam heating efficiency of 75 per cent was used for the basis of the calculations.

The cleaning time depends on the number of tubes and amounts to 1.20 minutes per tube.

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1. Stork, Ralph E., op. cit. p. 36.
2. Fouts, E. L., and T. R. Freeman, Dairy Manufacturing Processes, Wiley and Sons, N. Y., 1948, p. 107.
3. See discussion under separation.

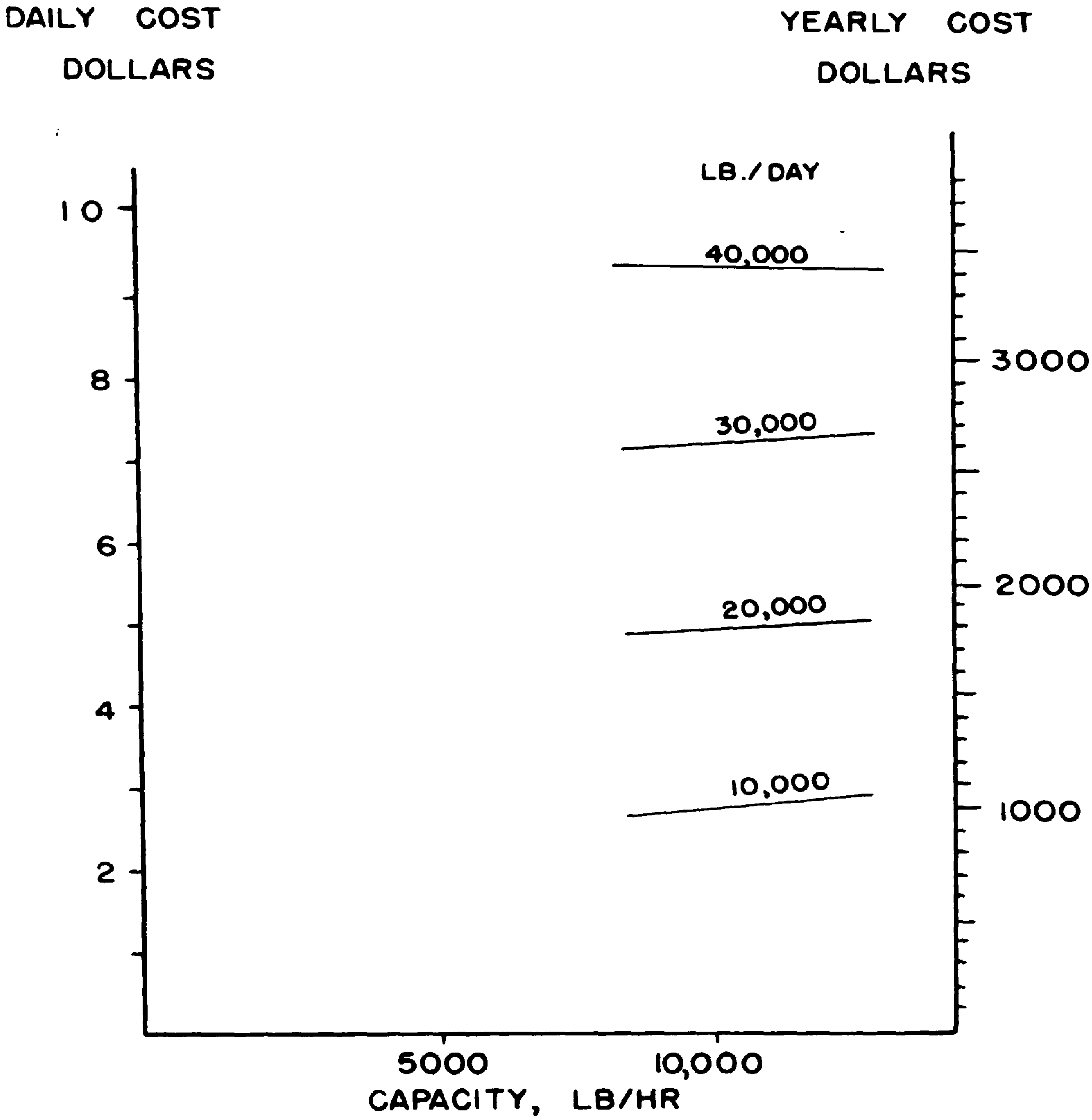

FIG. 28. TOTAL COST OF OPERATION OF INTERNAL TUBE HEATER

HEATING FROM 40 TO 90° F.

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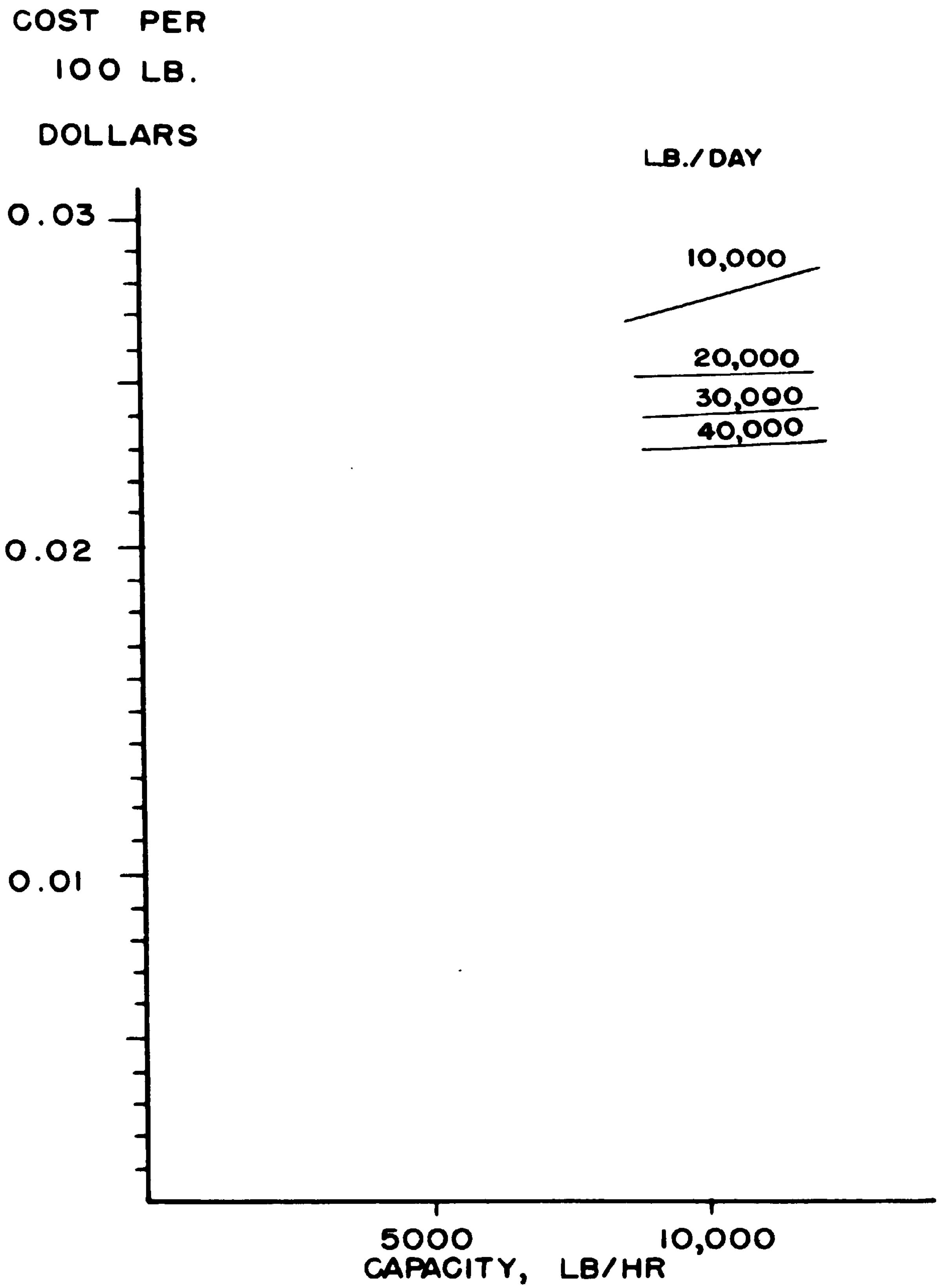

FIG. 29. UNIT COST OF OPERATION OF INTERNAL TUBE HEATER

HEATING FROM 40 TO 90 °F.

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6. Separator. The total and unit costs of the operation of the separator are shown in Figs. 30 and 31 for separating milk at 90° F. The costs are shown for separation rates up to 11,000 pounds per hour. One-tenth of the total operating time was charged against the operation as supervisory labor. This could be attained with one separator and heater operating together. However, the supervisory time in some plants is as high as one-third to one-half of the operating time when two or more separators are connected together.

The 3,500 pound per hour warm milk separator is the most economical for volumes up to and including 15,000 pounds per day; the 7,000 pound per hour separator is the most economical for 20,000 to 40,000 pounds per day; the 11,000 pound per hour separator for volumes above 40,000 pound per day. For cold milk separation, the 2,000 pound per hour unit is the most economical for volumes up to 10,000 pounds per day; the 4,000 pounds per hour unit for from 10,000 to 20,000 pounds per day; the 6,000 pounds per hour unit for volumes above 20,000 pounds per day.

The 3,500 pound per hour separator requires three-fourths of an hour for cleaning and the 11,000 pound per hour separator requires seven-eighths of an hour for cleaning, which amounts to a considerable charge to the operation. The larger separator does not require proportionately more labor for cleaning.

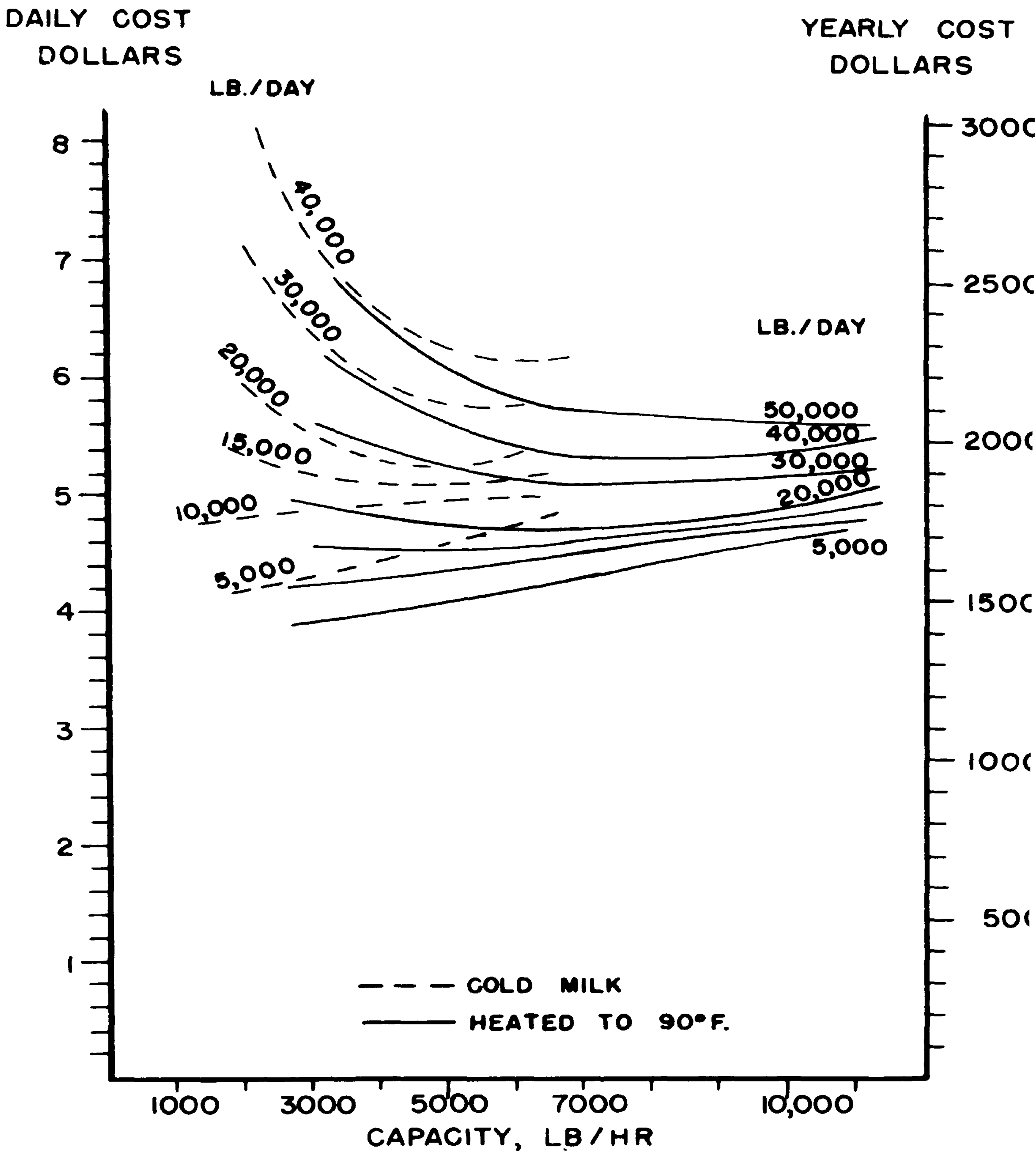

FIG. 30. TOTAL COST OF OPERATION OF SEPARATOR

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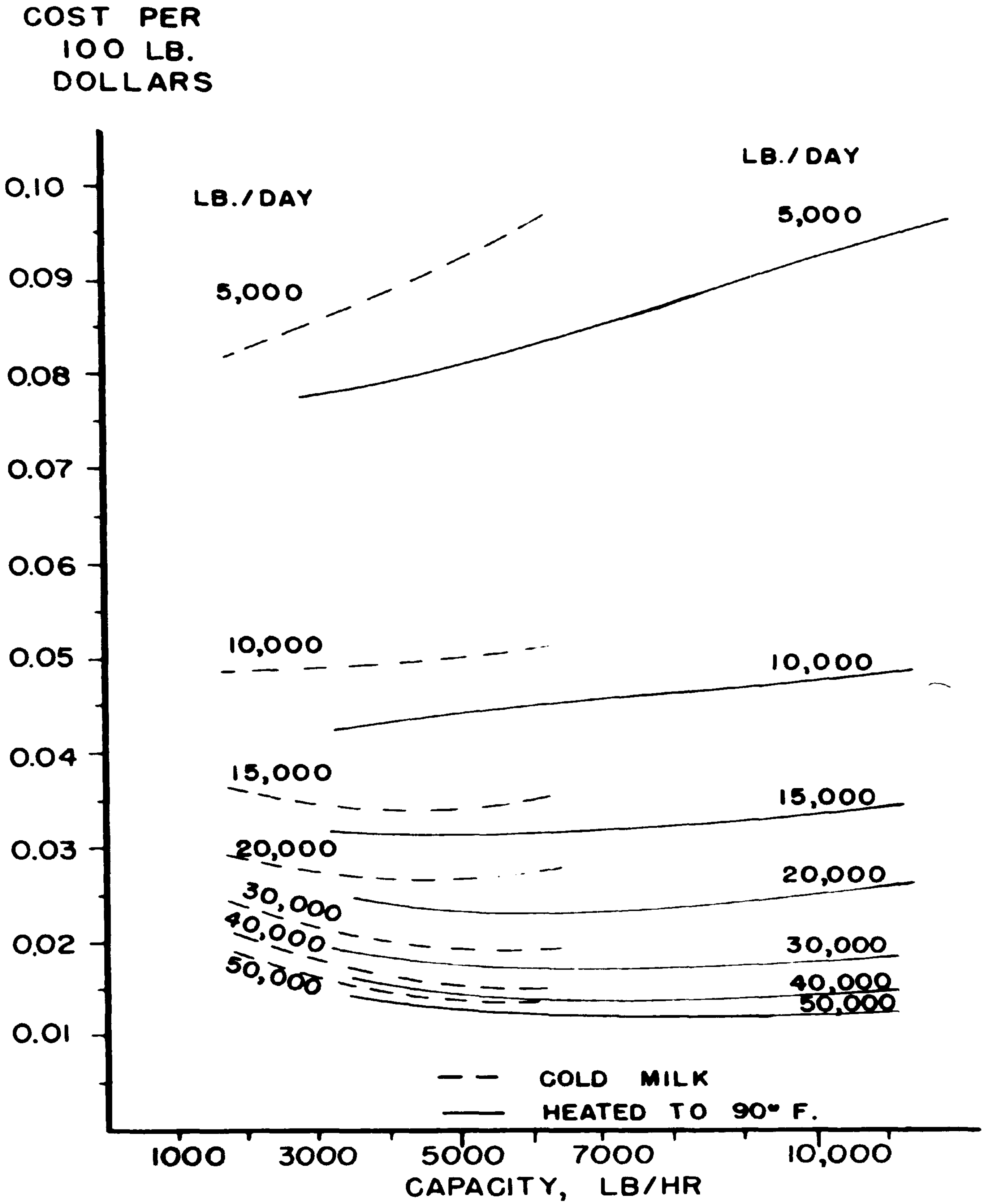

FIG. 31. UNIT COST OF OPERATION OF SEPARATOR

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There are several possibilities of reducing the cleaning time. There should be a parts rack upon which the parts can be placed as they are washed and on which the parts can be rinsed. The parts rack should be near the separator. A separator for a dairy plant which would not have to be taken apart every day for cleaning should be the prime objective of manufacturers. A drain should be close to the separator because of the long period of time required for washing, during which the water is running. The possibility of decreasing the cleaning time by having two men work together while cleaning the discs should be investigated.

Cold milk separation is coming into use. The capacity of the separator at 40° F. is approximately fifty-five per cent of the capacity at 90° F. The problems involved with auxiliary equipment as heating, cooling, and piping, as well as floor space requirements, are considerably less with a cold milk separator.

The conventional and cold milk separator can be compared by referring to the data in Fig. 30. If it is necessary to separate 20,000 pound of milk per day at the rate of 11,000 pounds per hour, the following daily costs are obtained:

(a) Separation at 90° F.

Cost of separating, 11,000 lb. per hr.	= $5.04
Cost of heating	= 4.97
Total (not including cooling)	10.01

(b) Cold Milk Separation, 40° F.
Need two separators, each at 5500 lb per hr.
Cost of each for 10,000 lb. per day = 4.85
Total cost = 9.70

The advantage in favor of cold milk separation would be greater if cold milk separators were available in larger sizes to eliminate the necessity of more than one unit. The cleaning time required for a unit twice as large could be expected to be one-sixth greater.

7. Homogenizer. In the continuous process using the HTST (1) pasteurization operation the milk is heated in the first stage, then it is homogenized at a temperature between 130° and 145° F. The milk goes to the plate heaters for pasteurization after homogenization. With this arrangement the capacities of each should be the same.

Homogenization of milk is carried out at 2000 to 2500 pounds per square inch pressure. The cost of homogenization could be reduced seventeen per cent with the 2000 gallon per hour unit when homogenizing 40,000 pounds per day at 1000 pounds per square inch. An experimental valve designed to homogenize at pressures of 1000 pounds per square inch has been studied, and offers considerable promise (2). Not only will a saving in electrical energy result, but a saving in floor space and initial cost will be realized.

The total cost of operation includes a labor charge of one-third of the operating time for supervision. It appears

1. High-temperature short-time (See explanation in Glossary)
2. Loo, Ching, The Utilization of Cavitation for Homogenization, Unpublished Doctor of Philosophy dissertation, Michigan State College, 1952, p. 73.

that the supervisory time could be reduced considerably by using a pressure regulated control valve to assure constant pressure at the homogenizer.

Thirty minutes are required for cleaning the 500 gallon per hour unit and forty minutes for cleaning the 2000 gallon per hour unit. Thirty-two per cent of the cleaning time is devoted to assembling the unit for use. A parts rack should be close to the homogenizer for holding the parts as the homogenizer is disassembled. Manufacturers have done much to improve the ease of cleaning the homogenizer. Much more can be done.

The cost of homogenization is shown in Figs. 32 and 33. The cost per 100 pounds ranges from $0.011 to $0.095. This agrees with the estimated cost stated by Fouts at 0.10 to 0.20 cents per quart (1). The cost is important because many dairies charge an extra cent per quart for homogenized milk.

8. <u>Pasteurization by the holding process</u>. In this process the milk is placed in vats, heated to 142° F. and held at that temperature for thirty minutes to accomplish pasteurization. The milk may be preheated before it is placed in vats. Three types of vats are used: the coil vat, the water-jacketed vat, and the spray jacketed vat. Of these three types the coil vat is not being installed

1. Fouts, E. L., and T. R. Freeman, *Dairy Manufacturing Processes*, Wiley and Sons, N. Y., 1948, p. 155.

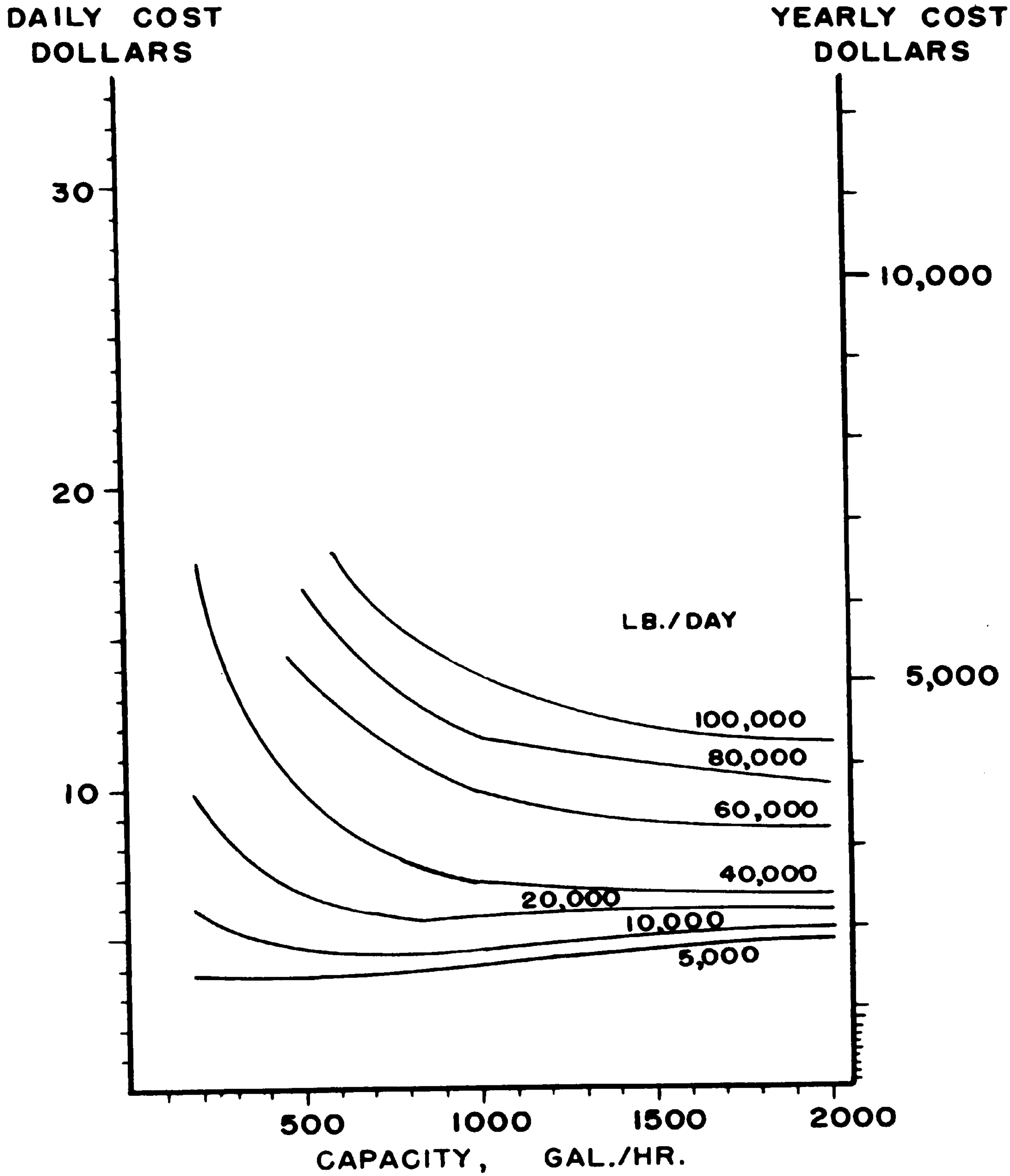

FIG. 32. TOTAL COST OF OPERATION OF HOMOGENIZER

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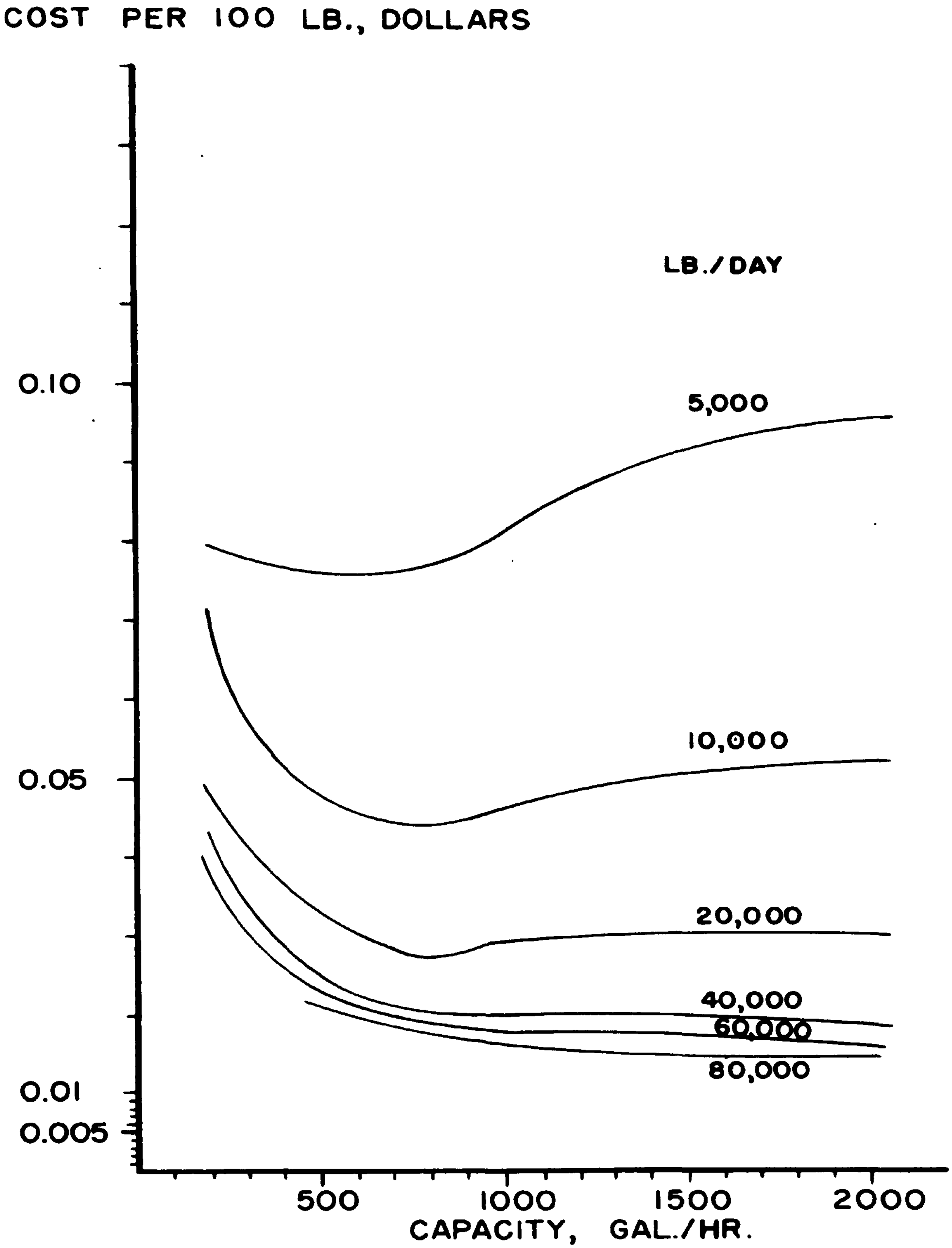

FIG. 33. UNIT COST OF OPERATION OF HOMOGENIZER

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extensively and is favored because it heats the milk rapidly with low temperature water. The milk is usually cooled over a surface cooler after batch pasteurization.

The total and unit costs of operation of the holding vats are shown in Figs. 34 and 35 for heating and cooling through 120° F. and 100° F. The 120° F. temperature difference is used for cream whereas the 100° F. temperature difference is used for milk. The process tank is less expensive to operate than the coil vat because of a lower initial cost and a lower building charge, which makes the fixed costs lower. The utilities for heating and cooling are more costly for the coil vat because its efficiency is 75.6 per cent as compared to 89 per cent for the jacketed unit. In addition, the labor for cleaning the coil vat is twice as great as that for the jacketed vessel, as is shown in Fig. 52. As the heat transfer rate through the coil vat is only two-thirds that of the process tank, the area of heat transfer of each piece of equipment was calculated, and the coil vat was penalized for the extra heating time required.

It is difficult to select the correct number and size of holding vats. For small batches it is best to have a small pasteurizer rather than to fill a large unit partially. The cost of the operation of the various sized units with different numbers of fillings can be compared by use of the cost charts. The pasteurizers are normally filled three or four times a day.

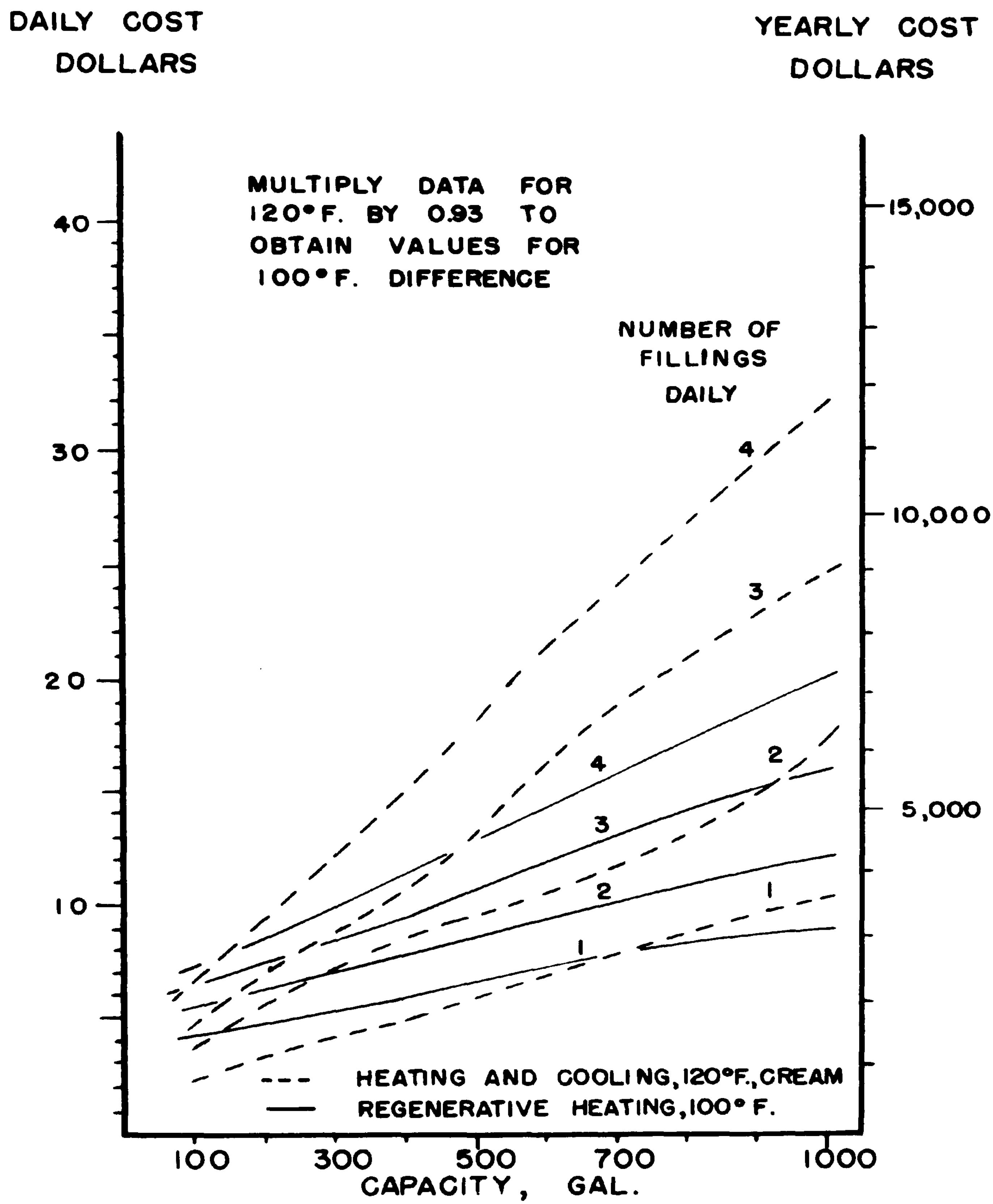

FIG. 34. TOTAL COST OF OPERATION OF PROCESS TANK

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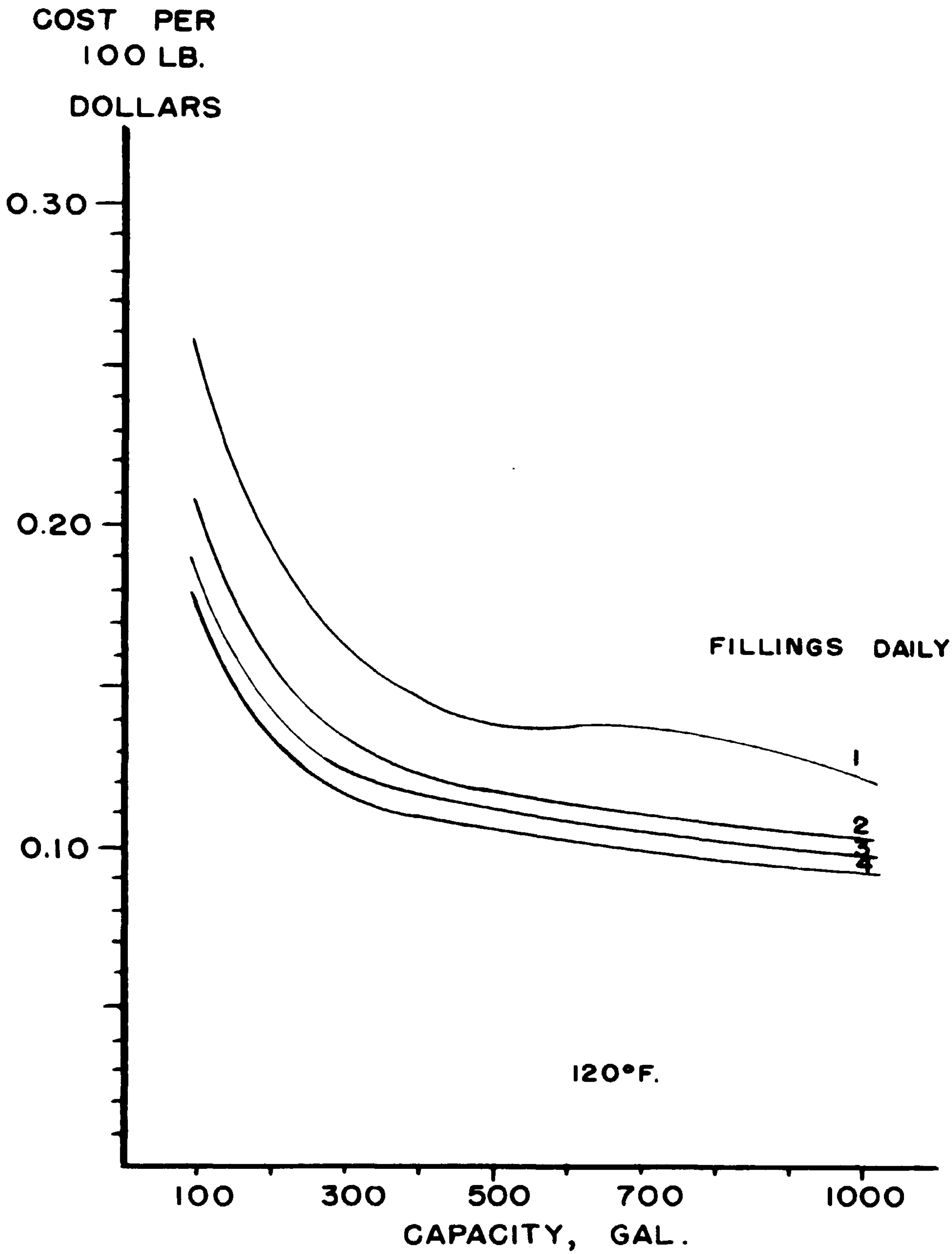

FIG. 35. UNIT COST OF OPERATION OF PROCESS TANK

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Regeneration is being used in the holding process by a few dairies. If used, the saving in steam and refrigeration requirements would be quite noticeable. Fig. 34 illustrates the comparative costs of using the holding method for processing with and without regeneration. A similar relationship exists for the coil vat. The added cost of equipment for regeneration, including a pump and motor, has been included in the analysis. This accounts for the fact that for one filling per day there is no economical advantage of using regeneration in vats of 700 gallon capacity or smaller; for two fillings per day there is no economical advantage of using regeneration in vats of 300 gallon capacity or smaller; for three fillings daily there is no advantage economically of using regeneration in vats of 250 gallon capacity or smaller; for four fillings daily there is no economical advantage of using regeneration in vats of 150 gallon capacity or smaller.

For the larger tanks, and the greater number of fillings per day, or the more milk handled daily, the greater the economic advantage of regenerative heating and cooling. In order for the holding process to compete with the HTST method, regenerative heating and cooling must be carried out.

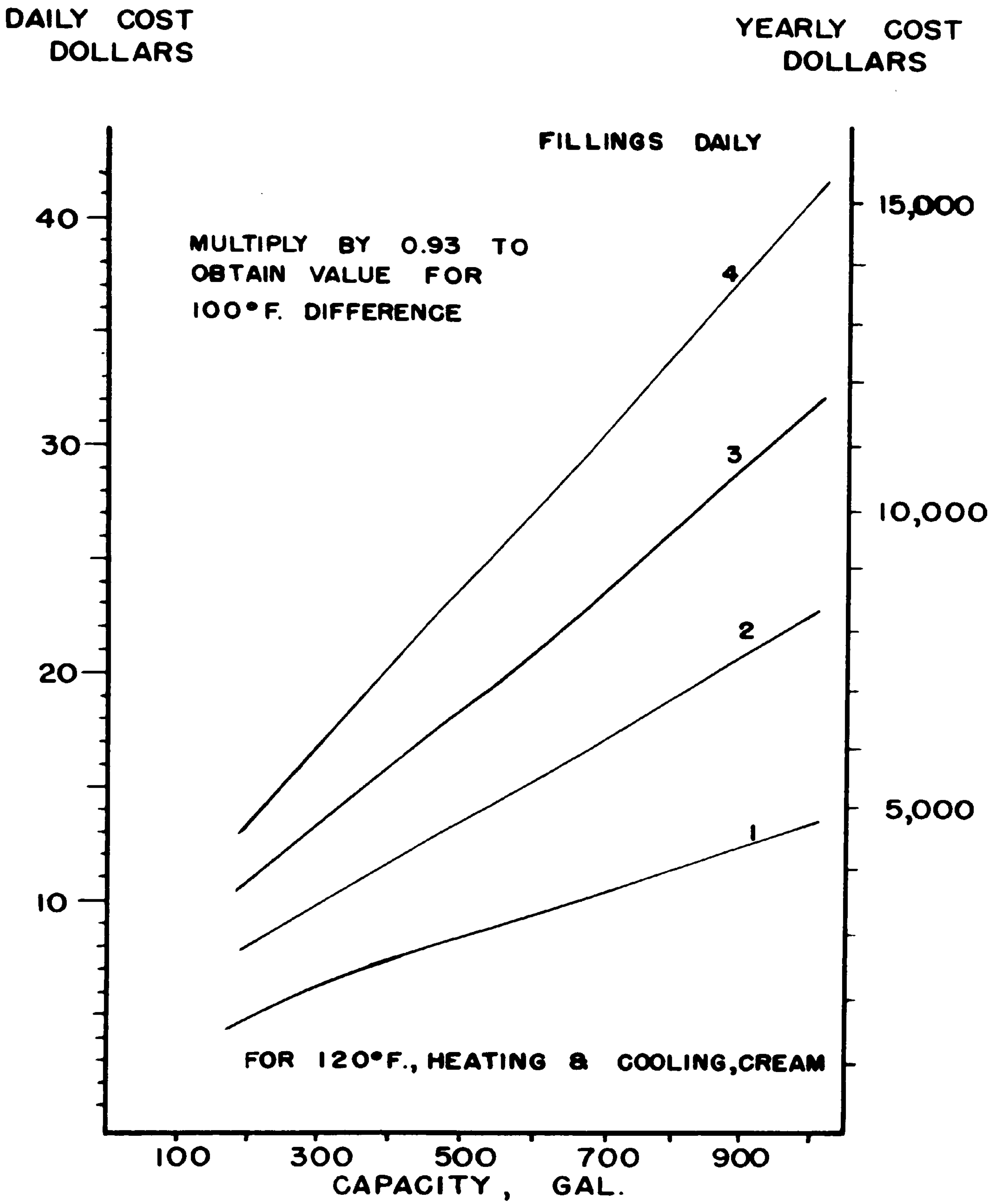

FIG. 36. TOTAL COST OF OPERATION OF COIL VAT

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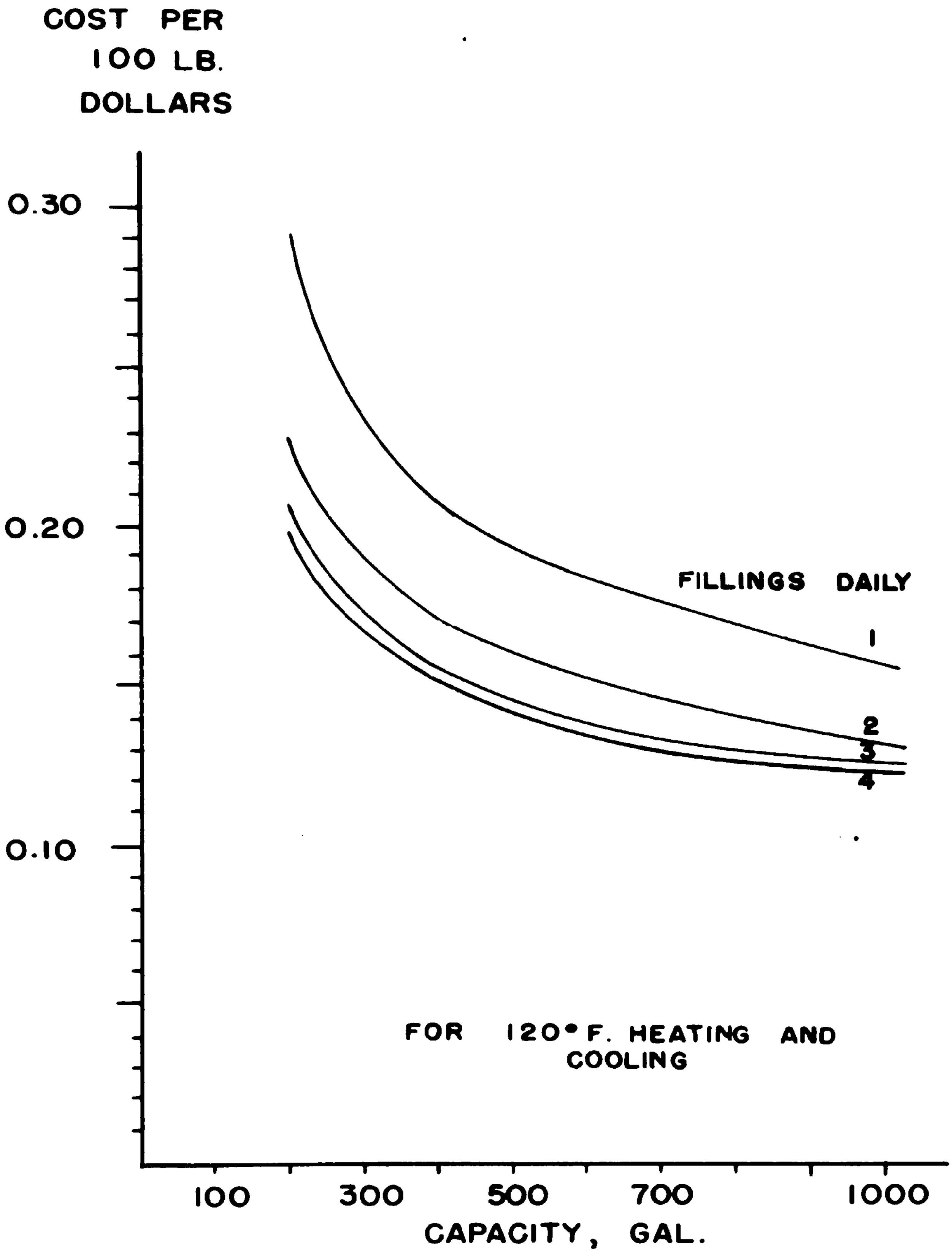

FIG. 37. UNIT COST OF OPERATION OF COIL VAT

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9. <u>High-temperature short-time pasteurization</u>. The HTST pasteurization process consists of heating the milk to not lower than 160° F., holding for fifteen seconds, and immediately cooling to 50° F. or lower. In actual practice the milk is heated to a temperature of from 160° to 163° F. The heating and cooling operations are carried out in a plate unit, similar to the plate heater, with appropriate controls.

The cleaning labor, which varies with the number of plates, is 0.65 hours for the 4,000 pounds per hour unit, and 1.95 hours for the 20,000 pounds per unit, exclusive of the positive displacement pump, as shown in Fig. 52. The first part of the cleaning is best accomplished by a centrifugal pump, which recirculates water through the plates, using the balance tank for a supply of cleaning solution. Two men can wash and inspect the plates with a total saving in time.

One-third of the total operating time was charged against the operation for supervision. The total and unit cost of the operation are shown in Figs. 38 and 39. The utility cost for heating and cooling is much less than with the holding process as commonly used, because of the benefits of regeneration. The cost of the utilities was based on seventy-five per cent regeneration, with the milk entering at 40° F. and leaving at 38° F. for bottling.

The HTST unit should be of a size to supply milk to keep the men working at the bottle filler fully occupied.

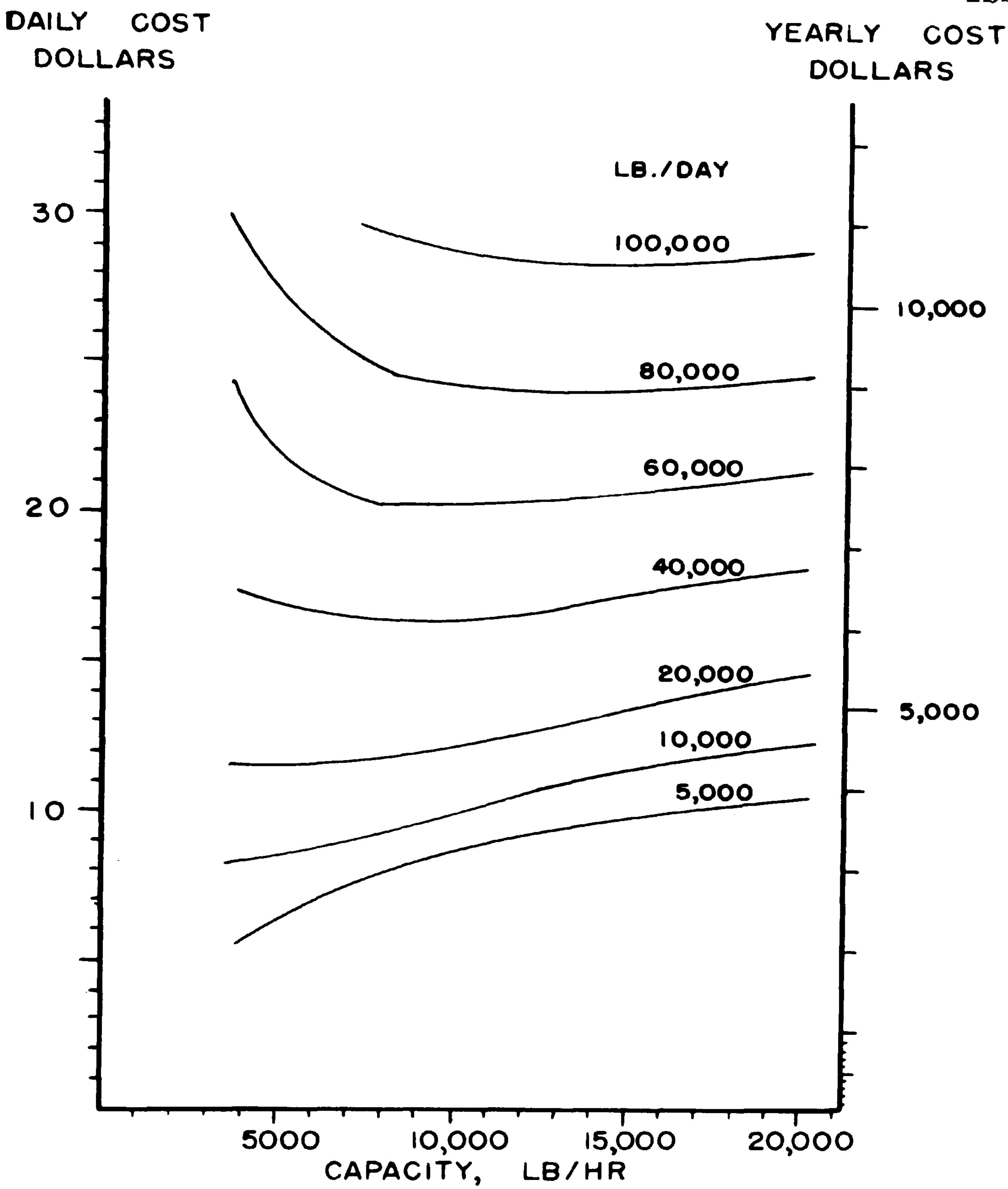

FIG. 38. TOTAL COST OF OPERATION OF HTST PASTEURIZER

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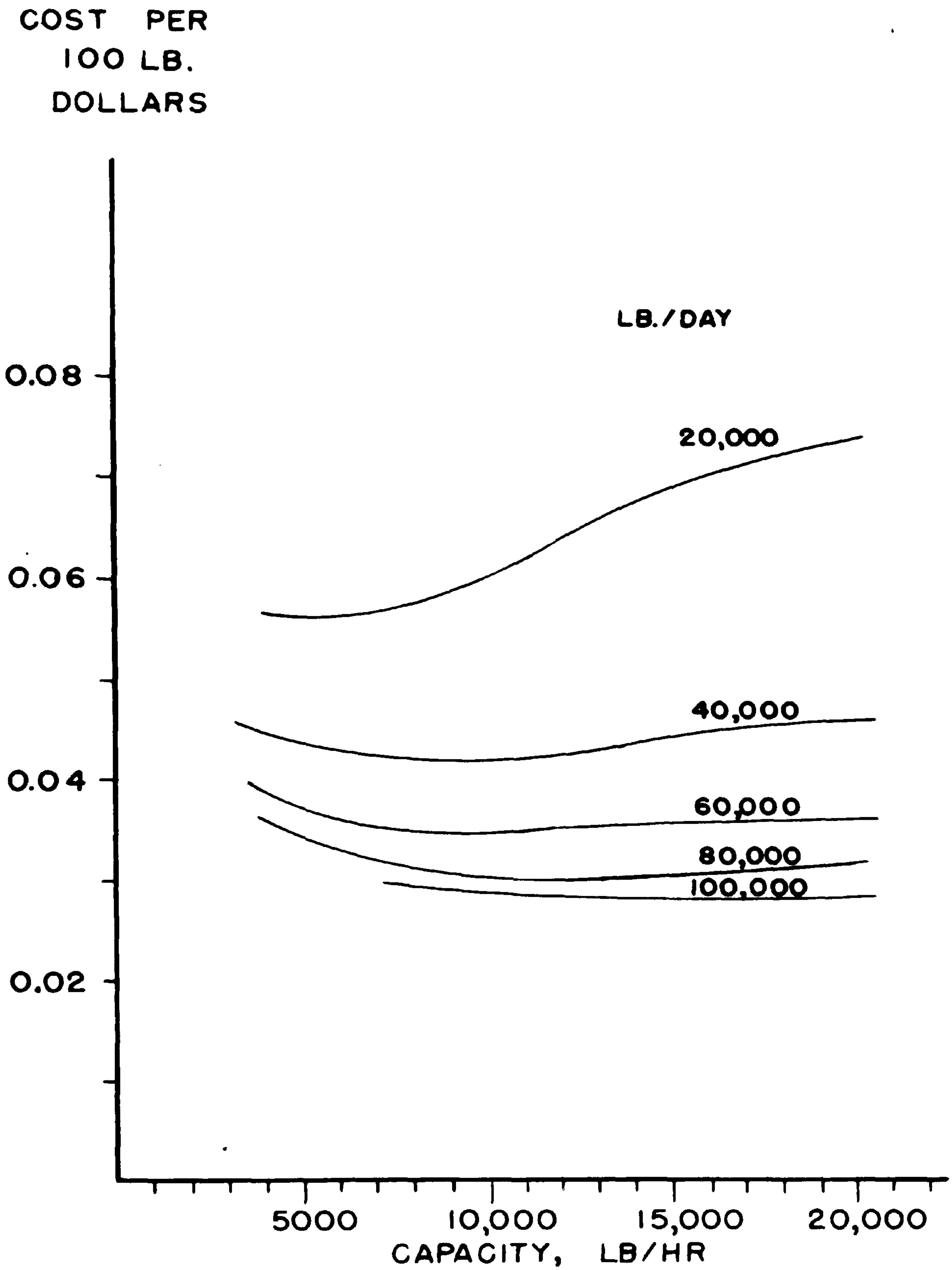

FIG. 39. UNIT COST OF OPERATION OF HTST PASTEURIZER

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One man at the glass filler can handle and inspect 63 quarts per minute or 7560 pounds per hour (1).

The question is often raised as to how small a dairy can justify having a HTST unit, which at 1952 prices costs $8,000 for a 4,000 pounds per hour unit as compared with $3,000 for a 200 gallon process tank. The question can be answered from the economical viewpoint by referring to the cost figures for the holding and HTST methods. Even if regeneration is used with the holding process, the HTST method is less expensive for any size of dairy down to 5,000 pounds per day. The cost of the additional equipment and labor required, makes regeneration more expensive for low volumes of milk in the holding process. Only at a volume of 8,000 pounds per day are the costs of both holding methods nearly equal. The economic advantage of the HTST unit and of regenerative equipment for the holding process is shown in Table XX.

When using the figures in Appendix Table XX for regenerative heating and cooling, the fact that only one set of regenerative equipment is needed, should not be overlooked. For example, if two 200 gallon process tanks are used, with two fillings daily for each, the cost for one tank with regenerative equipment is $6.22, as shown in Appendix Table XX. The daily cost of the other 200 gallon tank is $3.72 which

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1. See discussion of Glass Bottling and Paper Carton Operations for the rate of filling.

is obtained by subtracting $2.50 for the fixed cost of regenerative equipment from $6.22. Thus, the total cost of operation of the two tanks is $9.94, which is obtained by adding $6.22 and $3.72.

Table XX. Comparison of Cost of Operation of HTST and Holding Method for Pasteurization, Dollars (1)

Method	Size of Dairy, lbs. per day 5,000	10,000	20,000
HTST unit, 4,000 lb. per hr.	5.71	8.20	11.57
Holding Process, regeneration			
Using 2-200 gal. tanks	8.69	12.44	--
Using 1-600 gal. tank	7.32	9.83	14.85
Using 2-600 gal. tanks		12.14	17.16
Holding Process, no regeneration			
Using 2-200 gal. tanks	7.83	13.35	--
Using 1-600 gal. tank	6.56	10.08	16.34
Using 2-600 gal. tanks	--	13.10	20.16

10. Cooling after pasteurization. Milk should be cooled as quickly as possible after pasteurization, within thirty minutes at the most (2). The cooler is located between the pasteurizer and bottler to cool the milk. Surface, plate, or tubular coolers may be used for cooling. The cabinet surface-type cooler is usually used after the holding process. The HTST unit employs a plate cooler on the milk discharge side of the pasteurizer, which is an integral part of the unit.

The total and unit costs of the cooling operation with a surface cooler are shown in Figs. 40 and 41. The cool-

1. Approximate value of costs may be calculated from Figs. 34 and 38. Accurate costs can be calculated on the basis of the data in Appendix Tables XVIII and XX.
2. Fouts, E. L., op. cit., p. 123.

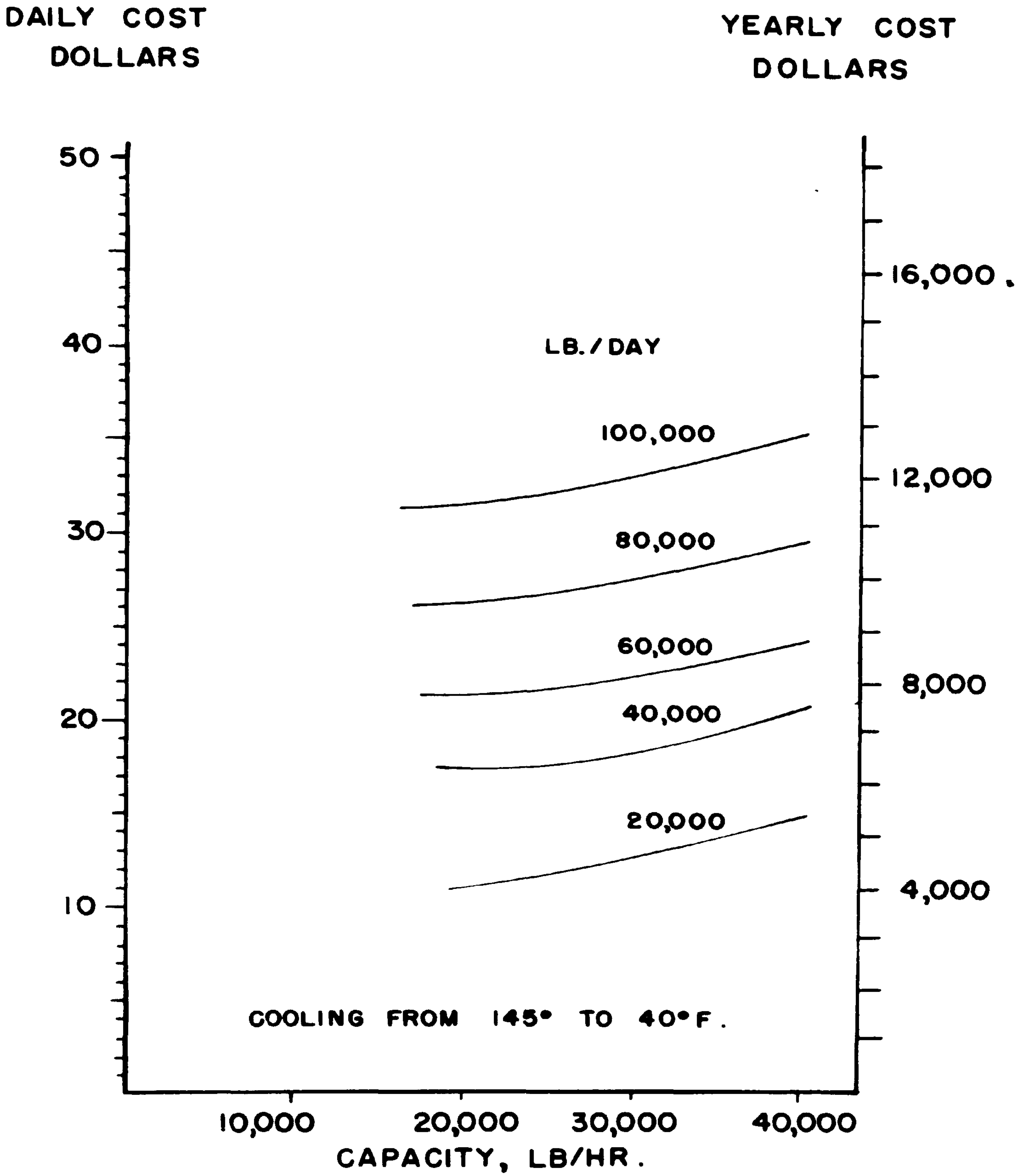

FIG. 40. TOTAL COST OF OPERATION OF SURFACE COOLER

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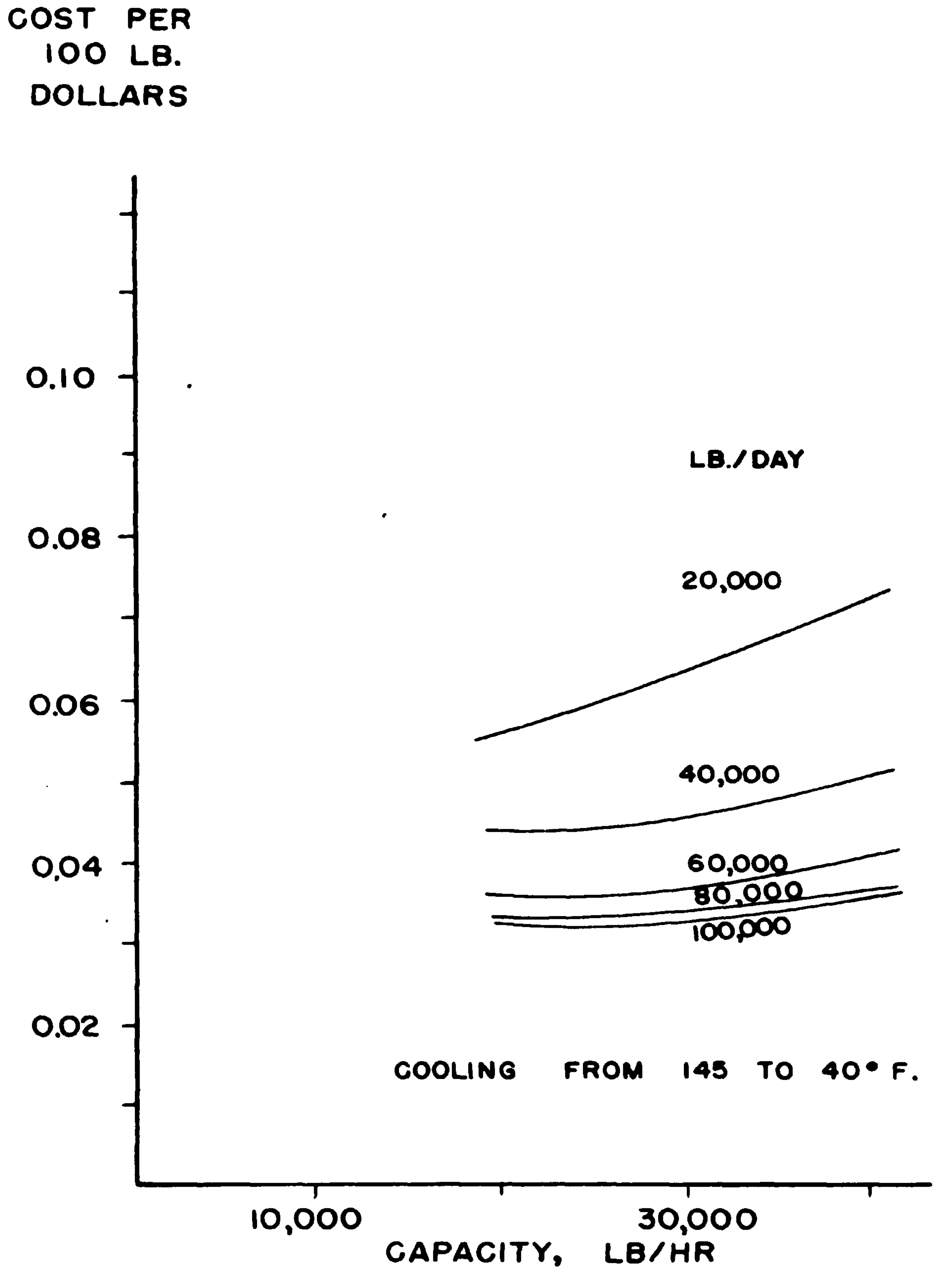

FIG. 41. UNIT COST OF OPERATION OF SURFACE COOLER

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ing was calculated on the basis of using water to cool the milk from 145° to 80° F., in which four times as much water as milk was circulated to do the cooling. The remainder of the cooling was done by an ammonia direct expansion system. The size of the cooler should be selected on the basis of the equipment with which it must function, and not on the basis of the individual costs presented in the chart.

A large reduction in the cost of cooling the milk can be accomplished by regenerative cooling, as has been discussed in a previous section. The surface cooler will then need to cool the milk from approximately 65° to 38° F.

11. Glass filling and capping. The bottling operation is the key to all the operations from the storage tank to the refrigerated bottled milk storage tank to the refrigerated bottled milk storage. The selection of a bottler of the correct capacity for present and future use should receive special consideration.

Individual glass fillers are made so that they can be adjusted for a wide range of speeds. The change of speed is practically a necessity when changing size of containers when using a continuous pasteurizer. The size of a bottle filler is designated by the number of valves and number of capping heads, respectively. For example, a 14-4 bottle filler and capper (14 valves, 4 capping heads) has a capacity of from 33 to 85 quarts per minute, and 90 pints or half-pints per minute.

It is very difficult to estimate the running capacity of the filler because of variations of products, cleaning time for different products, bottle sizes, and filler sizes in different plants. However, most fillers operate at less than 90 per cent of their rated capacity and 95 per cent of the packaged milk is in quarts (1).

On the basis of the data taken, one man can inspect and case quart bottles at the rate of 63 bottles per minute (BPM), and half-pints at 99 bottles per minute. One man can case 80 quart bottles per minute. These are the maximum speeds at which a person can be expected to perform. The values were obtained when the person doing the casing had an adequate supply of bottles in front of him, and he was working at top speed with good methods. The cases were placed so that the bottles could be easily placed in them. A foot trip was provided for releasing the cases to go into the cooler. Previously reported data gave a value of forty to fifty bottles per minute for the rate at which one man can inspect and case quarts (2).

If a bottler is operating at 90 bottles per minute, two men would be required to inspect and case the bottles in an operation where only one and one-half men would be required. It would be difficult to utilize fully the work

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1. Thompson, C. L., "Plant Operations and Efficiency," Milk Plant Monthly, May 1948, pp. 38-41.
2. Ibid.

capacity of these two men by other productive labor, unless another bottling or carton machine was feeding into the same table. The filler should be run at 60 bottles per minute for one man, or 120 bottles per minute for two men.

The charts in Figs. 42 and 43 for the total and unit cost of operation are based on 90 per cent of the milk in quarts with the remainder in half-pints. There is little difference in the cost of the operation with different filler sizes. Table XXIV in the appendix gives data for the bottling operation for 100 per cent quarts and 100 per cent half-pints. These values may be used for calculating the cost of operation of any proportion of milk in quarts and half-pints. The cost of the bottling operation for 100 per cent pints is approximately the same as the cost for 65 per cent quarts and 35 per cent half-pints. The cost of the bottling operation includes the interest and depreciation on the bottles and cases, and the cost of the caps. Calculations were carried out for an average of twenty-five and fifty trips per milk bottle.

The bottling operation is one of the most expensive of all those involved in milk processing. Methods are constantly being improved to reduce the cost of bottling. The bottle is the major item of cost and emphasis should be placed on increasing its life. Dairies can work together in recovering each others bottles through a bottle exchange. Employees should be educated and trained to handle the bottle

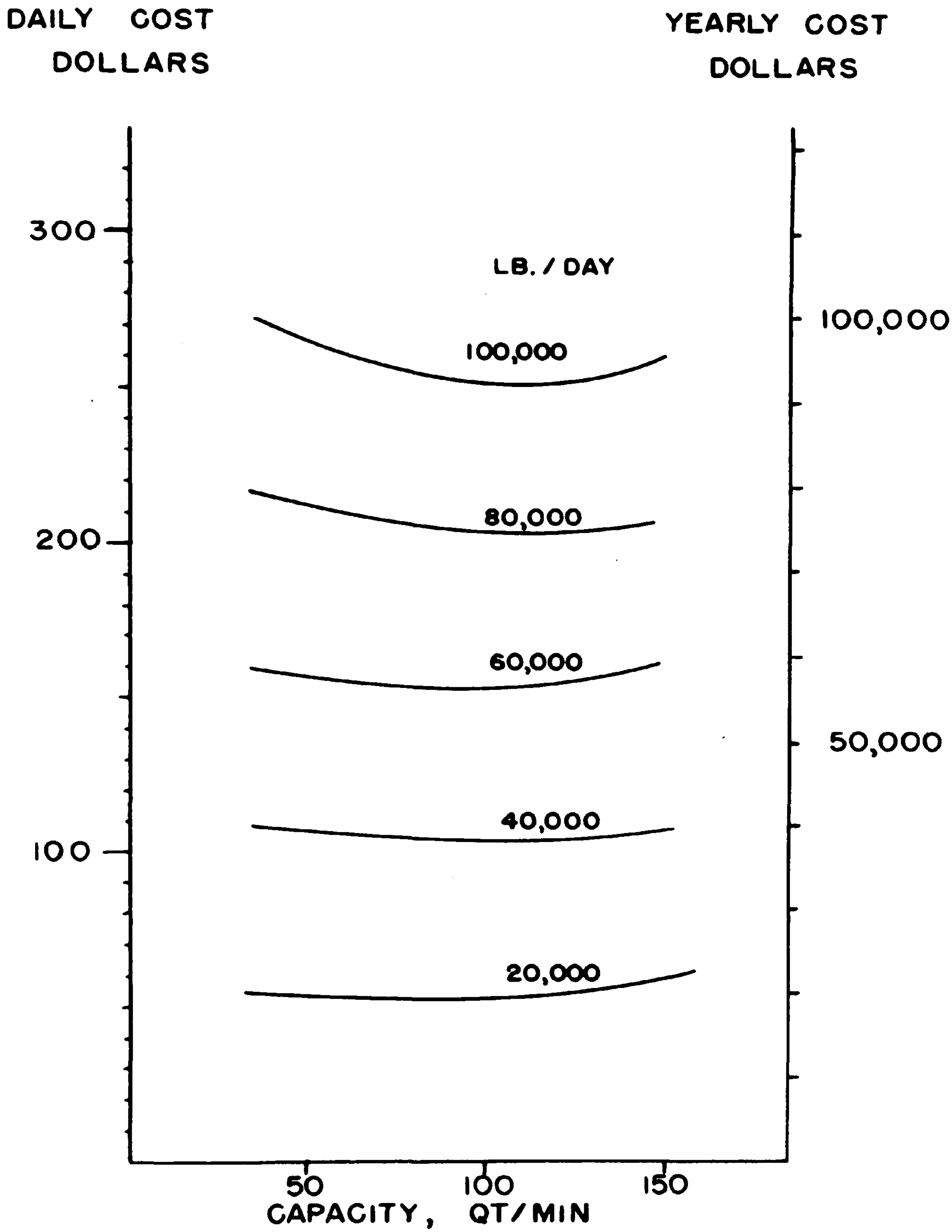

FIG. 42. TOTAL COST OF OPERATION OF FILLING AND CAPPING GLASS MILK BOTTLES
25 TRIPS PER BOTTLE
90 % OF MILK IN QUARTS

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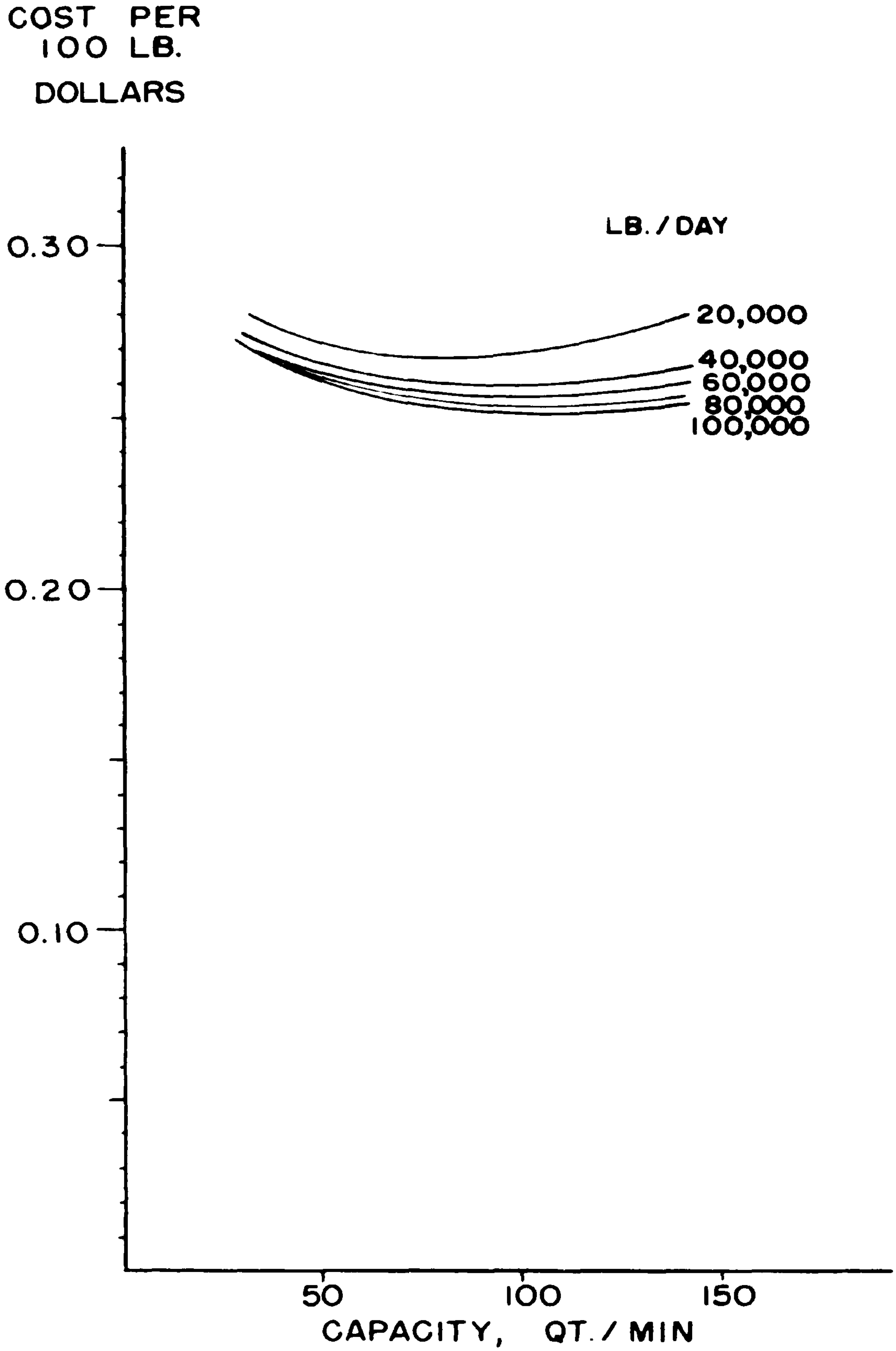

FIG. 43. UNIT COST OF OPERATION OF FILLING AND CAPPING GLASS MILK BOTTLES

25 TRIPS PER BOTTLE
90% OF MILK IN QUARTS

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with care to lengthen its life. A saving in the cost of operation of $0.05 per hundred pounds of milk can be realized by increasing the number of trips per bottle from twenty-five to fifty. This saving is greater than the cost of such operations as clarifying, cooling the raw milk, storage tank, internal tube heater, and homogenizer.

Several glass companies have developed a lightweight glass milk container which weighs about three-fourths as much as the regular bottle and costs about four-fifths as much as the regular bottle. If these bottles, which are more fragile and require easier handling, would make as many trips as the regular bottle, they would give a saving of one-fifth. The following quotation summarizes the general acceptance of the lightweight bottle:

> "We put approximately twenty-five truckloads of lightweight bottles in circulation last fall. When we first put these in circulation, most of the dairies did not want to use the regular bottle. The men on the washers like them better because of a lighter weight and the routemen liked them because of their ease in handling. After the bottles were out for about five trips, we began receiving complaints and some dairies began returning the lightweight bottle--- It (lightweight bottle) has done one thing in this market ---it has taught all of those who handle the bottle to be more careful with them." (1)

The cost of the bottle cap is nearly as expensive as the bottle. Many plants not only cap, but also hood the bottles to prevent contaminating materials from collecting on the cap. If the bottles are to be hooded, it would seem

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1. Hey, T. D., agent for USERVO, Inc., Fort Wayne, Indiana, Private Communication on June 19, 1952, in answer to letter addressed to the Fort Wayne Milk Dealers Association.

logical to select a hood which would suffice to serve as a cap as well, thus eliminating an operation. The more operations which can be eliminated at the bottler, the greater are the possibilities of keeping the machine running at rated capacity. The hooding and capping operation accounts for practically all the delays at the bottler. The bottles with smaller openings, manufactured at present with outside diameters as small as 38 millimeters, require less material for the cap, and thus reduce the cost.

The labor cost amounts to about one-sixth of the total operational cost, including cleaning, of the bottling operation. As the bottler is the final piece of equipment, and often the only one after pasteurization to touch the milk, it is very important that it be kept clean. In these tests the daily cleaning time for the fourteen and twenty-eight valve vacuum filler was 1.05 and 1.19 hours, respectively, exclusive of cleaning between different products. Five minutes are required for cleaning between different products. One and one-half minutes are required for changing the filler from quarts to half-pints, and vice-versa.

One fifth of the cleaning time of a filler is consumed in getting a hose and rinsing the inside of the bowl. A series of cleaning jets placed inside the bowl would decrease the cleaning time and add to the comfort of the worker between runs of different products, as well as at the end of the day.

Properly placed case conveyors to the storage room, and an adequate space for holding the filled bottles, are necessary to utilize labor efficiently. The empty bottle conveyor from the washer to the bottler should be covered to prevent foreign material from dropping into the clean bottles. The conveyors must be the correct height to prevent worker fatigue.

The cost of the bottling operations in Fig. 42 is based on an entirely manual handling of the bottles from the filler to the cases. The need for reducing the labor requirements at the filler has been recognized by the equipment industry. Bottles may be equipped with shoulders which may later be utilized for mechanical handling.

A semi-automatic casing system has been developed which an operator can use to increase his casing rate. Known as the Mapes system, Fig. 44, it consists of a device which will enable the operator to case 120 to 140 bottles per minute, thus doubling his working rate (1).

New handling methods which will increase the rate of casing, and reduce breakage, will inevitably be used in the dairy industry. This factor must be considered in selecting new processing equipment, not only the filler.

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1. ________ "Bottle Handlers Cut Labor, Breakage," Food Engineering, June, 1952, pp. 127, 184.

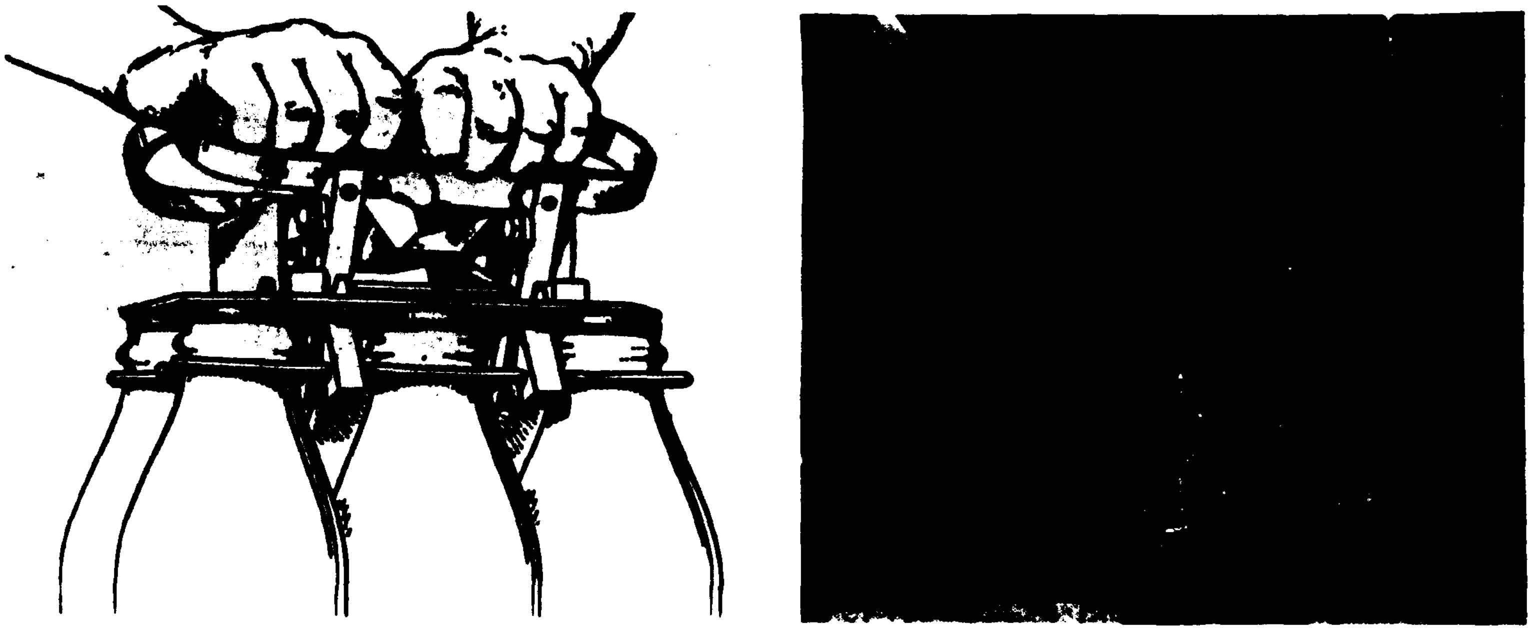

Fig. 44. The Mapes System of Casing Bottles (1)

12. <u>Paper carton former and filler</u>. Much discussion has evolved around the advantages and disadvantages of the use of paper cartons for milk containers. The discussion will be limited to tangible factual data. At present, only a limited number of companies manufacture the carton fillers, which are made in capacities of from twenty to sixty-five cartons per minute.

From the data shown in Figs. 45 and 46 the cost of the paper carton forming and filling machine operation can be compared to the entire bottle filling and bottle washing

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1. Op. cit.

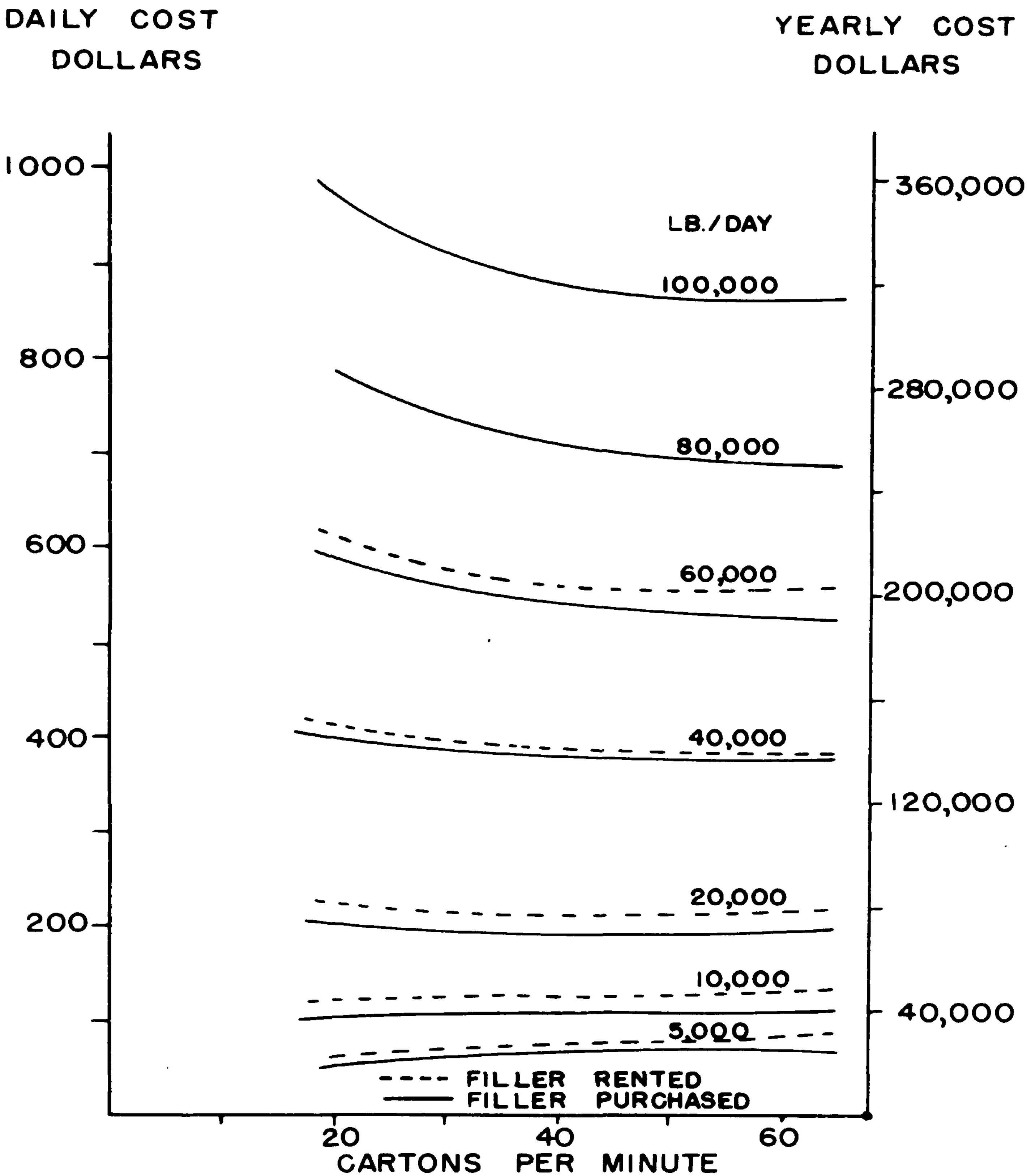

FIG. 45. TOTAL COST OF OPERATION OF PAPER CARTON MILK FILLER

90% OF MILK IN QUARTS

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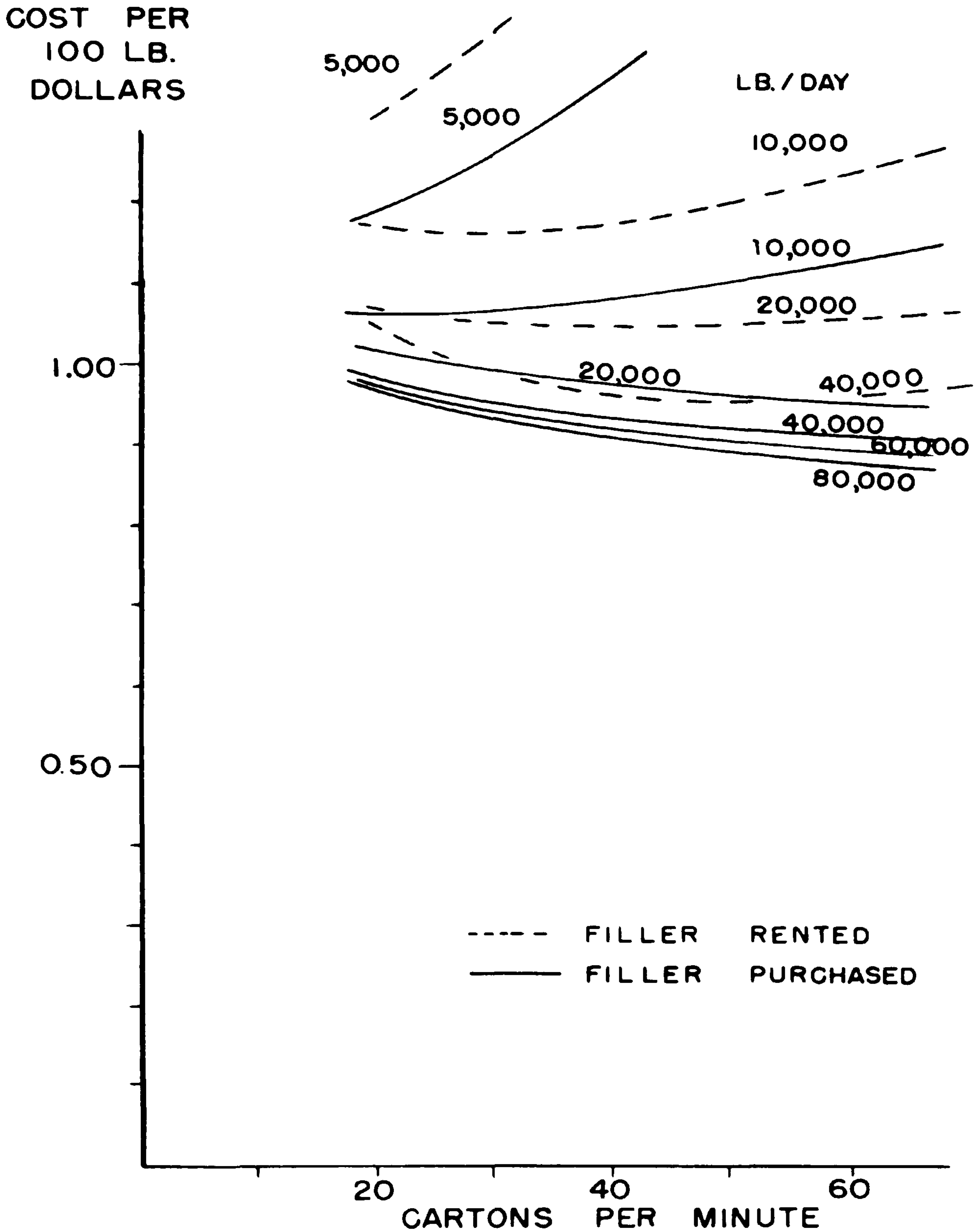

FIG. 46. UNIT COST OF OPERATION OF PAPER CARTON MILK FILLER

90% OF MILK IN QUARTS

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operation. The paper carton operation costs approximately $0.64 more per 100 pounds of milk than the glass filling operation, and $0.54 more per hundred pounds of milk than the glass filling and bottle washing operation. The difference in cost has been realized by the dairies and has resulted in a charge of an extra cent a quart for milk in the paper carton.

Two methods are used for financing the paper carton machines. They may be purchased or rented. The permanence of the use of the paper carton in the dairy industry was not seen at first. Consequently, most dairies rented their machines. The cost is considerably cheaper, however, for a purchased machine, if it is used throughout its life. The unit cost per 100 pounds is from $0.05 to $0.10 more for the rented machine.

Usually an attempt is made to reduce the cost of operations by replacing a series of operations with one operation. In the case of the paper filler the production costs have increased, and the item has stayed on the market because of customer acceptance, in spite of a higher price.

The higher cost of operation is attributed to the fact that the single service paper containers, whose initial cost is less than glass bottles makes only one trip. The total cost of a quart paper carton is $0.0001 for closing wire, and $0.0025 for wax (1).

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1. Based on operational costs of a medium-sized dairy, May, 1952.

The cleaning time is practically the same as the glass filler. The sixty-five carton per minute machine requires 1.10 hours per day for cleaning. The labor requirements could be reduced by increasing the ease of assembly and disassembly of parts. Further, labor saving could be made by reducing the supervision necessary while the machine is operating. The employee cannot conveniently supervise the machine operation and case the cartons at the same time, as can be done with the glass filler. Further reduction in labor requirement can be made by having the cartons and accessories stored close to the machine. Conveyors of the correct height, placed so the caser can quickly inspect the height of milk in the cartons are necessary. One man can handle 65 quarts in the carton per minute.

The paper cartons must be stored in a room with a temperature of 75° F., and a relative humidity of 40 per cent. The cost for cases and case handling is less per paper carton than for glass bottles because the same case is used for quarts and half-pints.

A substantial reduction of the cost of the operation of the carton filler to compete with the glass operation on an economical basis will be made possible only through a reduction in the container cost. Less expensive containers may be developed in the future, but with increasing paper costs, this seems doubtful. A substantial reduction in the cost of the carton per quart could be accomplished by concentrating the milk. Although consumer acceptance of milk concentrated to one-third of its original volume was not satisfactory in tests during 1949 and 1950 along the Eastern coast, such a procedure would offer excellent opportunities for reducing the cost to compete with glass bottles. The carton cost per quart could not be reduced greatly by using half-gallon containers (1).

13. Pipe line and accessories. The cost of the pipe line and accessories is shown in Fig. 51. The total cost includes interest and depreciation on the pipe line, valves, couplings, elbows, and labor required for cleaning, calculated on the basis of a survey of those items included in several plants. The length of pipe line will vary from plant to plant, but the values included are for plants which are considered to be well-designed. The total daily cost of a pipe line for a 60,000 pounds per day dairy is $13.47 of which $12.90, or ninety-five per cent is for cleaning labor. Seventy-five per cent of the cleaning time is required for the assembly and disassembly of the pipe line. A quick-coupling would be of great value for decreasing the labor requirements and increasing the ease of employee's work. The time required to clean different pipe line lengths and fittings is shown in Fig. 47.

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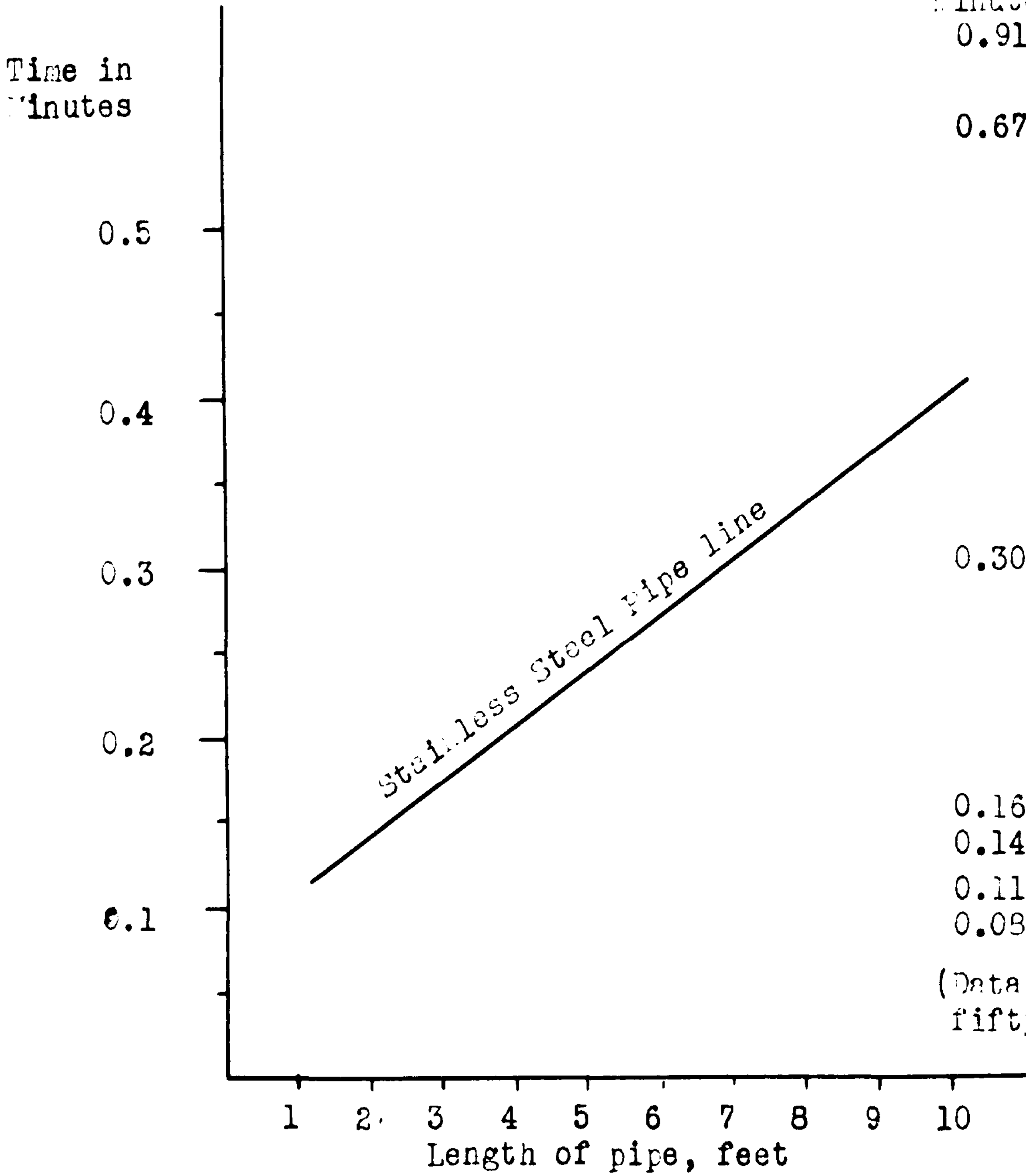
1. Based on price list A-10, June 25, 1952, the International Paper Company, N. Y. 17, N. Y., quotes quart containers at $10.40 per thousand, and half-gallon containers at $19.80 per thousand.



PIPE LINE ACCESSORIES

Minutes

- 0.914 — Cleaning valve
- 0.677 — Connect pipe with hexagonal nut and gasket

(Add 50% for placing parts on rack)

- 0.300 — Disassemble hexagonal nut and piping
- 0.161 — Wash L and place in rack
- 0.147 — Wash T and place in rack
- 0.115 — per 10 ft. of walking with pipe
- 0.080 — Wash cap

(Data calculated from at least fifty readings for each item.)

FIG. 47. TIME REQUIRED TO CLEAN PIPE LINE AND ACCESSORIES IN A DAIRY

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It will be possible to reduce the cleaning time considerably by using pipe which can be cleaned in place by recirculating methods. Based on the data of Table XXI, and assuming an equal investment for glass and stainless steel lines, glass lines cleaned by recirculatory methods would permit a daily saving of $8.90 for a 60,000 pounds per day dairy in comparison to stainless steel lines. Present health regulations do not permit universal use of permanent glass lines.

Table XXI. Comparative Time for Cleaning Permanent Glass and Conventional Stainless Steel Lines (1)

Length, ft.	Relative time Steel vs. glass
40	1/1
100	2/1
200	3/1
500	4/1
1000	5/1

1. Fleischman, F. F., Jr., and R. F. Holland, "Permanent Pipe Lines Cut Cleaning Costs," Food Engineering, November, 1951, pp. 58-60.

C. Bottle Washing Room

Glass bottle washing. Practically all plants use a soaker-type bottle washer which immerses the bottles in a strong alkali solution for about fifteen minutes. Figs. 48 and 49 show the total and unit cost of operation of a soaker bottle and case washer. The costs include the help necessary in receiving the empty bottles and a charge for broken bottles of four out of a thousand for quart bottles, plus utilities. The cost includes the cost of storage space for bottles and cases. Selection of the washer should be based on its operation in conjunction with the bottler.

The delay time at the washer is controlled by the delay time at the bottler. The bottler must be started about fifteen minutes before the bottles are needed. Planning must be done to assure the bottling operation that it will have the size of bottle desired, at the right time.

One man using good methods can feed 100 quart bottles per minute into the bottle washer. In order to do this, a washer of a width in multiples of four bottles is most satisfactory because four bottles are handled at a time.

A reduction in labor requirements will be accomplished by automatic uncasing of the bottles and loading of the washer (Fig. 50). One person would be required in the receiving room to check and stack the bottles, and at the same time supervise the operation of the automatic machine.

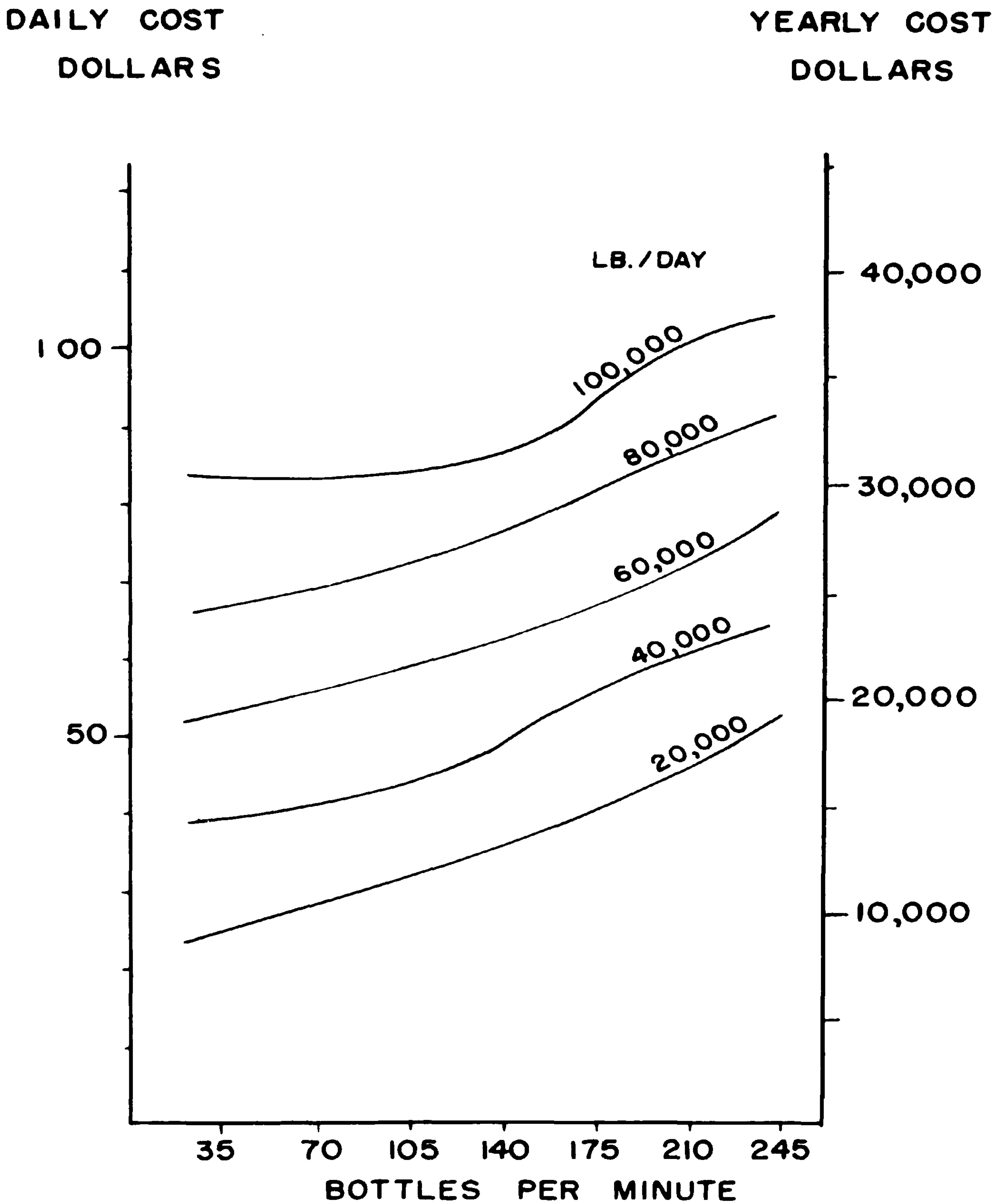

FIG. 48. TOTAL COST OF OPERATION OF BOTTLE AND CASE WASHER

90% OF MILK IN QUARTS

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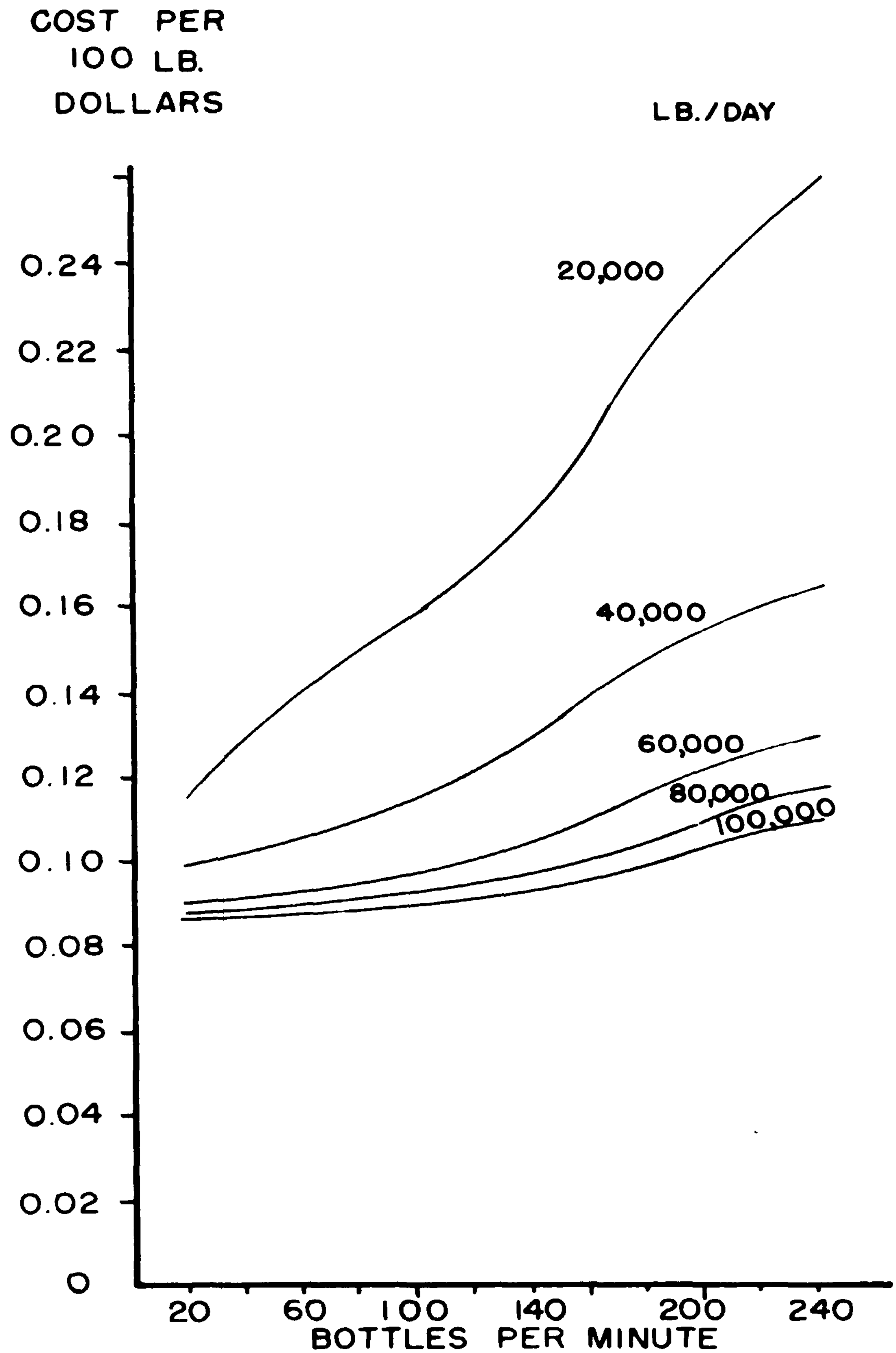

FIG. 49. UNIT COST OF OPERATION OF BOTTLE AND CASE WASHER
90% OF MILK IN QUARTS

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A bottle uncaser and washer-loader has been developed which will operate at capacities up to 576 bottles per minute and is priced in various sizes to sell from $11,000 to $20,000 (1). The automatic equipment would pay for itself by the labor replaced in a three year period.

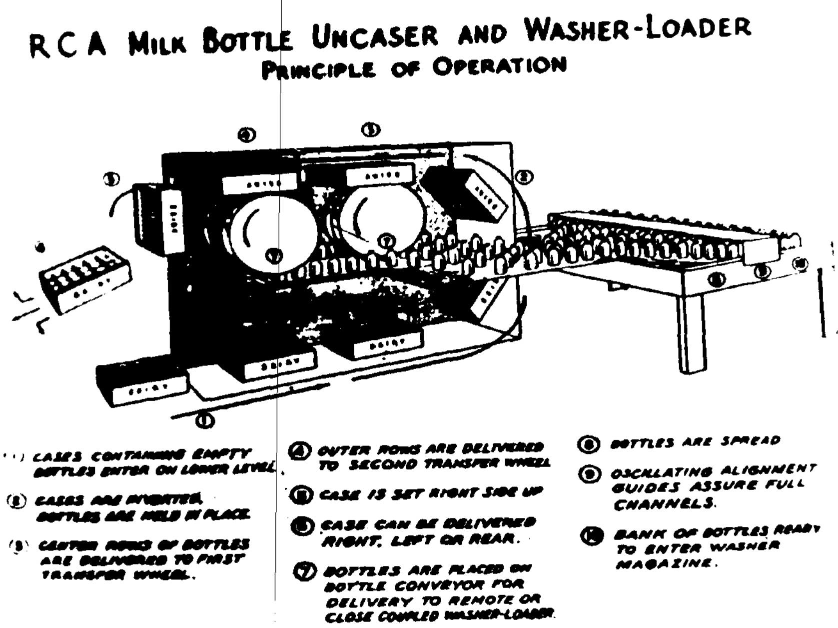

Fig. 50. Automatic Unit for Uncasing the Bottles and Loading of the Washer (2)

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1. ______________ "Automatic Uncasing and Washer-Loading with RCA Machine," Milk Plant Monthly, May, 1952, pp. 22-23.

2. Ibid., p. 23.

D. Refrigerated Storage

Refrigerated bottle and case storage. The total cost of operation of the refrigerated storage is shown in Fig. 51. The area of the cooler and the quantity of refrigeration required were based on the experience of refrigeration engineers in industry (1). The refrigeration cost is based on the use of wooden cases. The cost of conveyor and labor cost of filling the cooler were included, but the cost of loading-out was not included. The load-out labor requirements, nearly equal to the labor cost of loading-in, are shown in Fig. 51.

The possibility of reducing the labor requirement in the cooler is excellent. The milk should be stacked for easy load-out. The cases should first be stacked away from the conveyor and then stacked between the conveyor and stacked cases. Observations were made where the operator started stacking cases next to the conveyor, then walked around the cases for the subsequent stacking. A conveyor placed through the length of the storage is more desirable than one across the width, so that the cases need not be carried so far.

One person can handle a storage receiving 40,000 pounds per day in a six hour day with ninety per cent of milk in quarts, in a conveniently arranged storage. Many plants use twice as much labor.

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1. Kampman, W. J., "Principles of Mechanical Refrigeration," Creamery Package Co., Mimeograph of Dairy Engineering Short Course, University of Illinois, 1949.

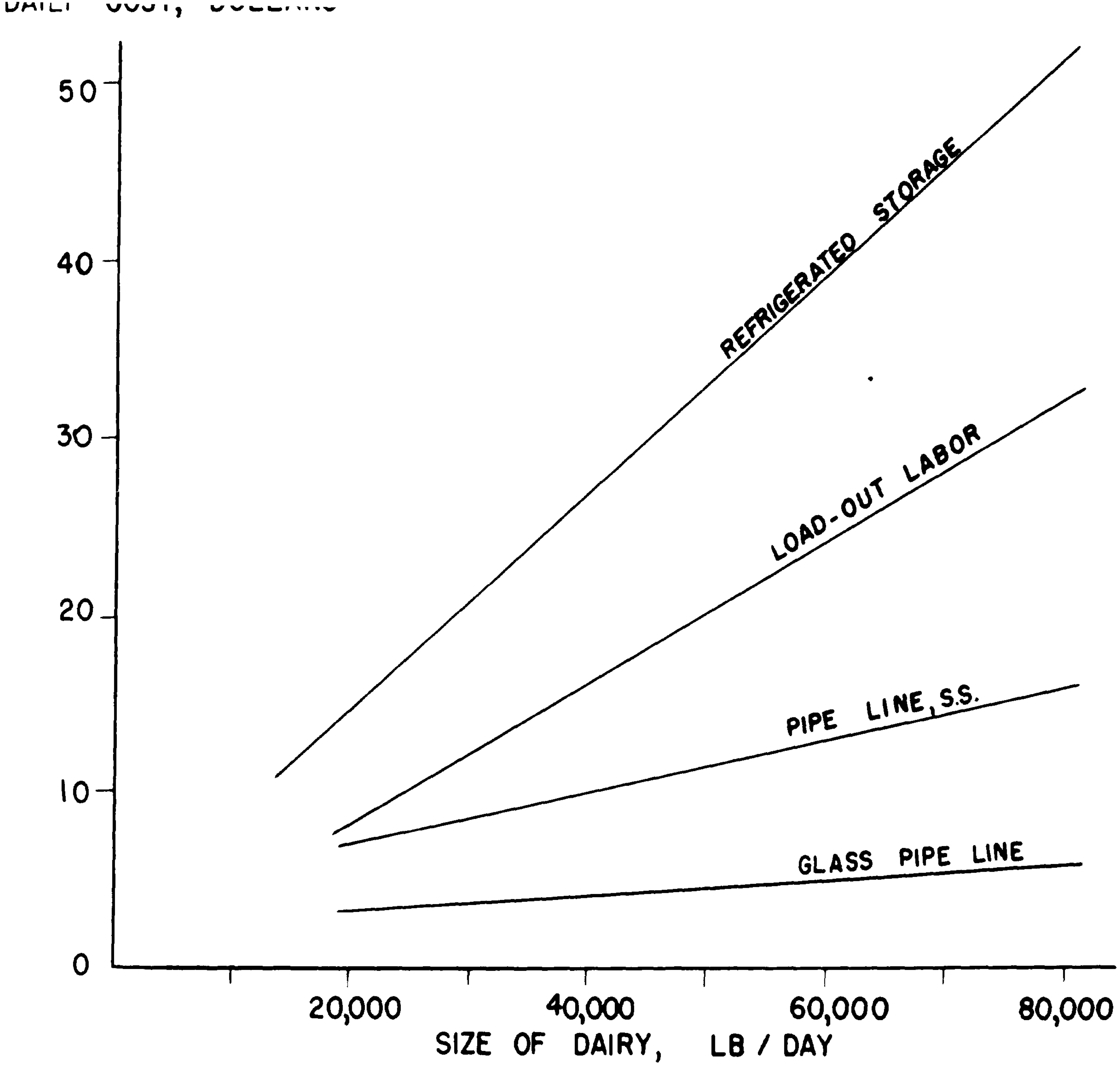
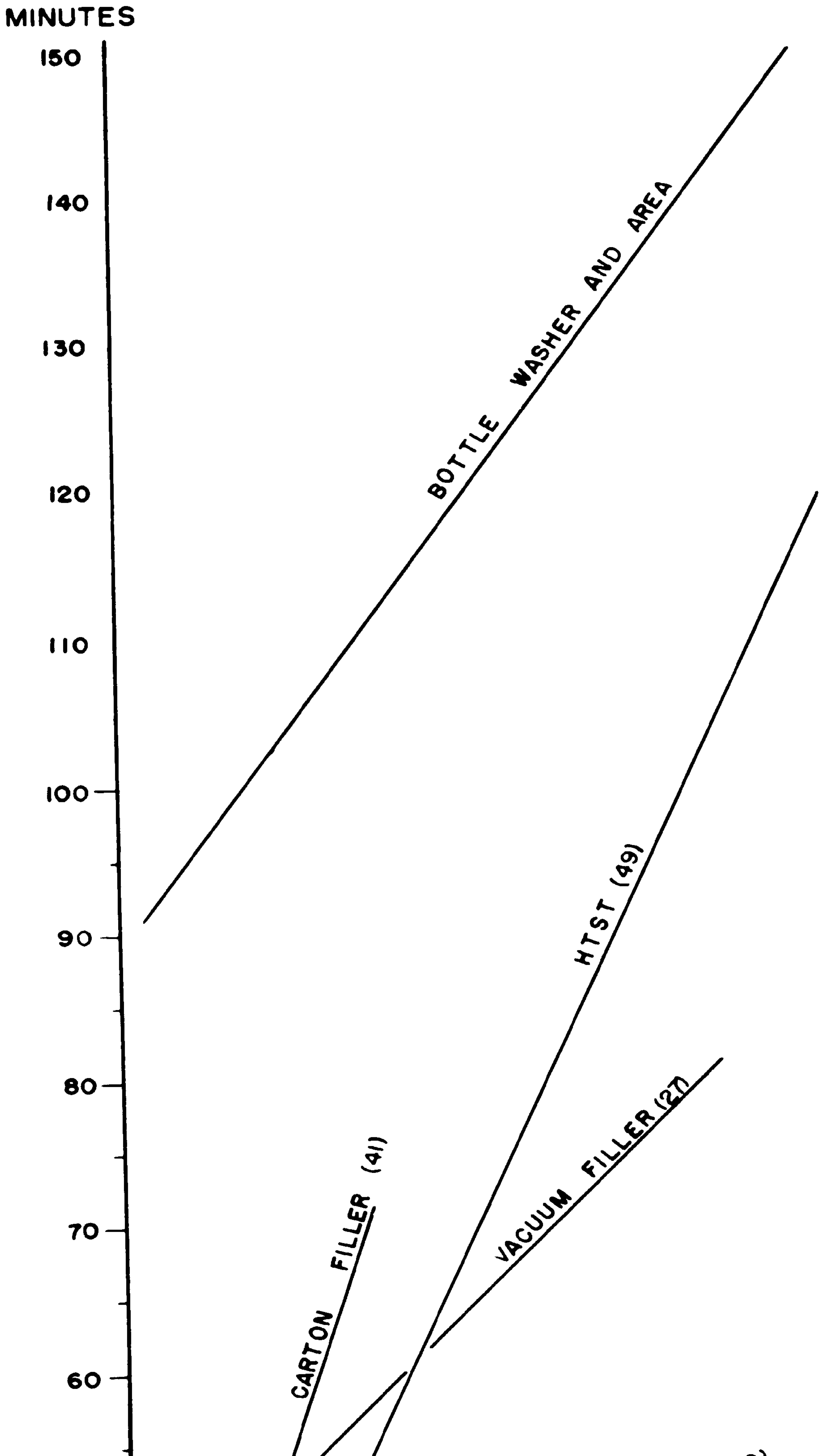


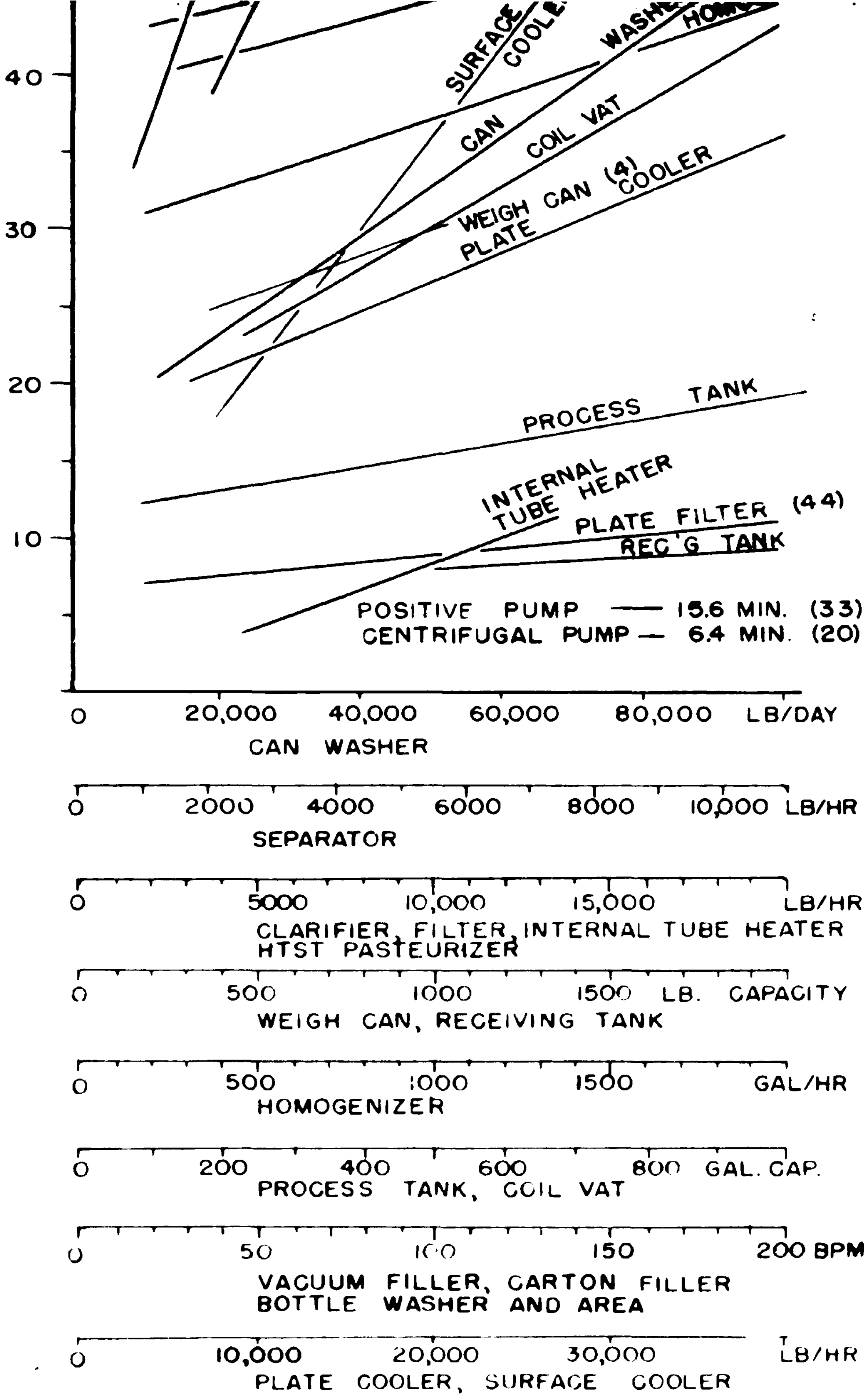
FIG. 51. TOTAL COST OF OPERATION OF PIPE LINE, REFRIGERATED STORAGE, & LOAD-OUT OF CASES

Even with a pallet system of handling, it would be necessary for a person to place the cases on the pallets. The time saving would come in loading-out the milk to the delivery trucks. A labor saving of fifty per cent could be realized (1) by using pallets. An over-all saving of five dollars a day could be made for a storage handling 40,000 pounds per day.

Pallet loaders are available in other industries, which place the cases on pallets. The use of a pallet loader is not desirable for the dairy plant because of the necessity of making up pallet loads for the delivery trucks of several different products.

1. See discussion of Materials Handling in the Review of Literature.


MINUTES
150
140
130
120
110
100
90
80
70
60
BOTTLE WASHER AND AREA
HTST (49)
VACUUM FILLER (27)
CARTON FILLER (41)



(NUMBER IN PARENTHESIS REPRESENTS PER CENT OF TOTAL TIME REQUIRED FOR ASSEMBLY OF PARTS)

FIG. 52. TOTAL DAILY CLEANING TIME OF VARIOUS PIECES OF DAIRY EQUIPMENT

VII. CHECK LIST

A. Receiving Room

1. Dumping

Cans should not pinch while dumping.

Water on the floor should drain away from the operator.

To secure a rapid dumping rate, the trucker should loosen the can lids; two truckers may work together in unloading the cans and loosening lids.

If the trucker does not loosen the lids, the person doing the dumping should loosen several lids at a time; not just one.

An automatic can lid loosener should be used for receiving at rates faster than 7.0 cans per minute.

Cans should be permitted to drain before going into the can washer; an extension should be provided on the can washer to catch the drippings from the cans.

2. Weigh can, scales, weighing, sampling

A self-closing valve on the weigh can should be given consideration. There is justification for a self-closing valve on the weigh can, particularly for a multiple-man operation.

An air-operated valve should be used to lighten the work of the weigher.

The correct size of scales and weigh can should be selected according the the size of dairy and the size of the producers.

A scales installed in a dairy should have a capacity of either 750 or 1000 pounds.

A permanent table should be placed near the sampling position for recording weights.

A foot-operated weigh can valve control should receive consideration.

The receiving tank need not be more than three times as large as the weigh can; a receiving tank two times as large as the weigh can is usually sufficient.

There is little justification for a 1000 pound weigh can unless the plant has a capacity of 60,000 pounds or more per day with fifty per cent of the producers shipping less than 500 pound lots.

The use of a print-weigh device on the scales should be considered to speed up the receiving operation.

The dial of the scales should be positioned so that it is easy to read.

A permanent place should be provided for the weigh sheets where they can be kept in order.

In a two-man operation, the weigher should be able to see can numbers easily, without the dumper retating the can.

Dumper should be able to see receiving tank so that he may avoid running it over.

Make sure that there are no obstacles to encounter when obtaining the sample.

Man dumping the cans should be able to see discharge from can washer to see if cans are being removed from the washer.

Sample bottles should be easy to obtain, clearly marked, and fitted with a lid which is easy to manipulate. Both hands should be used simultaneously when sampling.

3. <u>Can washer</u>

Can washer should operate as rapidly as worker's normal dumping speed.

The water and steam valves should be within easy reach of the operator.

The can washer should be checked regularly to see if lids are feeding through properly.

The speed of the receiving operation may be affected by direction in which the lids are taken into the washer. The cap (flat side) of the lid may be fed into the can washer to the right or left.

The lid rack from the can washer should be extended so that it is within easy reach of the dumper.

The safety devices on the can washer should be checked periodically to prevent breakage in case of an obstruction.

4. Conveyor

The connections between the gravity conveyor and roller conveyor should be carefully designed and periodically inspected to prevent lodging of the cans.

The possibility of including a cross-over between conveyor loops to facilitate handling small truck loads should be investigated.

The incoming conveyor should be level with or slightly higher than the bed of the truck.

The outgoing conveyor should be close to the incoming conveyor, but there should be sufficient area for one truck to be unloading and one truck to be loading at the same time. In large operations, the possibility of having two incoming conveyors so that two trucks could unload simultaneously should be investigated.

Conveyors should not "box in" the workmen.

Conveyors should be arranged so that a short reject line is required.

The incoming and outgoing conveyor lengths should be selected so that the dumping will not be delayed.

Conveyors should be lubricated regularly.

The pinching of the cans at the dump can be eliminated by dumping at right angles to the conveyor.

If the dumper must remove the lids, the incoming conveyor should be arranged so that he can easily travel around it.

There should be a conveyor control for the truck driver near the unloading platform.

Minimize cost of conveyor system by utilizing a single chain whenever possible.

If conveyor goes to the outside of the building, a method of locking the can pass doors must be provided. The doors should be easy to open and close.

Conveyor should be placed about 30 to 32 in. above the floor.

5. General receiving room

A truck door should be provided which can be either opened or closed or both, from the cab of the truck to eliminate the trucker from getting in and out of the truck at the loading and unloading platform.

The handling of two grades of milk should be considered when designing the receiving room.

A wash basin should be in the receiving room for the dumper.

The washing of ten gallon cans from processing room which may have been used in other operations should be considered.

The total and unit costs of the operation should be used as a guide to equipment selection.

The receiving operations should be balanced with the processing operations.

The trucks bringing in the milk from the farms should not interfere with the milk route loading and return positions.

The receiving room should be planned so that it can be easily adapted to bulk handling.

If a storage tank is placed in the receiving room, a door should be provided with adequate size to move the tank through.

Adequate ventilation should be provided--a minimum of 300 cubic feet per minute of air movement for each can per minute capacity of the washer.

Window should be placed by the unloading platform so that the trucker can see into the receiving room.

The receiving room should be well lighted--natural and artificial light.

B. Processing Room

1. Pump

A pump of adequate capacity should be selected to move the milk as rapidly as the milk is dumped in the receiving room.

A positive pump is recommended in the receiving room to avoid excessive milk loss. The centrifugal pump will leave some milk in the receiving tank.

2. Storage tank

Adequate capacity should be available for storage. In one plant six people were delayed for one and one-half hours in one day because of insufficient storage.

A storage tank is needed which is easy to get into.

3. Homogenizer

An automatic device for adjusting and maintaining the homogenizer pressure is needed to decrease the supervisory time.

Efforts should be directed toward decreasing the time of assembly and disassembly of the unit.

Low pressure means of homogenization offers a method of reducing the power requirements of homogenization.

4. Glass filler and capper

There should be sufficient space around the filler for a few empty cases and bottles.

The possibility of using rubber base crates or a pad under the bottles to prevent bottle breakage during casing should be investigated.

The glass fillers timed operated at about eighty per cent of the rated capacity.

One man should be able to inspect and case 60 to 65 quart bottles per minute.

One man should be able to case 80 quart bottles per minute.

A foot operated conveyor control should be used by the person doing the casing to release the cases to go to the storage room.

A water valve and drain should be close to the filler because it is necessary to wash and rinse the bottler several times a day.

The hooding operation should be checked regularly because it is the major source of delays at the filler.

The bottle caps should be close to the place of use.

The use of a self-cleaning and/or rinsing device for the filler should be investigated.

5. Paper carton former and filler

There is a tendency toward inefficiency when both the glass and paper fillers are used. Check to see if maximum efficiency is being obtained.

Renting a carton filler costs about ten cents more per 100 pounds of milk than when purchasing a carton filler, if the filler is used throughout its life. Careful analysis should be made to determine which method of financing a carton filler would be most economical in a particular plant.

A paper carton machine runs at about eighty per cent of its rated capacity.

The paper cartons, wax, and wire should be stored close to the filler. A two-wheeled cart is best for moving the supplies because it can be moved over a hose easier than a four wheeled cart.

The carton should be inspected for fullness by the person doing the casing.

Storage for paper cartons should be maintained at 75° F and 40 per cent relative humidity.

6. General processing room

Equipment should be placed so that the pipes can be easily lined up for assembly

There should be a minimum number of hexagonal nuts and connections.

Instruments should be mounted where there is no danger of breaking while cleaning equipment.

Instruments and gages should be placed where they can be easily seen.

Plant should be designed to permit all processing on one floor.

Dry storage should be near processing room.

Floor drains should be properly placed so that workmen need not walk through water.

Doors should be fitted so that they open and close easily.

Doors to toilet rooms must not open into the processing room.

Sills should slope down from the window at a forty-five degree angle on the inside to prevent accumulation of dust.

Milk leakage and wastage should be eliminated.

The number of manufactured products should be held to a minimum. Too many manufactured products will increase the unit cost of production.

Milk returned to the plant from the delivery routes should be utilized.

The equipment should be laid out for function.

An operation time schedule should be prepared.

The processing should be done in one shift.

C. Bottle washing

High post cases should be used to prevent bottle breakage.

The bottle washing room should be laid out so that one man can handle cases and bottles at the filler.

Clean bottles should be protected from the contaminating spray of bottles being fed into the machine.

A cover should be placed over the clean bottle conveyor to keep dirt from falling into the bottles.

A means should be provided for inspecting the cleanliness of the bottles.

The bottle washer should be started from ten to fifteen minutes before the bottles are needed at the filler.

An extra case of empty bottles should be placed beside the bottle filler operator to supply bottles to replace the broken ones. In a twelve bottle wide washer there is room for four cases in front of the operator.

The conveyors and bottle equipment should be inspected for sharp edges which may scratch the bottles and later cause breakage.

The conveyor line speed from the washer to the filler should be synchronized to prevent clashing of bottles.

The possibility of cushioning the work surfaces where bottles are handled should be investigated.

D. Refrigerated Storage

Conveyors should go all the way into the storage.

A long narrow storage, comparatively speaking, with the same conveyor for incoming and outgoing milk is desirable.

The crates should be placed away from the conveyor, and then the storage filled toward the conveyor.

If there are possibilities for expanding the business, the storage should be designed to be used for cases containing quart bottles to be stacked five cases high, then may go to seven or eight cases high to expand the use of the storage; pints may go up to ten cases high.

Loading-out time may be reduced by use of pallets.

Refrigerated storage designs should include consideration for present or future use of pallets for loading out.

E. Utilities

1. <u>Steam requirements</u>

The cleaning water should not be heated excessively for the first rinse.

Open steam lines should be used for easy maintenance.

Condensate should be returned to the boiler.

Equipment should be used as close to rated capacity as possible.

The feed water should be checked and treated conscientiously.

The exhaust gas from the boiler should be checked to determine efficiency of burning of the fuel and measures taken to improve utilization of fuel.

The agitator in the regular pasteurizer should be started before heating to prevent burning-on.

The steam valve of the can washer should be turned off after use and between loads for some washers.

Economical boiler units should be selected. The initial cost of a single boiler is less expeasive than two smaller ones. The lower operating cost of two smaller boilers is often sufficient to balance the difference in initial cost because of seasonal variations in use.

2. Refrigeration

Two small compressors should be used instead of one large one. One for sweet water, one for storage cooler.

The method of handling the milk should be analyzed to minimize opening of the doors.

Can-pass doors should be used whenever possible.

Cold water should be used generously for cooling when available.

3. Water

The use of a cooling tower for condensing water should be considered.
Valves should be used on the end of the cleaning hose for turning off and on.

F. Miscellaneous Items

1. Cleaning

Excessive rinsing of the outside parts should be avoided.

The equipment parts should be handled as little as possible.

As parts are disassembled and washed, they should be placed on a wash rack on which the parts may be rinsed.

Water should be convenient for cleaning and rinsing.

The possibilities of using high velocity jets for cleaning equipment should be investigated.

The possibility of placing the water hose on a self-winding reel should be investigated. From three to four minutes are required to wrap the hose after use.

A water valve should be placed on the cleaning end of the hose.

The water hose should not cross an alley.

2. Milk losses

The dump rail in the receiving room should not be too high.

Proper gasket connections on the pipe line and equipment should be used.

The bottles should not be filled too full.

A drip extension should be used on the washer to prevent the solids and fats from entering the sewer.

Adequate drainage of the milk can into the weigh can should be provided.

Adequate use should be made of the milk returns.

The clarifier and auxiliary equipment should be large enough to take the milk from the receiving can as quickly as it is dumped so that milk will not run on the floor.

VIII. MACHINERY SELECTION

It is usually necessary for an industry to justify changes in equipment by economical returns. At least, justification for a change in equipment can be completed more intelligently if a dollar value of costs and returns is available. These costs include not only the difference in the original cost of the equipment, but the difference in labor, floor space, utilities, etc.

One of the most popular items in the jargon of manufacturing concerns is "labor saving." In order for labor saving to be profitable, the worker must be gainfully employed on another operation, once his original task is simplified.

There are beneficial changes which do not show a financial return. Changes that provide leisure, add to the comfort of the worker, and reduce the hazards of the worker, are often necessary even though the changes would not be justified from a purely economical analysis.

The over-all process cost should be used as the economical basis of equipment selection. The same equipment would not be chosen for an operation in all plants, as an operation is only one part of the entire process. A form, similar to that of Table XXII, filled out and totaled for several

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Table XXII (a)
UNIT COST ANALYSIS
DAIRY PLANT OPERATIONS

Plant Able
Arrangement Proposal I
Chart No. 1 Sheet No. 1
Charted by CWH
Date June 25, 1952

Step No.	Equipment	Type	Capacity	Miscellaneous Information	Estimated cost per 100 lbs. (Dollars)
1	Conveyor, weigh can, etc.	Conventional	500 lb weigh can	50% milk in lots less 500	0.018
2	Can washer	Straight-away	8 CPM		0.014
3	Clarifier		20,000 lb per hr		0.0145
4	Cooler	Plate	20,000 lb per hr		0.0104
5	Storage tank	Insulated	3000 gal		0.0146
6	HTST	Plate	8000 lb per hr		0.0406
7	Homogenizer		1000 gal per hr	2500 psi	0.0191
8	Pipe line	Stain. steel		Including cleaning	0.0260
9	Glass filler	Vacuum	60 BPM	90% quarts	0.269
10	Bottle and case washer	Soaker	60 BPM	90% quarts	0.101
11	Refrig. storage				0.0678
				Total	0.5950

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Table XXII (b)
UNIT COST ANALYSIS
DAIRY PLANT OPERATIONS

Plant Able
Arrangement Proposal II

Chart No. 1 Sheet No. 2
Charted by CWH
Date June 25, 1952

Step No.	Equipment	Type	Capacity	Miscellaneous Information	Estimated cost per 100 lbs. (Dollars)
1	Conveyor, weigh can, etc.	Conventional	500 lb. weigh can	50% milk in lots less 500	0.018
2	Can washer	Straight-away	8 CPM		0.014
3	Clarifier		20,000 lb per hr		0.0145
4	Storage tank	Cold wall	3000 gal		0.0241
5	HTST	Plate	8000 lb per hr		0.0406
6	Homogenizer		1000 gal per hr	2500 psi	0.0191
7	Pipe line	Glass		Circulatory cleaning	0.0100
8	Filler	Paper	65 CPM	90% quarts	0.908
9	Refrig. storage				0.0678
				Total	1.1161

different combinations of equipment, would serve as a guide to determine the combination which would give the most economical selection.

If all the equipment were purchased in 1952, the charts and tables in this dissertation could be used for obtaining the unit cost of each operation. However, the problem of equipment selection usually entails replacing used or obsolete equipment. The original cost of the equipment, and the charges based on the cost, would usually be different. The same item of equipment manufactured by different companies have different specifications. For these reasons charts were developed to aid the dairy plant operator or engineer to calculate the fixed and production costs of equipment. The fixed costs are based on the original cost of the equipment and the production costs are based on the specifications of the equipment and the operating time. These same data can be used for comparing new pieces of equipment. No consideration has been given to the possibility of taking advantage of certain income tax laws in buying new equipment.

An example is presented to illustrate the use of the cost charts. Equipment may be replaced in a plant before or at the end of its estimated useful life. Equipment which needs excessive repairs, requires excessive utilities, or requires excessive manual labor may need replacement.

Two machines which operate 365 days per year will be compared. The old machine has not been used through its estimated useful life, but is being considered for replacement because the new machine requires less steam and labor to do the same job.

Machine A. Old machine
Total estimated life is 15 yrs., present age = 10 yrs.
Original cost = $8,000, salvage value = $500
Present area requirement = 200 sq. ft., at $1.50/cu. ft.
Electrical consumption = 3 kwh at 2 cents per kwh
Steam consumption = 20 BHP
Labor requirement, operating = 1 man per hour
cleaning = 1 1/2 hr. per day
Daily operating time = 4 hr.

Machine B. New machine
Total estimated life is 15 yrs.
Original cost = $12,000, salvage value = $700
Area requirement = 175 sq. ft. (other 25 sq. ft. can be utilized for an other operation)
Electrical consumption = 5 kwh.
Steam consumption = 15 BHP.
Labor requirement, operating = 1 man per hour
cleaning = 1/2 hr. per day
Daily operating time = 4 hr.

The annual operating costs of each piece of equipment are summarized in Table XXIII. For the comparison to be valid, the present piece of equipment must be sold for $3,000. Otherwise, the annual cost of the depreciation and interest is greater than estimated. In addition, the cost of the new piece of equipment must include the cost of installation.

Table XVIII
EQUIPMENT SELECTION & REPLACEMENT
Dairy Plant Planning
Carl W. Hall

	Old Equipment A	New Equipment B
A. Annual Fixed Costs		
1. Taxes, insurance, licenses, 3 %		
a. Building (Fig. 53)	110	90
b. Equipment (Fig. 54)	223	365
2. Depreciation,		
a. Building (Fig. 55)	75	55
b. Equipment (Fig. 56)	500	870
3. Interest, 4 %		
a. Building (Fig. 57)	75	55
b. Equipment (Fig. 58)	160	250
4. Repairs, maintenance, supplies, 4 % (Fig. 54)	320	480
Total Fixed Costs	1463	2165
B. Annual Production Costs		
1. Labor		
a. Operating	2555	2555
b. Cleaning, assembly, disassembly	958	319
2. Electricity (Fig. 59)	88	145
3. Steam (difference)	242	
4. Refrigeration		
5. Water		
6. Other, itemize: (a) ______		
(b) ______		
(c) ______		
Total Production Costs	3843	3019
C. Total Annual Operating Costs	5306	5184
D. Difference in Annual Operating Costs, Least Expensive Equipment		122

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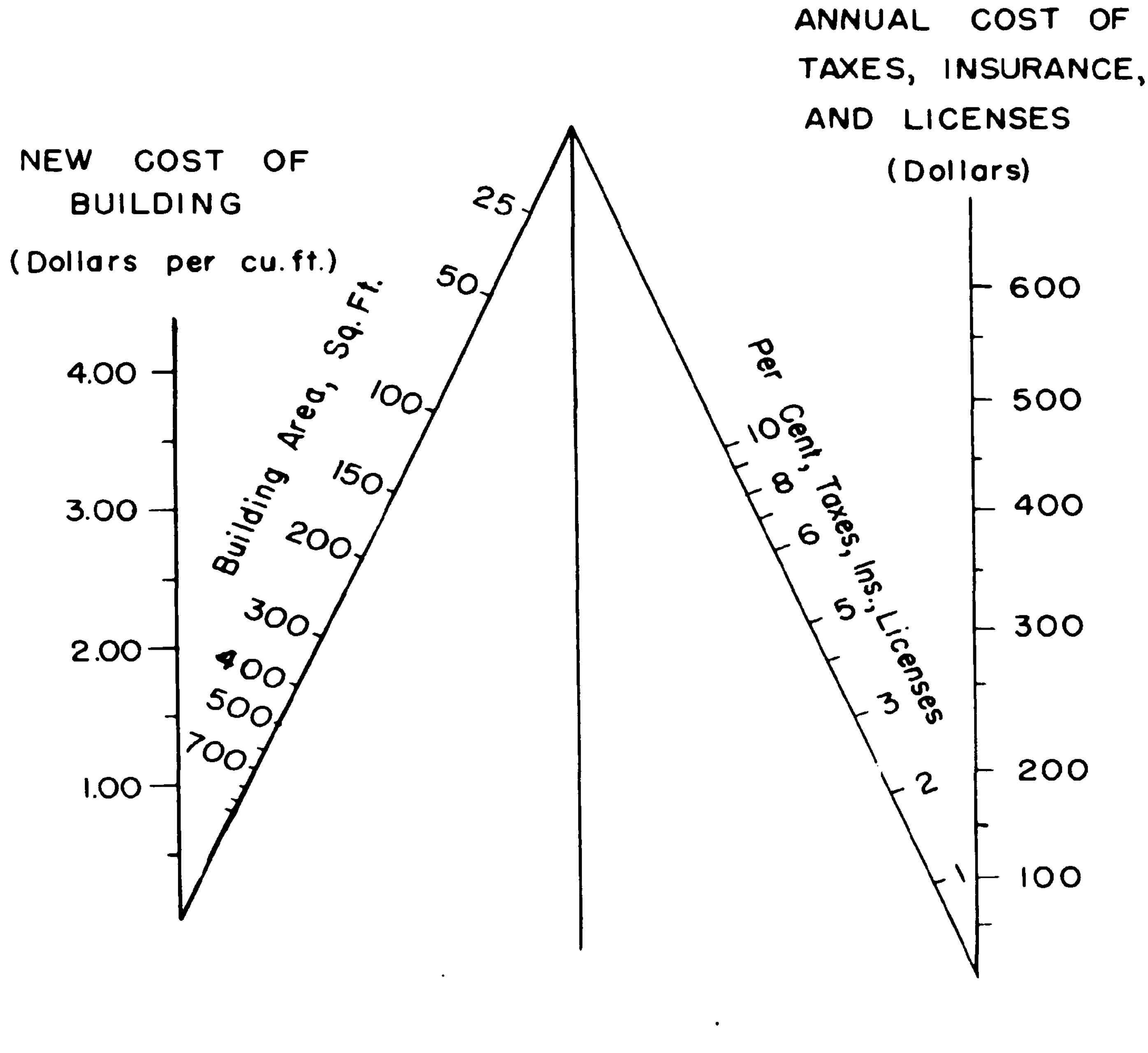

FIG. 53. CHART FOR DETERMINING ANNUAL COST OF TAXES, INSURANCE, AND LICENSES FOR BUILDING

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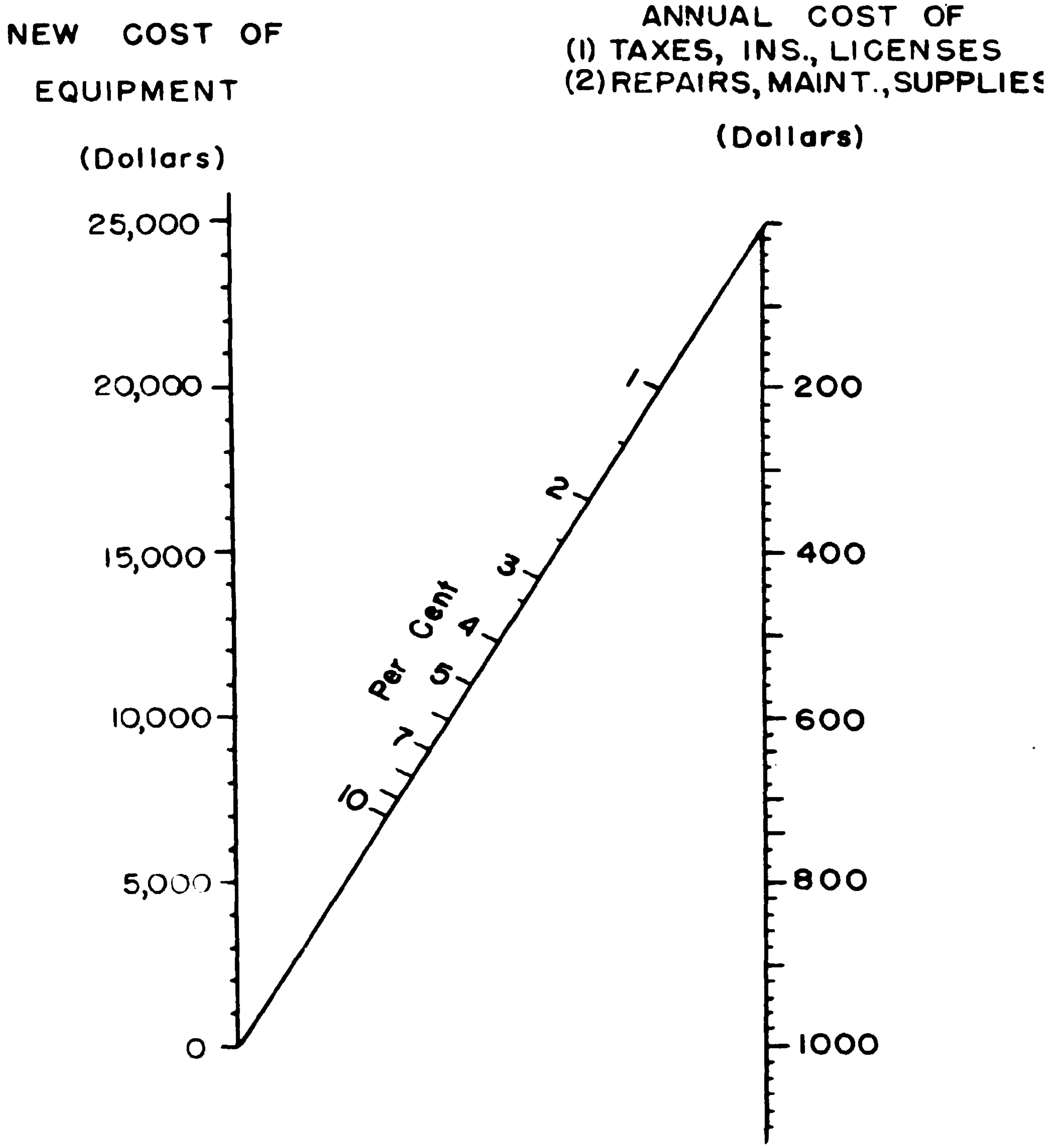

FIG. 54. CHART FOR DETERMINING ANNUAL COST OF (1) TAXES, INSURANCE, LICENSES (2) REPAIRS, MAINTENANCE, SUPPLIES FOR EQUIPMENT

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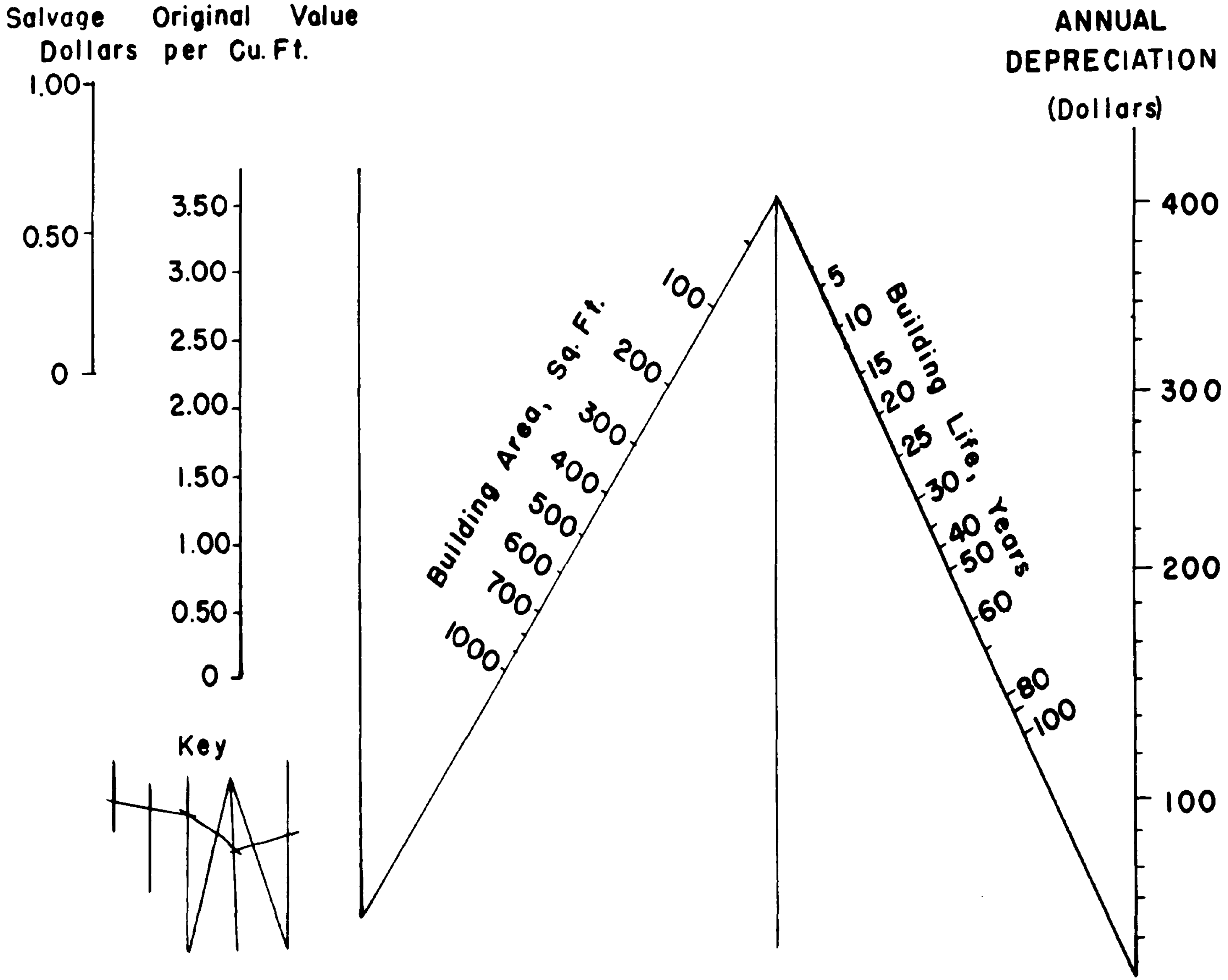

FIG. 55. CHART FOR DETERMINING THE ANNUAL DEPRECIATION OF A BUILDING

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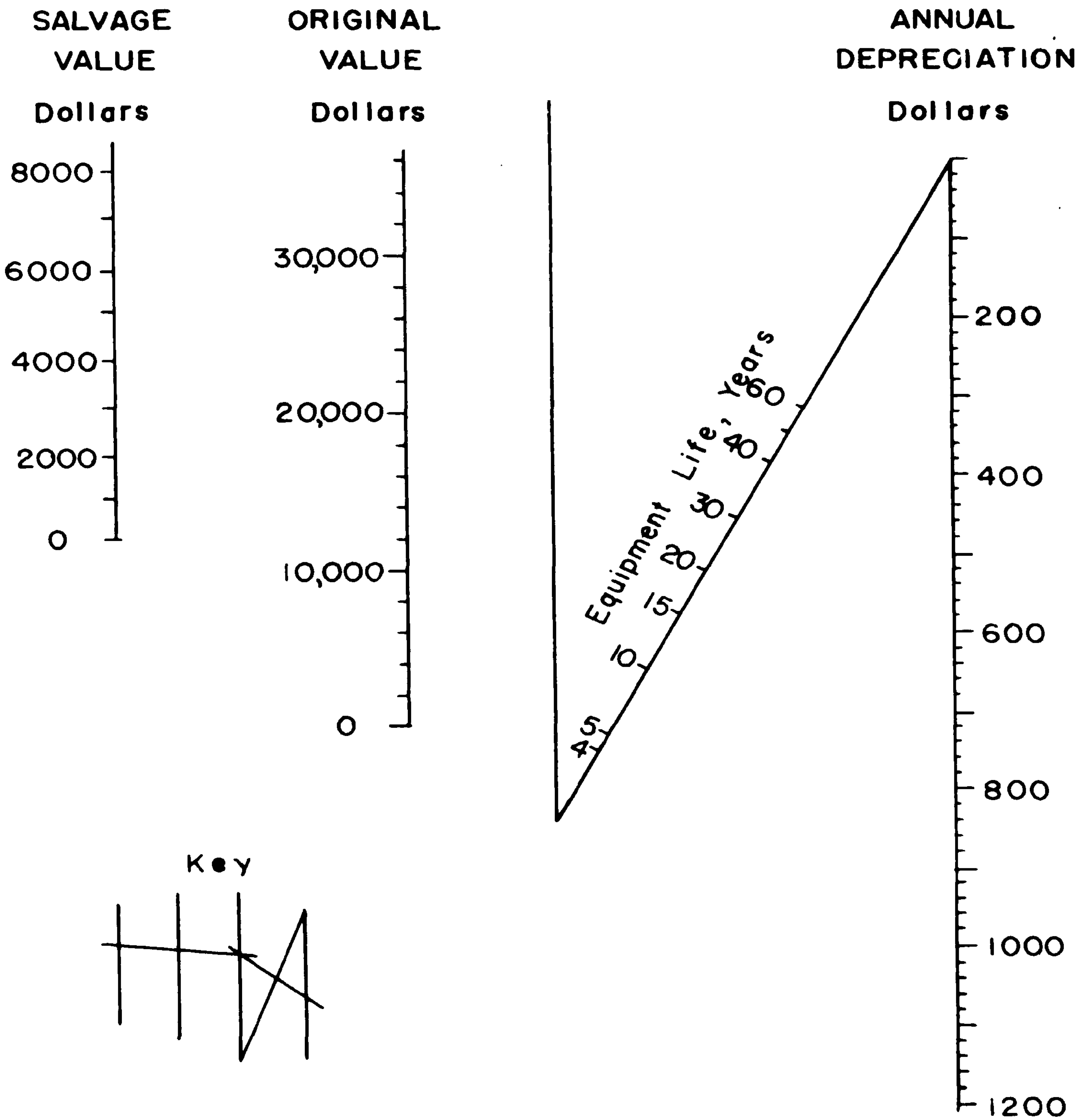

FIG. 56. CHART FOR DETERMINING ANNUAL COST OF DEPRECIATION OF EQUIPMENT

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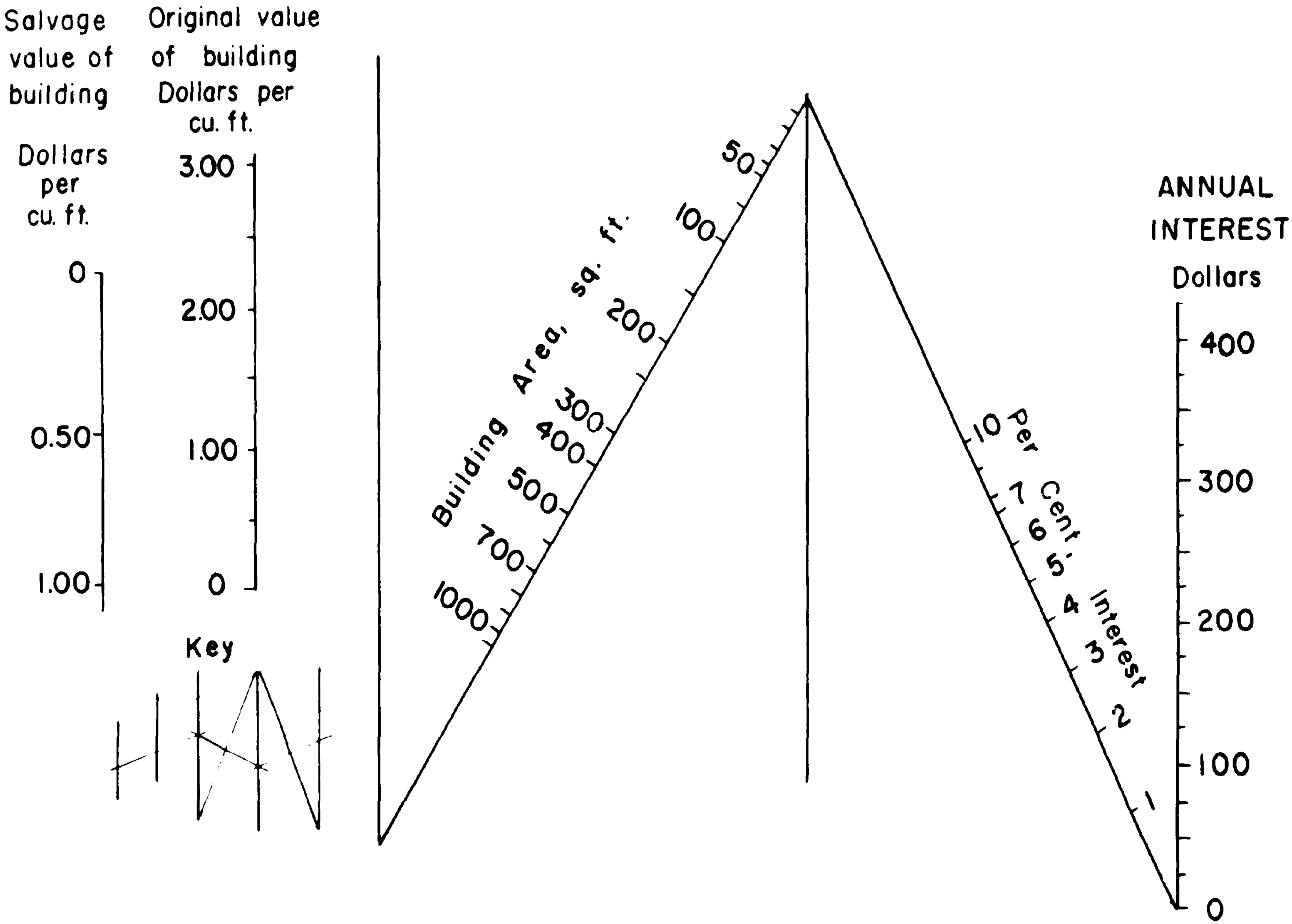

FIG. 57. CHART FOR DETERMINING ANNUAL COST OF INTEREST FOR A BUILDING INVESTMENT

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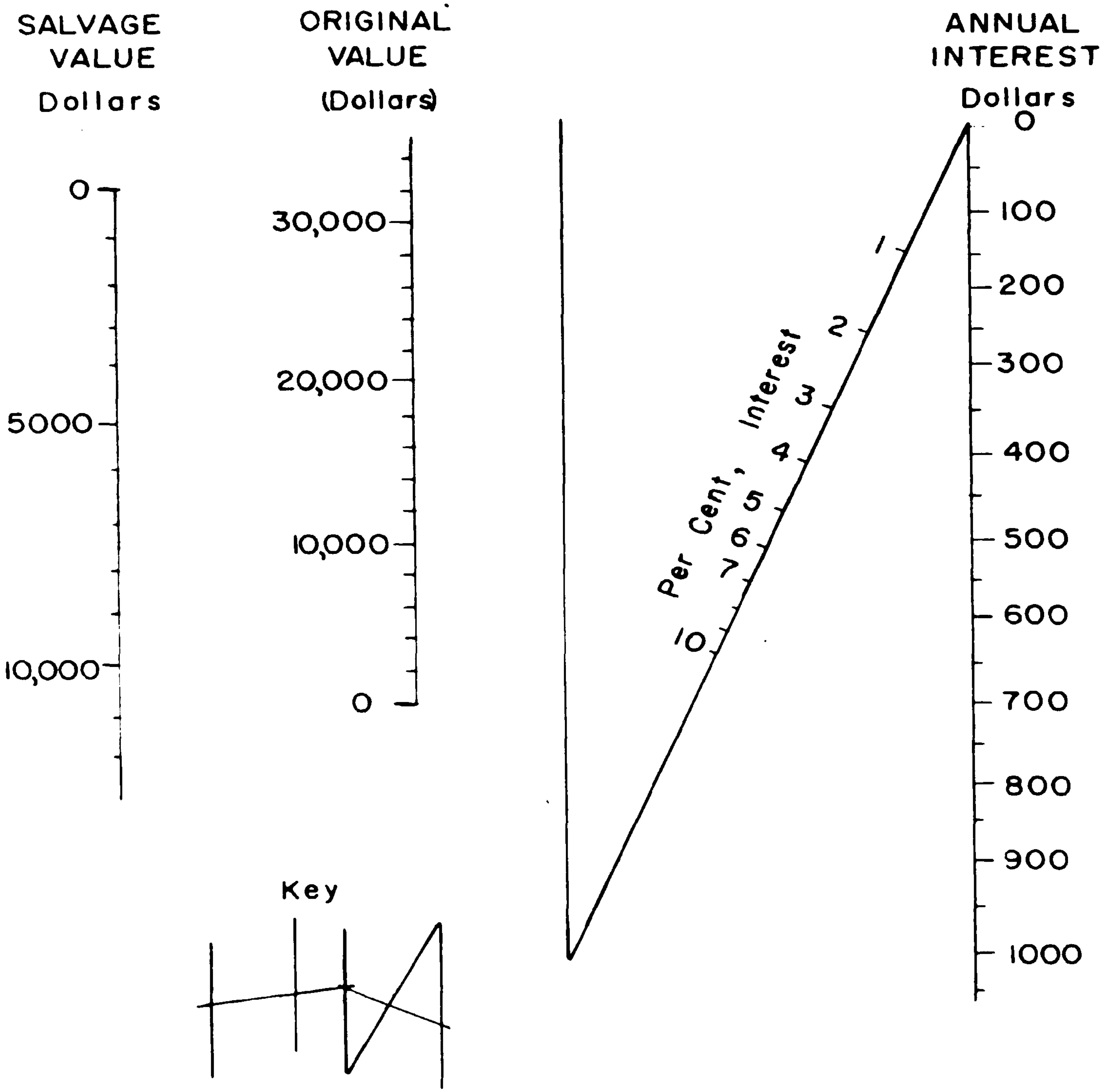

FIG. 58. CHART FOR DETERMINING ANNUAL COST OF INTEREST ON EQUIPMENT INVESTMENT

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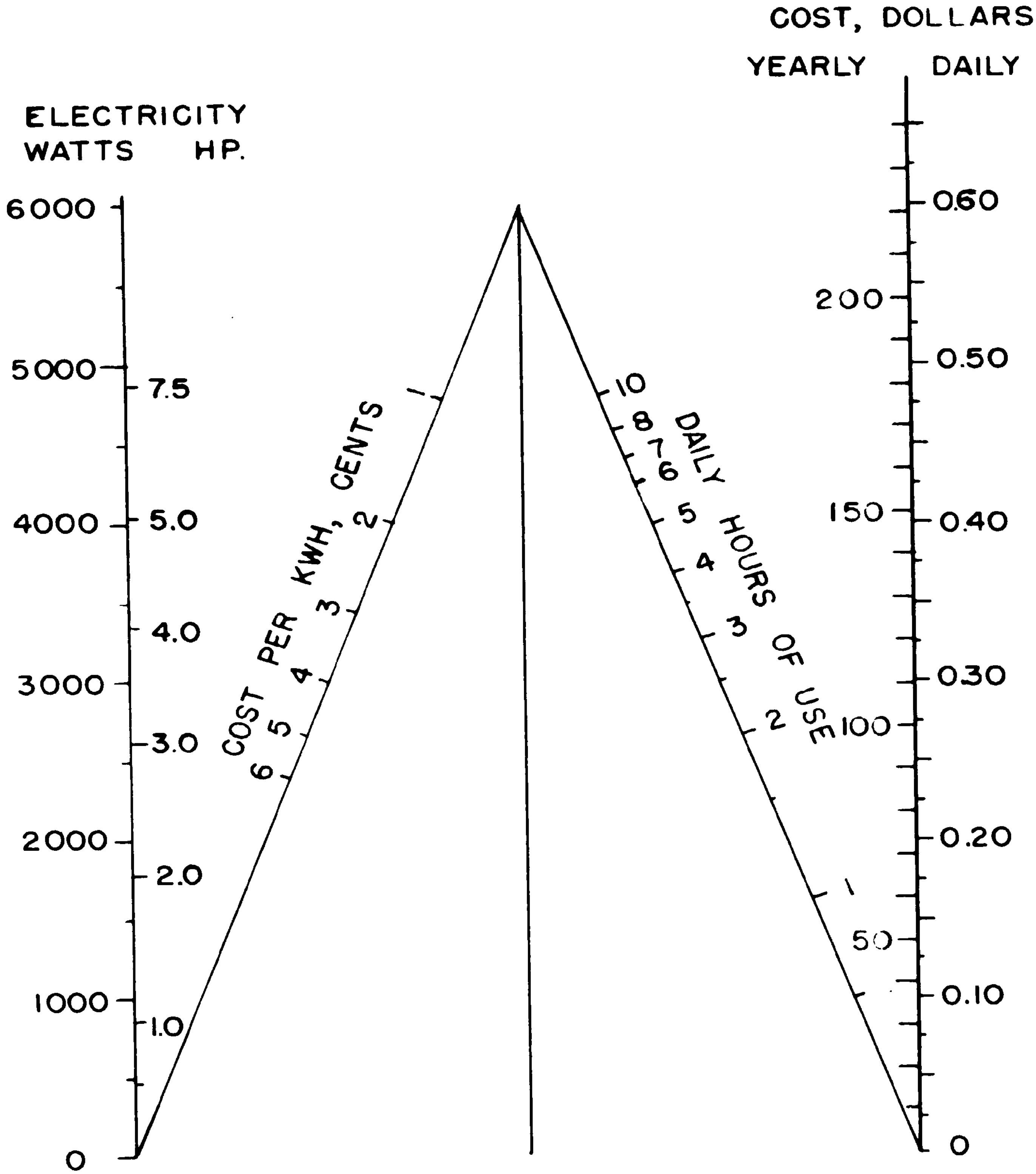

FIG. 59. CHART FOR DETERMINING COST OF ELECTRICITY

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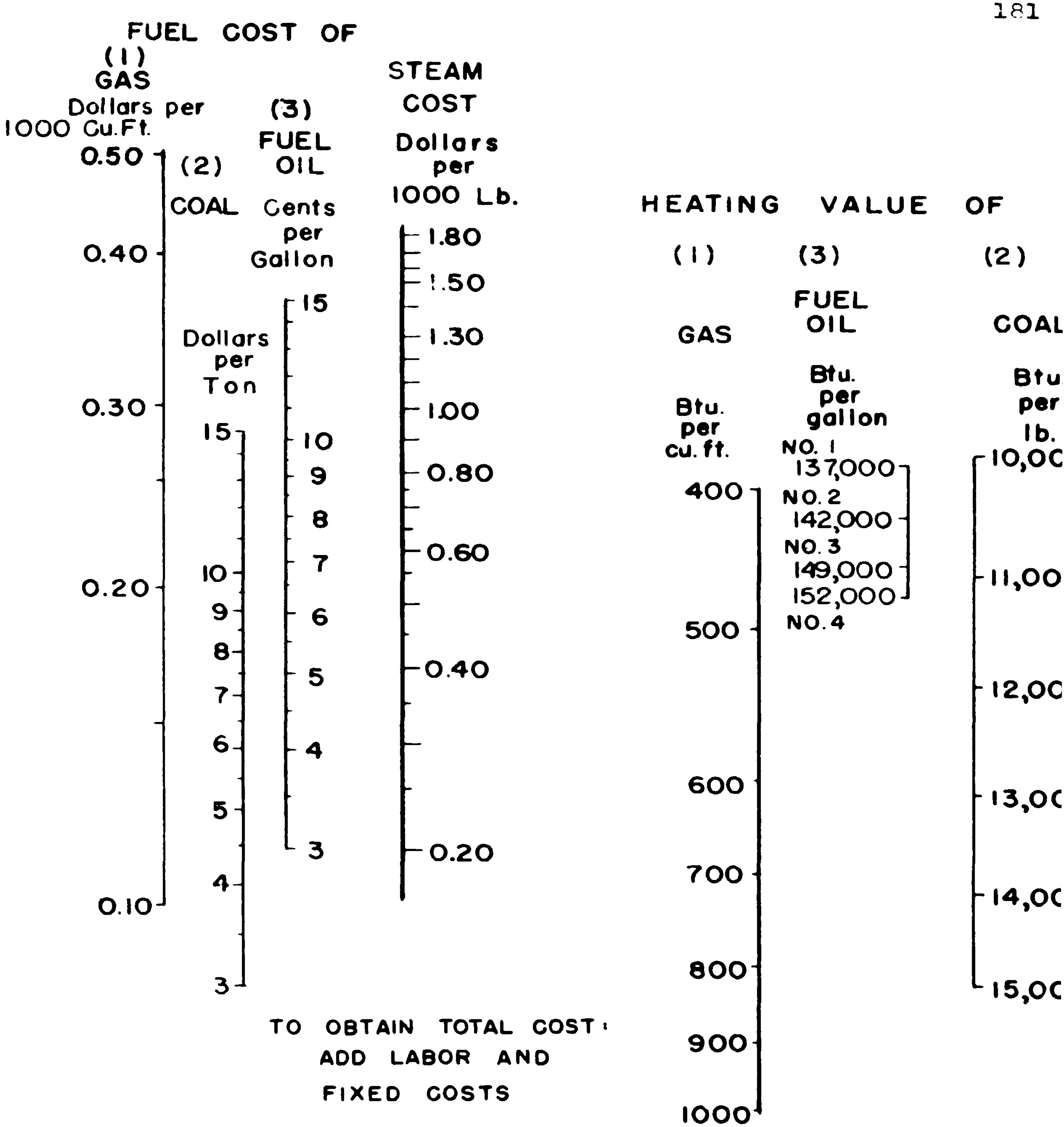

FIG. 60. CHART FOR DETERMINING FUEL COST OF PRODUCING 1000 LB. OF STEAM WITH BOILER OPERATING AT 80% EFF.

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IX. LAYOUT PLANNING

After the proper size of capacity of equipment is selected, the equipment must be placed in the plant in a position to utilize fully the labor and space. Methods are presented in this section for analyzing the equipment layout.

The best way to visualize the plant layout is to use scale models of various equipment. Scale models which show most of the details of construction can be used. A less elaborate method is to use block scale models. They are easily made and are advantageous for dairies because dairy plant equipment is usually simply contoured, approaching a cylinder or parallelopiped in shape. A scale of one-fourth inch equal to one foot is used in plant layout. The equipment is placed on a grid background for a floor. The grid is marked off in one-fourth inch squares. Each square represents a square foot. The grid system facilitates determining the distance between equipment. An example of a layout of block models on a grid background is shown in Fig. 61.

After the equipment is tentatively placed in the plant, each item of the check list is compared with the layout. Changes are made to conform with the check list and judgement of the planner and plant personnel. The workmen in the plant have good ideas and their opinions should be sought and considered.

It is desirable to take a picture of each layout which is submitted to a check list or activity analysis. A proposed one-man receiving room layout is shown in Fig. 62. When submitted to a check list analysis, the layout has the following characteristics:

1. Trucker can unload on short or long leg of incoming conveyor, as shown at points A and B of Fig. 62;

2. Worker is not "boxed in" by conveyors;

3. Short reject line;

4. Cans dumped at right angles to conveyor;

5. Conveyor next to building so that it can be placed under roof;

6. Can washer in a position so that it is more difficult to wash ten gallon cans from the processing room than if the washer were turned end for end.

The next step is to make an operation analysis of the layout. An analysis is presented in Figs. 63 (a) and 63 (b). Fig. 63 (a) represents the work of the present operation of a one-man receiving room. Fig. 63 (b) represents the proposed work schedule of a one-man receiving room based on the data in previous sections of this dissertation.

The symbols given in Table VII are used to illustrate the activity of a worker in the receiving room. The work should be planned, and the equipment placed so that the

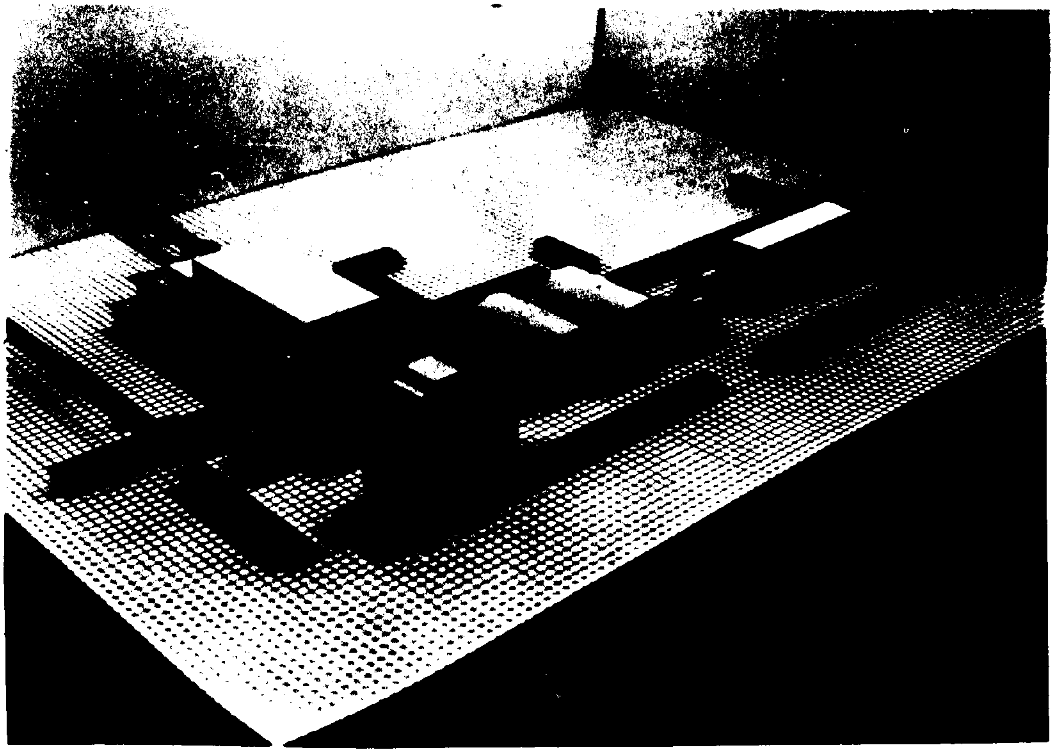


Fig 61. Block Layout of Dairy Plant Equipment

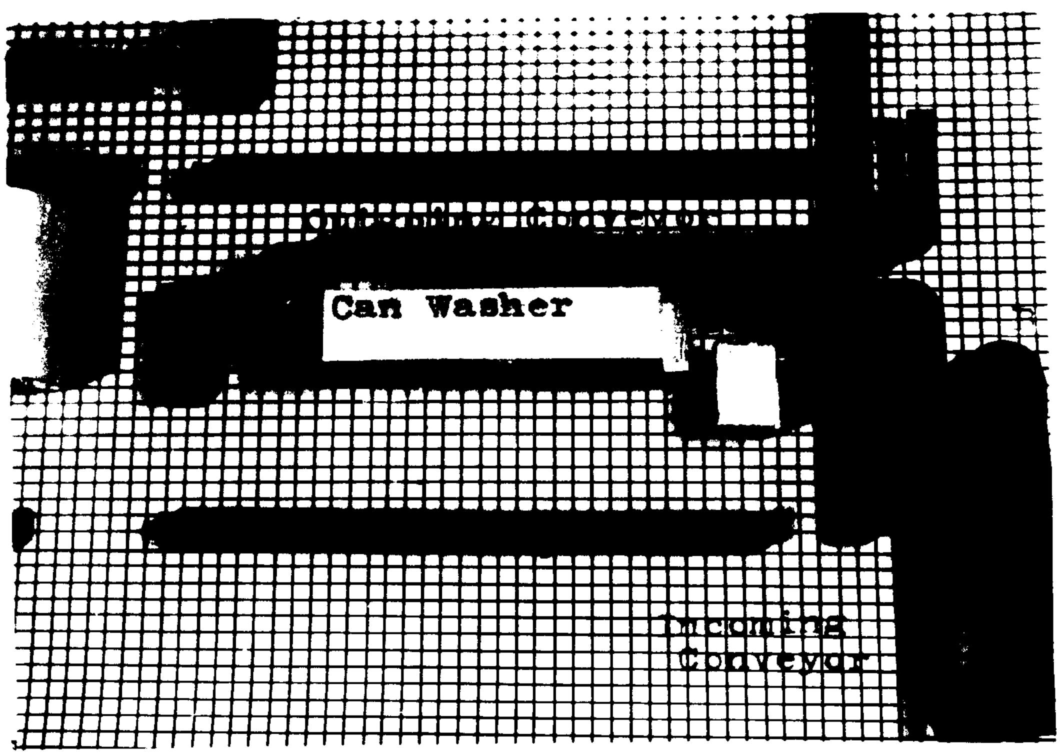


Fig 62. Block Layout of One-man Receiving Room

symbols are as close to being completely blacked-in as possible. Before the changes can be made, an analysis must be made of the delays and plans made to eliminate them. An analysis of Fig. 63(a) shows that the following changes would be required to improve the work schedule to obtain the work plan as shown in Fig. 63(b).

1. Increase conveyor length to avoid waiting by receiving room worker when there are a large number of cans per producer.

2. Schedule the farm trucks to arrive at a desirable time for both the trucker and plant personnel.

3. Have clarifier parts on a cart near the clarifier. Do not store parts of other equipment on clarifier cart.

4. Store sample bottles in receiving room near position of sampling.

5. Have pipe line rack close to place where they are used.

6. Repair washer to prevent cans or lids from jamming.

7. Assign laboratory man the responsibility of checking fullness of storage tanks.

Whether all of the suggested changes should be made depends on the work schedule of the other workers. In a plant an activity analysis should be made of each worker. Consider balancing the work of the employees by:

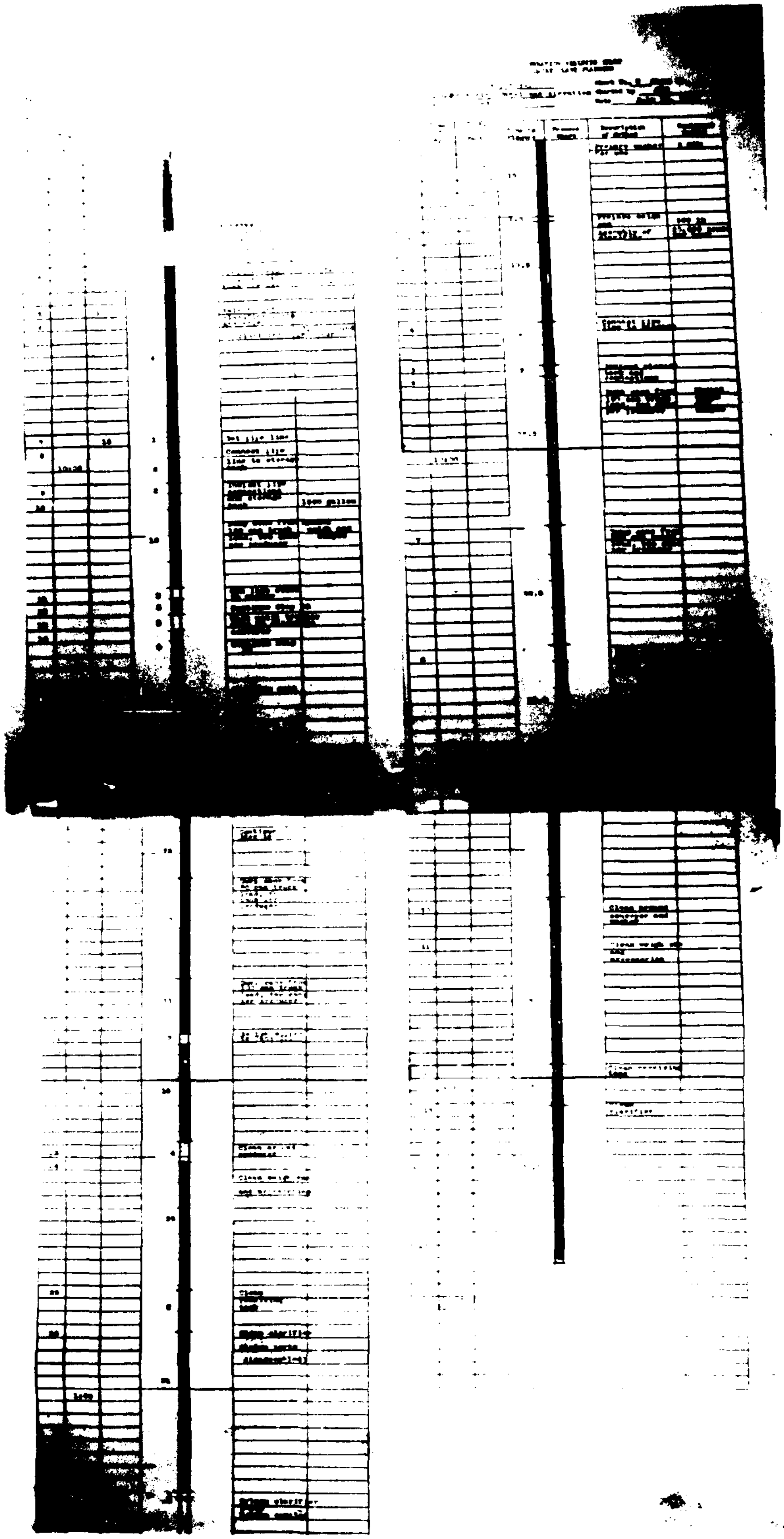
1. Combining steps

2. Simplifying steps

3. Changing layout

4. Changing production schedule

5. Changing position of controls



(a) Present Method (b) Proposed Method

Fig. 63. Operation Analysis Chart

6. Redistributing the work

7. Eliminating unnecessary work

8. Changing equipment.

A production schedule should be developed, similar to the one shown in Fig. 64. The operation analysis of each worker should be based on the production schedule. Changes can often be made in the production schedule to balance the work. The utility use should also be balance, particularly for steam and electricity. Fig. 65 illustrates the steam, electricity, water and refrigeration required for the production schedule shown in Fig. 64. Consider balancing the utility requirements by:

1. Changing production schedule

2. Changing equipment

Operational plans and proposed layouts should be made for expected future capacities. If this is done, expansion will be much easier and less expensive to carry out. The operational plans should be recorded and the proposed layout photographed so that new management personnel can be aware of the plans.

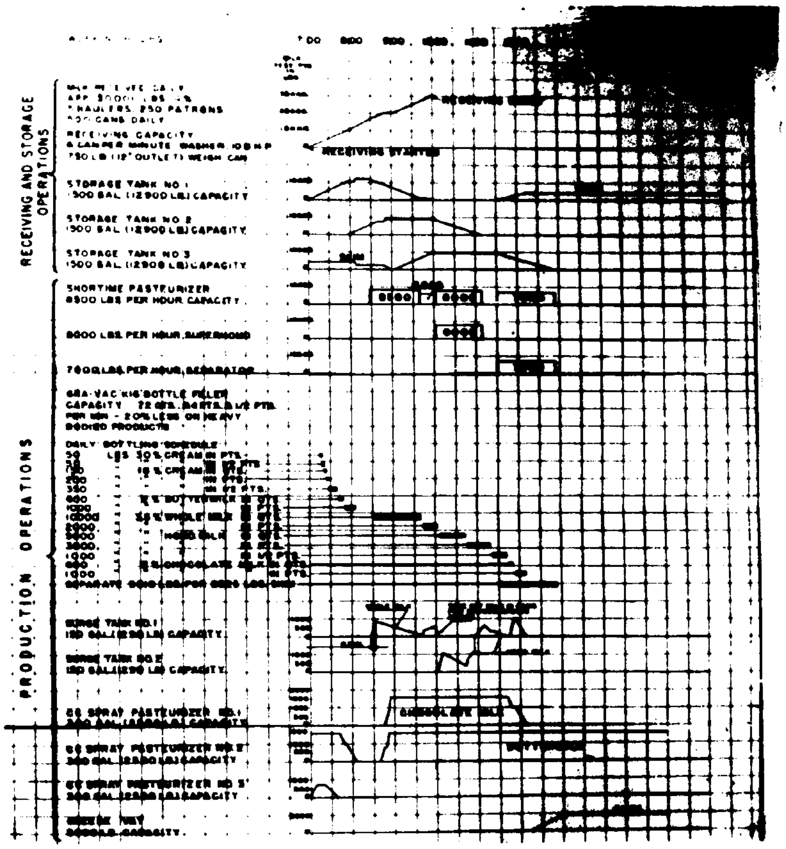


Fig. 64. Production schedule of 25,000 lb. per day dairy (1)

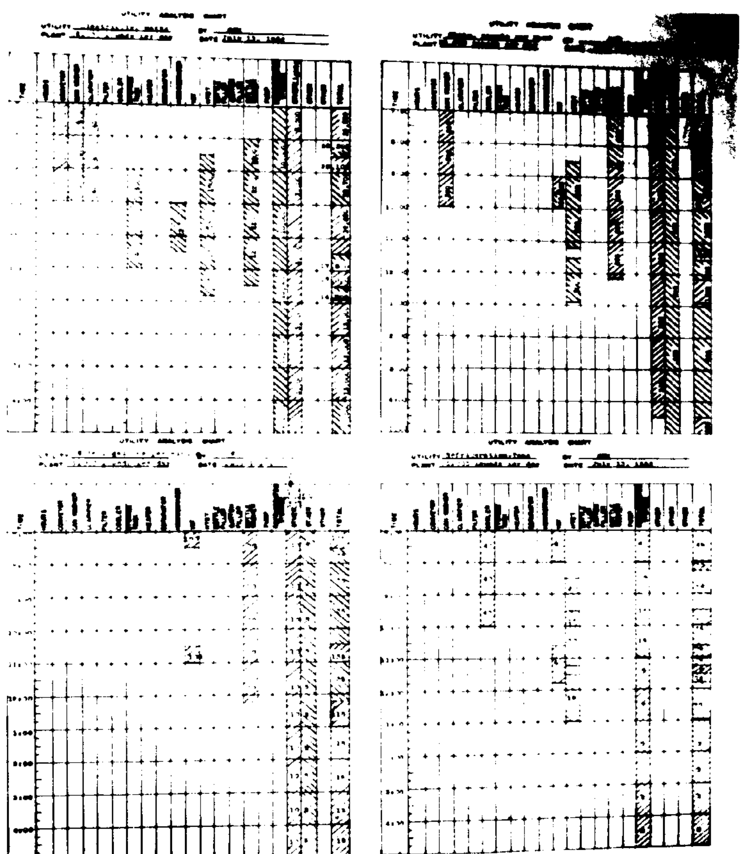


Fig. 65. An Analysis of Utility Requirements of a 25,000 pound per day dairy

1. Dairy Plant Engineering, Cherry-Burrell Corporation, Chicago, Illinois, September 1, 1948.

X. SUMMARY

The one-man receiving room operation with a straight-away can washer is the most efficient for labor utility. The size of weigh can and can washer should be selected on the basis of an over-all economical analysis--not just on the labor requirements. A minimum number of man-minutes per 100 cans in the receiving room should not be the sole objective, although it is an important one. The operations in the entire plant must be planned to function together. Each plant manager must use the data as a guide to his decisions.

One man cannot conveniently unload cans from the truck and loosen lids rapidly enough to steadily supply a can washer at a rate above seven cans per minute. The speed of unloading cans from the truck, conveyor trip, weigh can size, clarifier capacity, and sampling and weighing methods are factors which often prevent the can washer from working at full capacity.

Several multiple-man operations with various arrangements were observed. The dumper should not be assigned any additional task except checking the milk for quality as he dumps the cans.

For a dumping rate of eight cans per minute, the dumping time is reduced from 14.3 to 12.5 minutes as the conveyor length is increased from zero to thirty feet. When the incoming conveyor is thirty feet in length, a total conveyor length of 130 feet is required. As the length of the incoming conveyor is increased from thirty to ninety feet, the time required for dumping does not change, but the total length of conveyor required decreases from 130 feet to 118 feet.

The size and capacity of equipment from the storage tank back to the weigh can should be selected on the basis of the rate of the receiving operation. The equipment from the storage tank to the refrigerated storage should be selected on the basis of the rate at which a person can case and inspect the bottled milk. The clarifiers manufactured at the present time are too slow to keep up with the receiving operation. The receiving rate is slowed down and milk wasted from running over the receiving tank when the clarifier has too small a capacity. A 25,560 pound per hour clarifier would be required for a one-man operation.

The time required to clean the storage tank varies with the capacity and diameter of the tank. The 600 gallon tank required longer for cleaning than the 1000 gallon tank. The 3000 gallon tank is manufactured in 84-inch and 96-inch diameters. The 84-inch diameter, 3000 gallon tank required five minutes less to clean each day than the 96-inch diameter, 3000 gallon tank. The tank with the smaller diameter requires more building area. The additional cost of the building area should be compared to the value of saving in cleaning labor. The use of air will considerably reduce the power and time required for milk agitation.

The cost of separation of cold milk is less than heated milk, in spite of the fact that the capacity of a unit used for cold milk separation is only fifty-five per cent of its capacity for heated milk separation. The advantage in favor of cold milk separation would be much greater if larger units were available, because the cleaning time for a unit with twice as great a capacity would be much less than for cleaning two smaller units with the same total capacity.

The homogenizer has undergone very few changes since its invention. The total cost of operation can be substantially decreased by increasing the ease of cleaning and experimental evidence indicates that pressures may be reduced under certain conditions which in turn would decrease the cost of the operation. The labor required for supervision could be decreased by using a pressure regulated control valve to assure constant homogenizer pressures.

Pasteurization can be carried out more economically with the high-temperature short-time unit than with the holding vats. This is done in spite of the fact that the short-time unit has a higher initial cost because the benefits of regeneration are built into the unit. Separate equipment is needed to utilize regeneration in the holding process.

One man can case and inspect 63 quart and 99 half-pint bottles per minute at the filler. The filler should operate at a speed to utilize fully the work of the men casing the bottles. Semi-automatic casing equipment can double the rate of casing. The major cost of the bottling operation is the cost of the bottle and cap. The cost of the bottle can be substantially reduced by increasing the number of trips per bottle. The lightweight bottle, even though it has a lower initial cost, has not reduced the cost of the operation, because of greater bottle breakage. Cleaning jets located in the filler bowl would facilitate the bottling operation. There is little difference in operational cost with different filler sizes.

The paper carton operation costs $0.0108 per quart more than the glass bottle washing and filling operation which it replaces. The use of a single service carton accounts for the added cost. The cost of the operation can be substantially reduced only by decreasing the cost of the container, or by concentrating the milk before it goes into the carton.

Large savings in pipe line cost and cleaning can be realized by replacing the conventional pipe lines with permanent lines which can be cleaned by circulatory methods.

One man can feed 100 bottles per minute into a bottle washer. Automatic uncasing and washer-loading equipment has been developed which will pay for itself by the labor saved within a three-year period.

A labor saving of fifty per cent in loading-out the milk from the refrigerated storage can be obtained by use of pallets. A careful analysis would be required to ascertain the advisability of converting present storages for pallet handling.

Check lists of the various pieces of equipment should be used by the dairy plant superintendent, plant designer, and equipment designer to analyze present and proposed operations.

Before new equipment is purchased, or old equipment replaced, the over-all process cost analysis should be made. A piece of equipment is usually used for one operation, which is a part of a process. The operational cost includes a charge for interest and depreciation, taxes, insurance, licenses, repairs, supplies, building space, labor, and utilities.

The planning of a dairy plant should be carried out by as many different people as possible. No one person can remember every item to be considered. The plan can be visualized best with a model layout. The operations of various layouts can be compared with an operation analysis chart, based on the standard time of each operation.

XI. CONCLUSIONS

1. A one-man receiving room operation is more efficient than the multiple-man operation if the processing schedule is not interrupted.

2. In a multiple-man receiving room operation, the person dumping the cans should not be assigned any additional task, other than checking for quality.

3. The standard time required for receiving room operations should be used for planning schedules.

4. The trucker cannot normally unload cans from the truck and loosen the lids at a rate faster than seven cans per minute.

5. The size of weigh can should be selected according to the size of dairy and the size of the producer.

6. A 750 pound scales, or larger, should be installed in the dairy, even though a 500 pound weigh can is installed.

7. The vacuum sampler, although an aid to the person doing the sampling, often requires more time than sampling with the manual dipper.

8. Rooms which are well-lighted are more likely to be kept clean and neat.

9. In a one-man receiving operation, a can washer with a capacity above ten cans per minute is not used to capacity and a six can per minute washer is too slow.

10. The conveyor system should be arranged so that the cans can be dumped at a ninety degree angle to the conveyor to prevent the cans from pinching while dumping.

11. In many plant arrangements, the time required for dumping the milk and the total length of can conveyor could be decreased by lengthening the incoming conveyor.

12. Horizontal cylindrical storage tanks with diameters from 69 to 84 inches are easier to clean than those with smaller or larger diameters.

13. Cold milk separators should be built in sizes larger than 6,000 pounds per hour.

14. A saving of seventeen per cent in the operational cost of homogenization could be realized by reducing the pressure from 2500 to 1000 pounds per square inch.

15. The use of regenerative heating and cooling equipment with the holding process for pasteurization is less expensive than without the regenerator equipment for capacities above 8000 pounds per day.

16. For a 5000 pound per day dairy, the daily cost of using a short-time unit for pasteurization is nearly one dollar less than the cost of using the holding process. The short-time unit is more economical for capacities above 5000 pounds per day.

17. Management personnel should give special attention to training the workman in handling glass bottles with care. A saving of $0.05 per hundred could be realized by increasing the number of trips per bottle from twenty-five to fifty.

18. Dairies are justified in charging an extra cent per quart for milk in paper cartons.

19. Methods must be developed, and approved by health authorities, to clean equipment and pipe lines without disassembly.

20. A new medium-sized plant could justify the use of automatic casing equipment, automatic uncasing and bottle washer feeding equipment, and pallet system of loading and unloading delivery trucks.

21. An operation should not be analyzed by itself. The entire process surrounding the operation must be considered. A cost analysis should be made which includes all factors, not just the original equipment cost.

22. It is imperative that all new layouts or revisions in layout be studied with the aid of scale models and operational analysis charts.

XII. APPENDIX

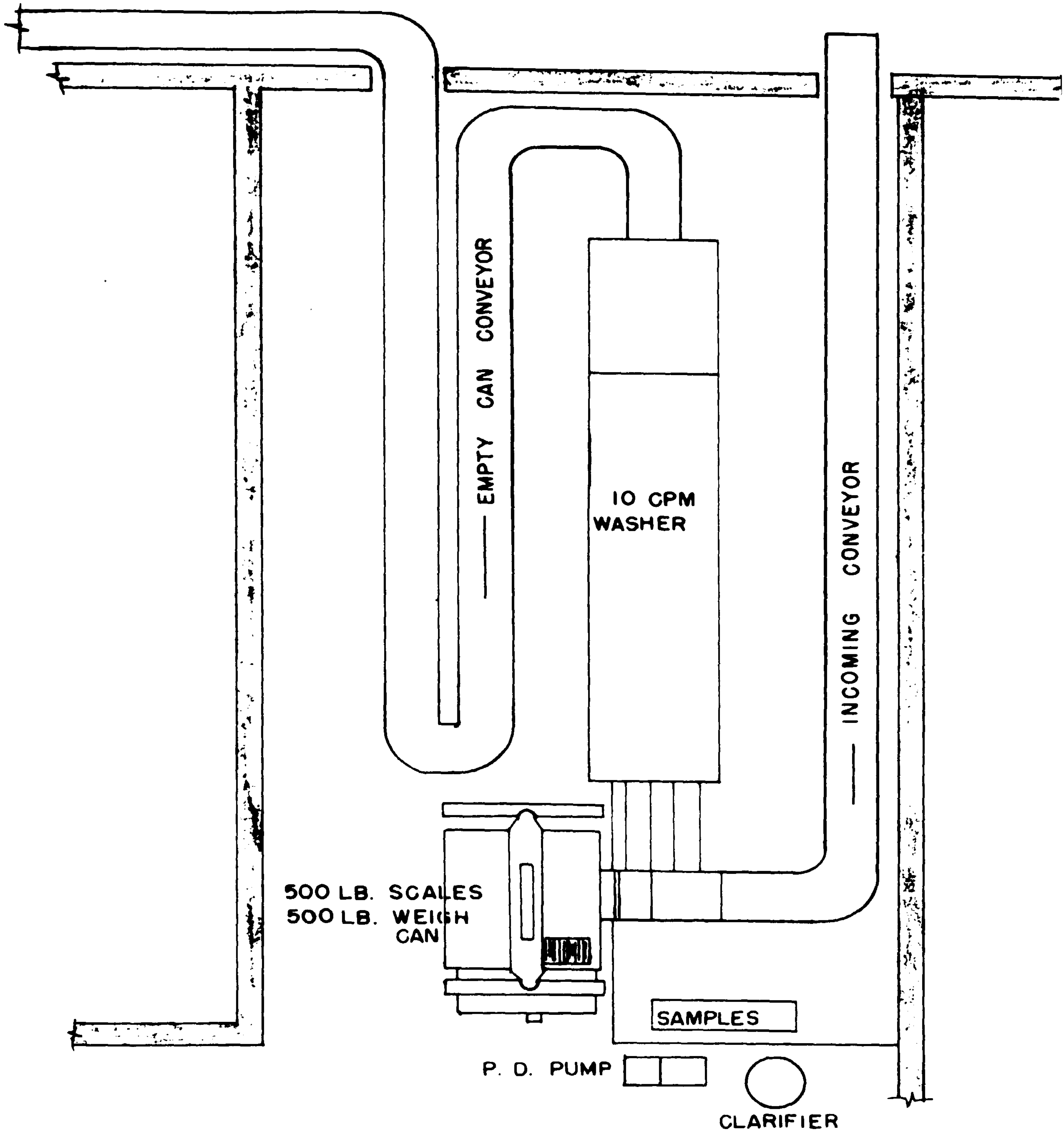
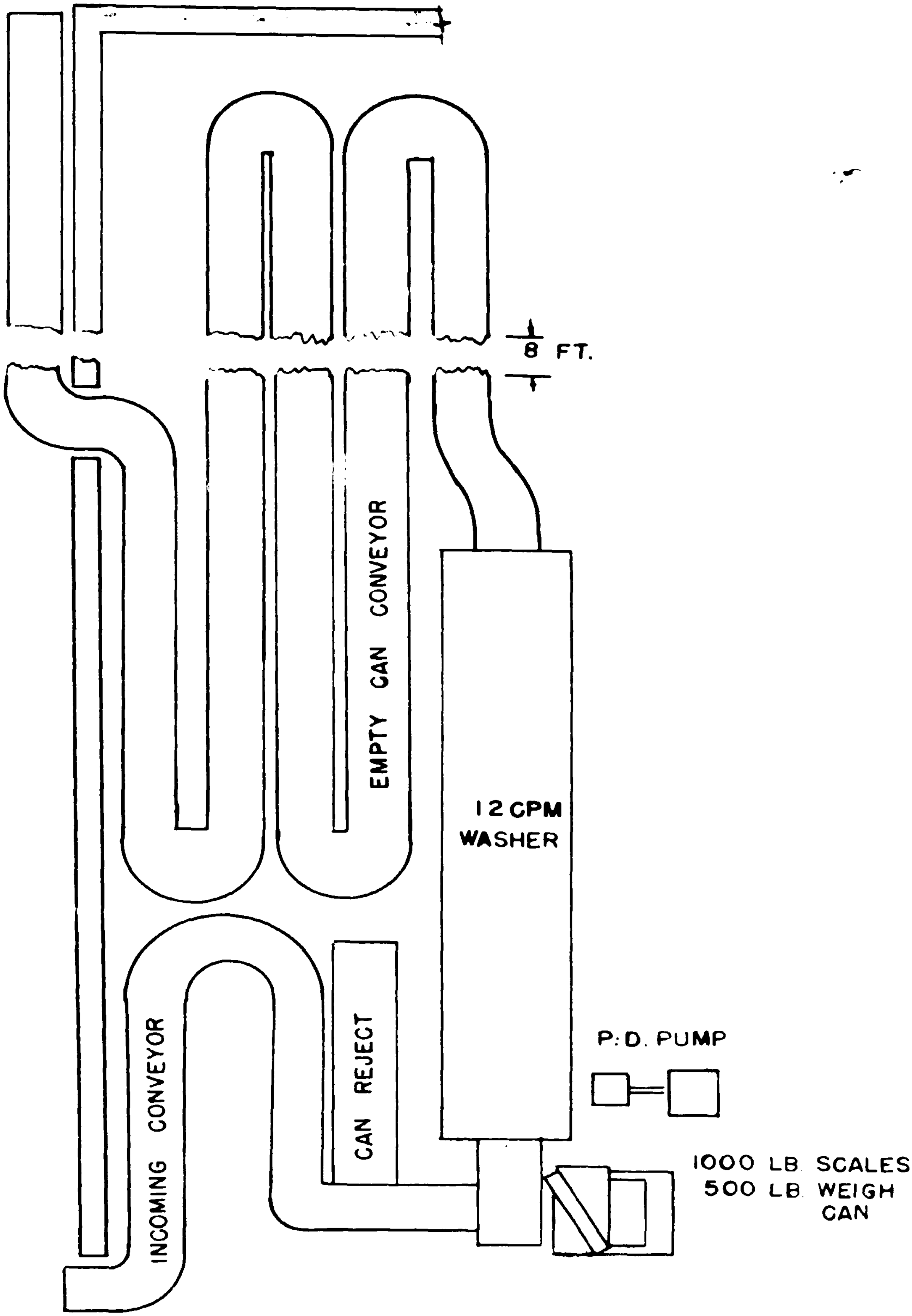


FIG. 1. DAIRY "A" ONE MAN RECEIVING ROOM

SCALE: 1/4" = 1'

GWH

3/18/52



CWH
4/2/52

FIG. 2. DAIRY "B" ONE MAN RECEIVING ROOM

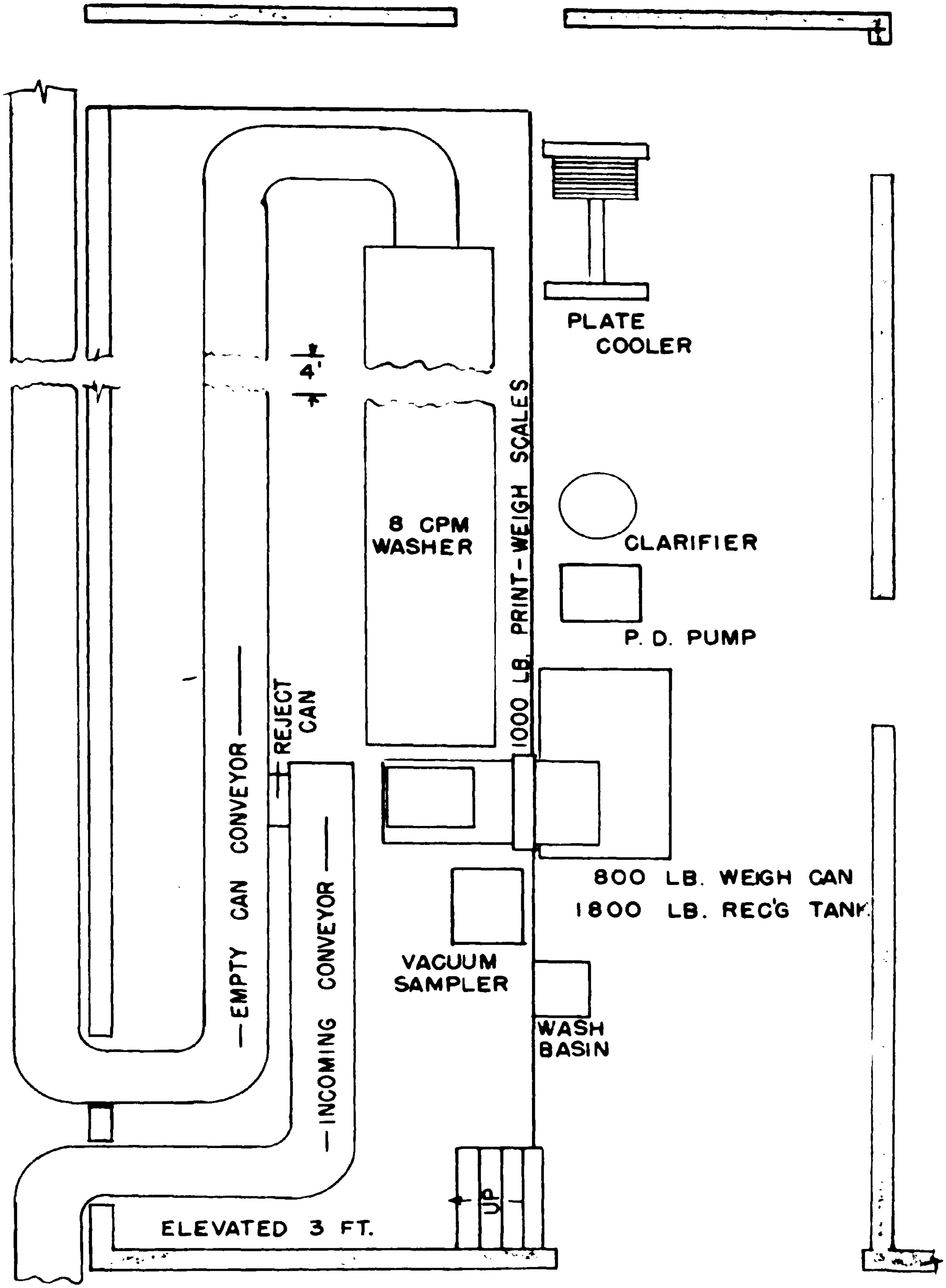


FIG. 3. DAIRY "C" ONE MAN RECEIVING ROOM

1/4" = 1'

CWH

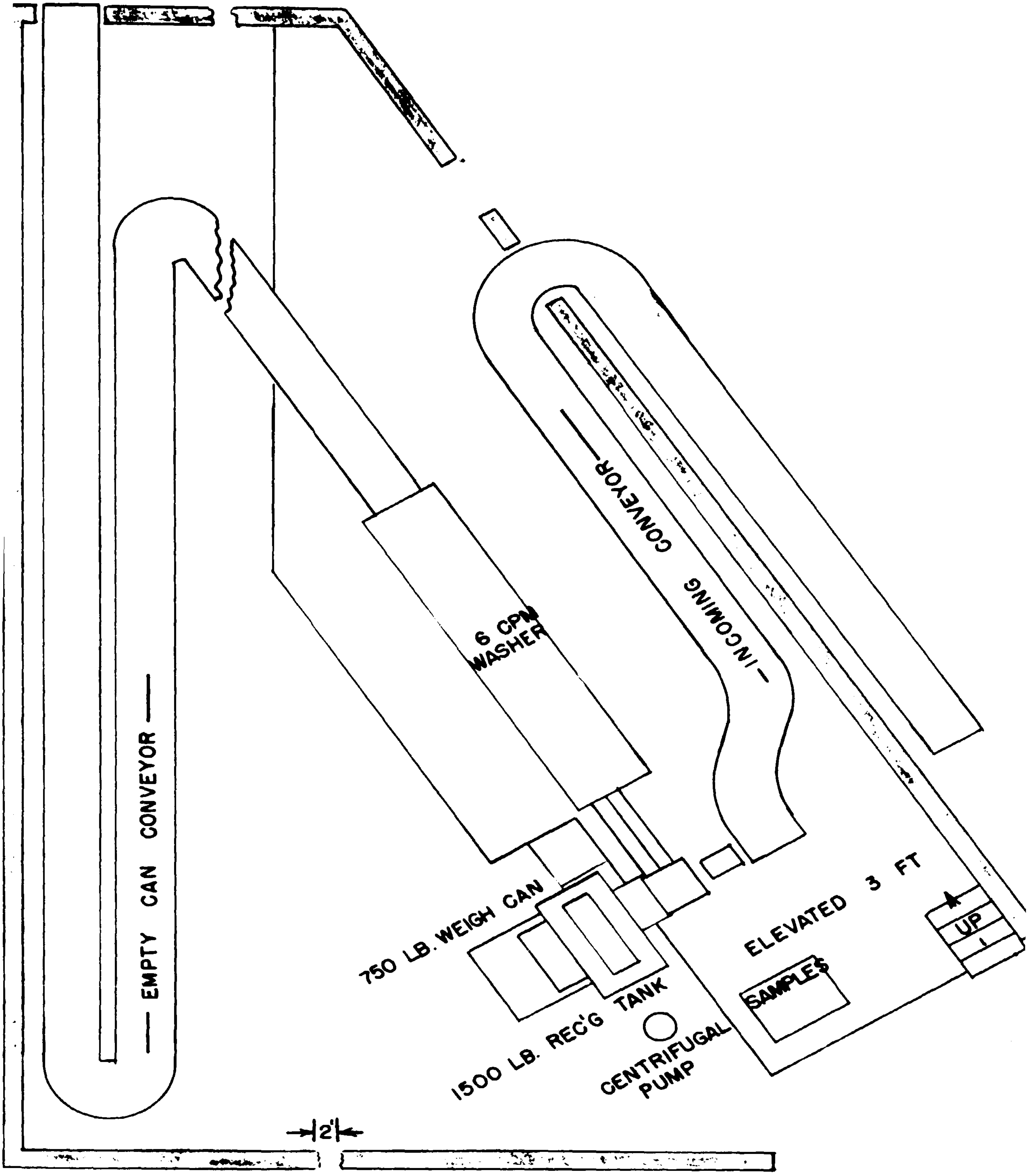


FIG. 4. DAIRY "D" ONE MAN RECEIVING ROOM

1/4" = 1'

CWH
6/9/52

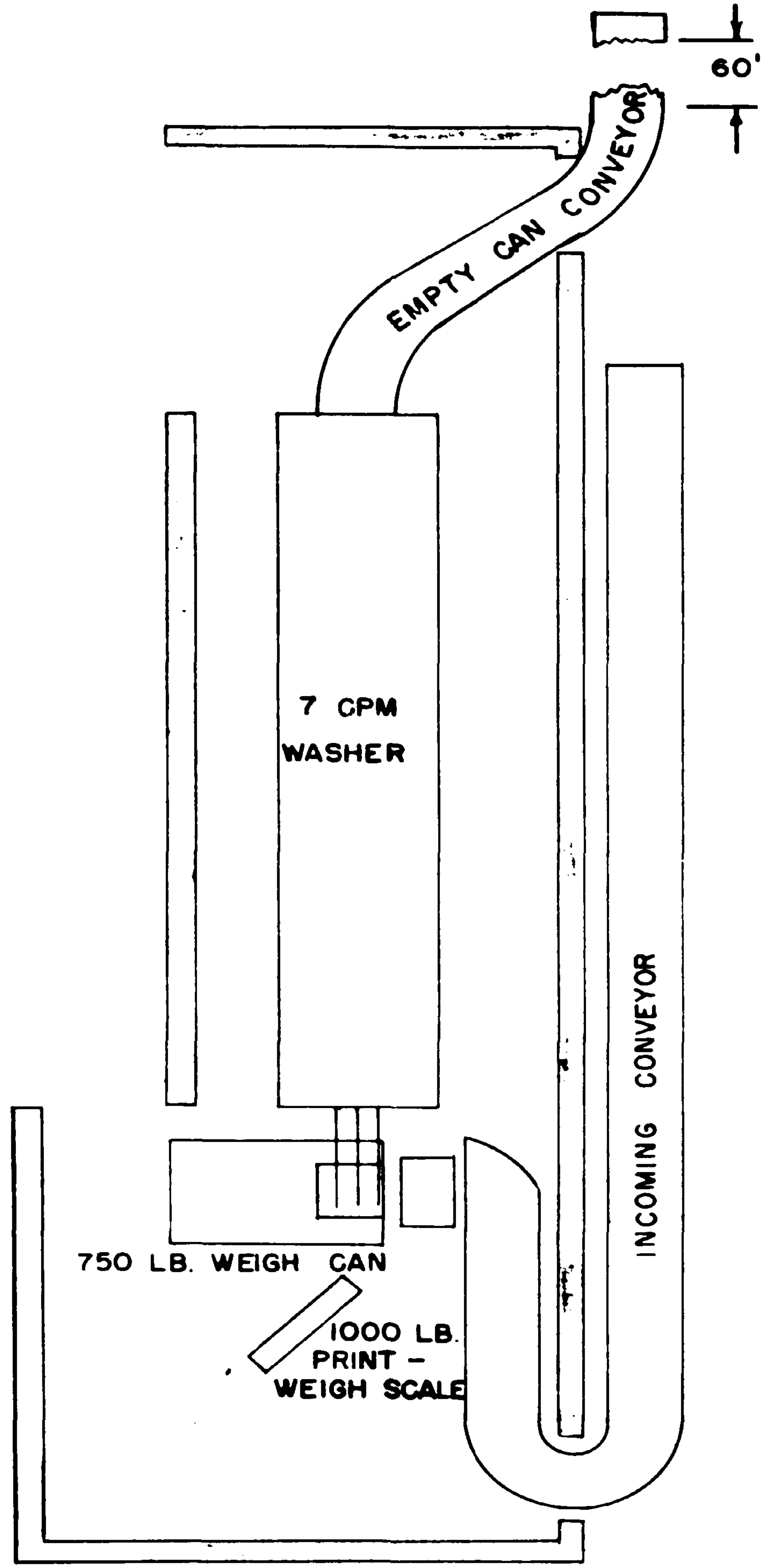


FIG. 5. DAIRY "E" TWO MAN RECEIVING ROOM

1/4" = 1'

CWH

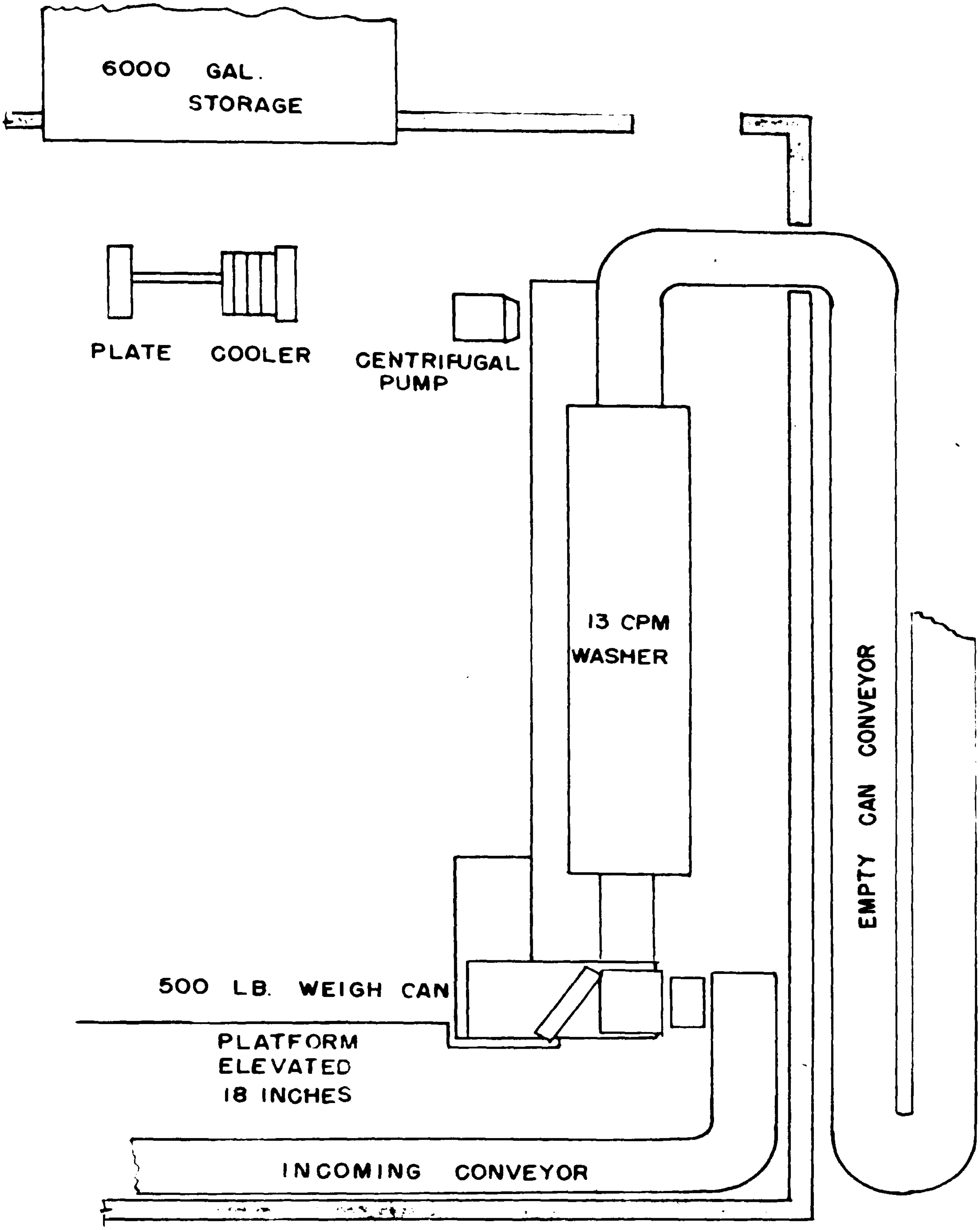


FIG. 6. DAIRY "F" TWO MAN RECEIVING ROOM

CWH
5/19/52
1/4" = 1'

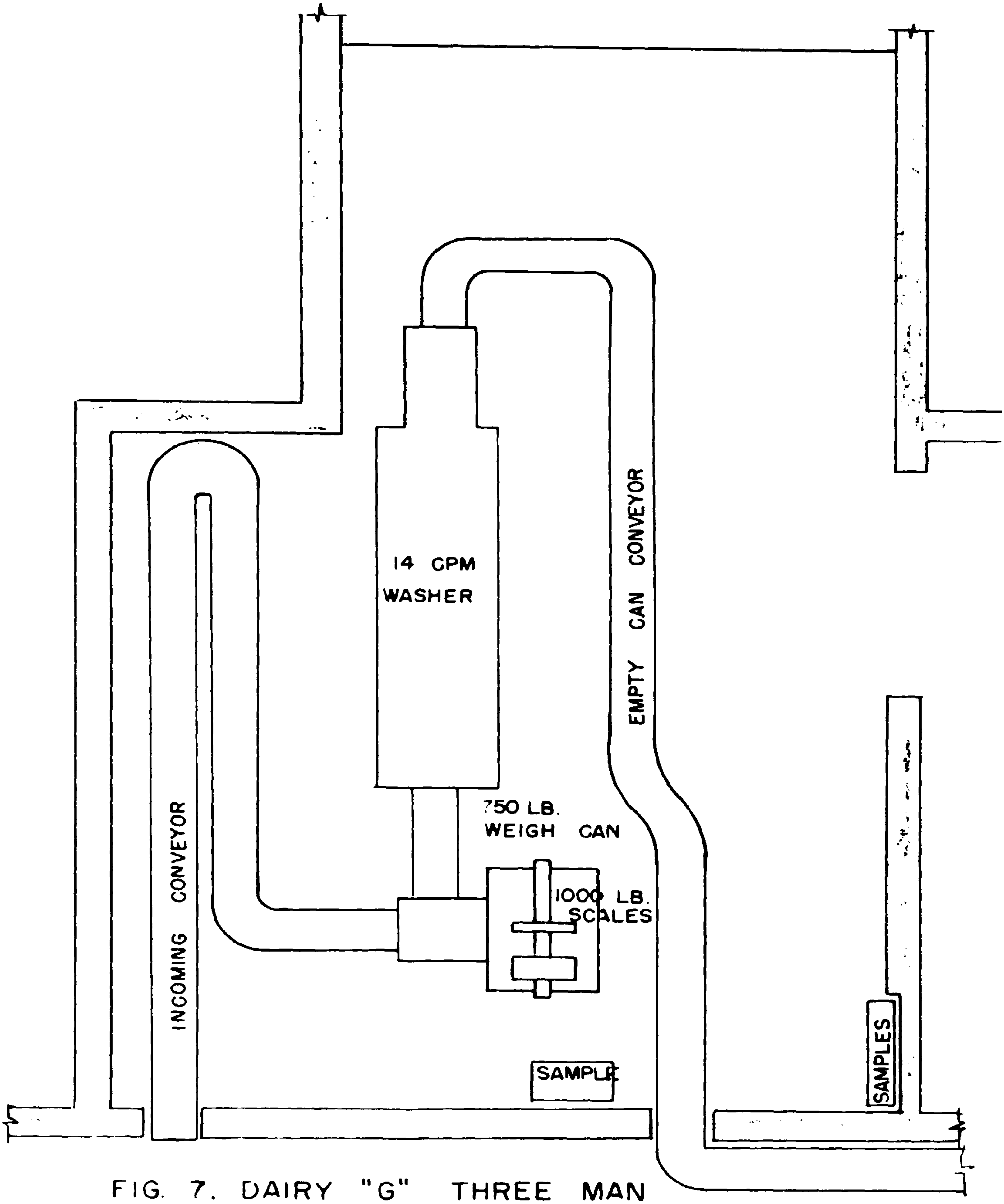


FIG. 7. DAIRY "G" THREE MAN RECEIVING ROOM

CWH
4/1/52

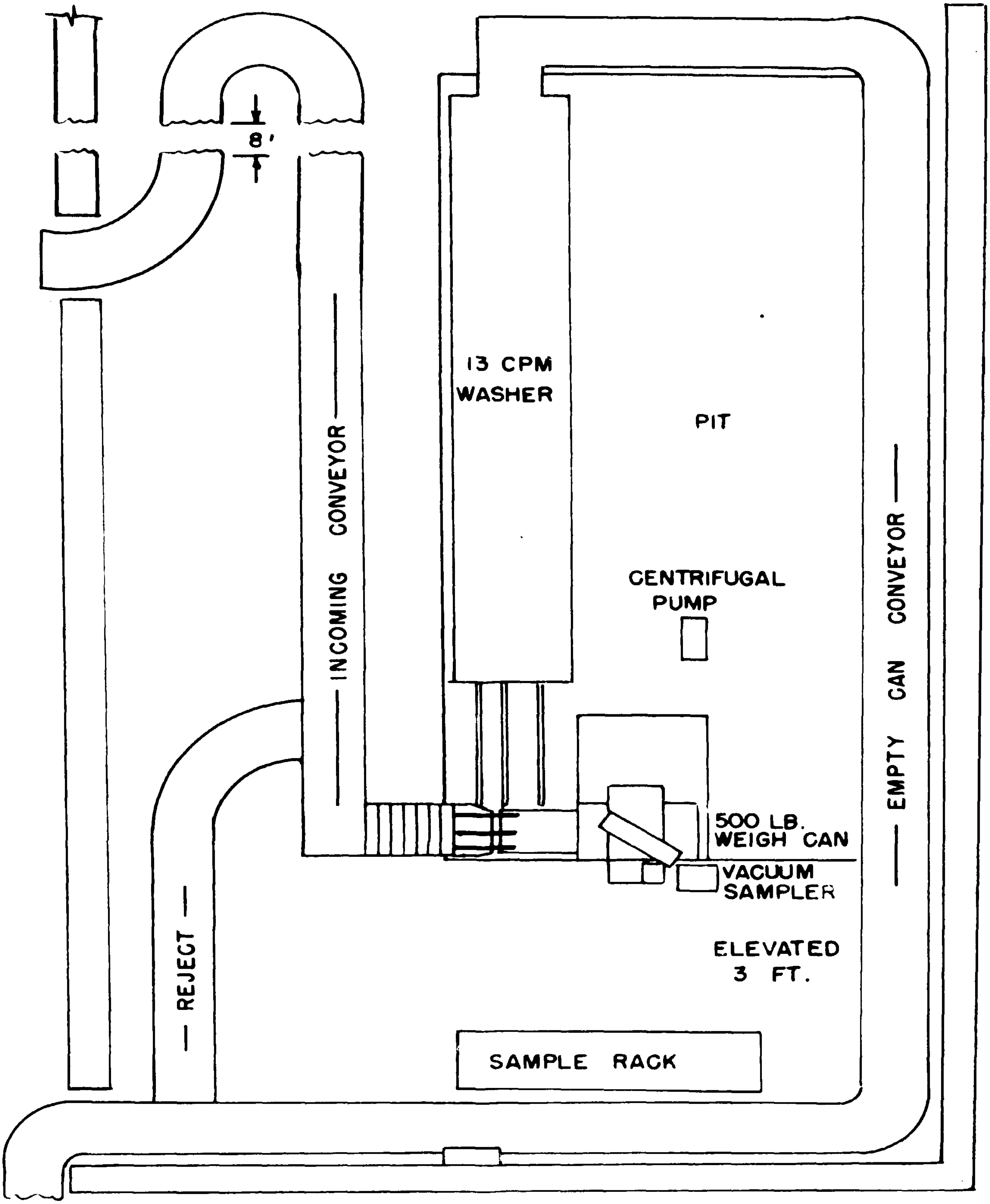


FIG. 8. DAIRY "H" THREE MAN RECEIVING ROOM

1/4" = 1'

CWH
5/19/52

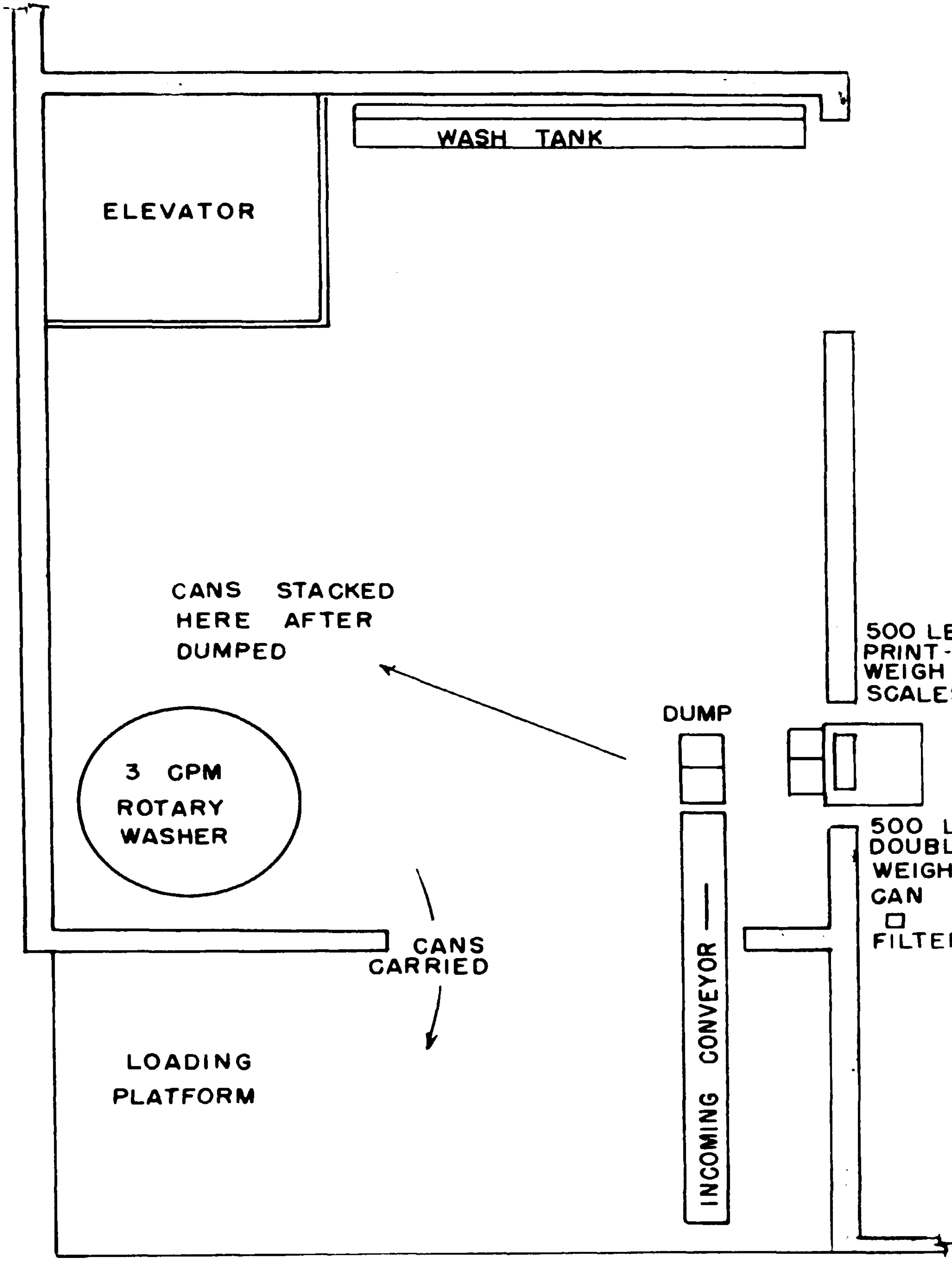


FIG. 9. DAIRY "I" THREE MAN RECEIVING ROOM

1/4" = 1'

CWH
6/7/52

Appendix Table I

Milk Production on Farms by States, 1949 (1)

Wisconsin	15,568,000,000 lb.
New York	8,700,000,000 lb.
Minnesota	8,320,000,000 lb.
California	5,972,000,000 lb.
Iowa	5,921,000,000 lb.
Pennsylvania	5,800,000,000 lb.
Michigan	5,677,000,000 lb.

Appendix Table II

Number of Milk Dealers by States, 1949 (1)

New York	1937
Pennsylvania	1019
California	1002
Illinois	958
Ohio	856

Author's Note: Minnesota and Wisconsin have only 515 and 618 milk dealers, respectively. These two states carry on extensive processing of milk, which is the reason that the number of milk dealers is low even though the milk production is high.

(1) ____________ Dairy Industries Catalog, Olsen Publishing Company,

Appendix Table III (1)

Economic Indexes for Different Items
Base: 1926 = 100

Year	All commod- ities	Foods	Fuel and light- ing	Metals and metal products	Bldg. mater- ials	Labor
1920	154.4	137.4	163.7	149.4	150.1	102
1921	97.6	90.6	96.8	117.5	97.4	94
1922	96.7	87.6	107.3	102.9	97.3	89
1923	107.6	92.7	97.3	109.3	108.7	95
1924	98.1	91.0	92.0	106.3	102.3	99
1925	103.5	100.2	96.5	103.2	101.7	99
1926	100.0	100.0	100.0	100.0	100.0	100
1927	95.4	96.7	88.3	96.3	94.7	100
1928	96.7	101.0	84.3	97.0	94.1	101
1929	95.3	99.9	83.0	100.5	95.4	103
1930	86.4	90.5	78.5	92.1	89.9	101
1931	73.0	74.6	67.5	84.5	79.2	94
1932	64.8	61.0	70.3	80.2	71.4	82
1933	65.9	60.5	66.3	79.8	77.0	82
1934	74.9	70.5	73.3	86.9	86.2	97
1935	80.0	83.7	73.5	86.4	85.3	100
1936	80.8	82.1	76.2	87.0	86.7	101
1937	86.3	85.5	77.6	95.7	95.2	112
1938	78.6	73.6	76.5	95.7	90.3	112
1939	77.1	70.4	73.1	94.4	90.5	113
1940	78.6	71.3	71.7	95.8	94.8	121
1941	87.3	82.7	76.2	99.4	103.2	133
1942	98.8	99.6	78.5	103.8	110.2	156
1943	103.1	106.6	80.8	103.8	111.4	176
1944	104.0	104.9	83.0	103.8	115.5	185
1945	105.8	106.2	84.0	104.7	117.8	188
1946	121.1	130.7	90.1	115.5	132.6	198
1947	152.1	168.7	108.7	145.0	123.7	226
1948	165.1	179.1	134.2	163.6	135.0	248
1949	155.0	161.4	131.7	170.2	140.0	259
1950	161.5	166.2	133.2	173.6	146.5	270

(1) ______________ The Economic Almanac 1951-2, The National Industry Conference Board, 247 Park Avenue, New York, N. Y. p. 110.

Appendix Table IV (1)

Currents and Wattage of Various Types of Induction Motors at Full Load

HP.	I single-phase 110 v.	Watts	I three-phase 440 v.	Watts
0.5	5.6	616	0.8	488
1.0	10	1100	1.4	855
2.0	20	2200	2.9	1770
3.0	30	3300	4.3	2620
5.0	49	5400	6.6	4030
7.5	67	7380	9.6	4880
10.0	89	9800	12.8	7800
15.0	130	14300	18.7	11400
20.0	176	19400	25.3	15400
25.0	212	23200	30.5	18600
30.0	260	28600	37.4	22700
35.0	298	32780	42.9	26100
40.0	338	37180	48.6	29600
45.0	382	42020	54.9	33500
50.0	406	44660	58.4	35600
75.0	620	68200	89.0	54200
100.0	812	89320	116.0	72000
150.0	1220	134200	175.0	116500

(1) Ibbetson, W. S., Electrical Power Engineers' Handbook, Chemical Publishing Company of New York, Inc. 1939, p. 134, source of current values.

Appendix Table V

Daily Cost of Operation and Saving of 84 in. and 96 in. Diameter Horizontal Insulated Milk Storage Tanks, dollars--May 7, 1952

Capacity, gallons	3000		4000		5000		6000	
Diameter, inches	84	96	84	96	84	96	84	96
Depreciation and interest on tanks	1.05	1.05	1.15	1.15	1.34	1.34	1.51	1.51
Depreciation and interest on buildings	0.34	0.33	0.46	0.42	0.58	0.50	0.68	0.59
Taxes, insurances, licenses	0.69	0.67	0.82	0.78	0.99	0.93	1.14	1.06
Repairs, maintenance, supplies	0.57	0.57	0.63	0.63	0.73	0.73	0.82	0.82
Cleaning labor	0.87	1.07	1.25	1.40	1.49	1.61	1.80	1.90
Electricity	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09
Total costs	3.59	3.76	4.39	4.46	5.21	5.19	6.04	5.97
Annual yearly saving of 84 in. diameter	62		25.55		-7.30		-25.55	
Life (18 yr.) saving	1116		459		-131		-459	

a. Labor at $1.75
b. Same insulation and holding temperature was assumed for both tanks
c. Same initial cost for large and small diameter tank of the same capacity was assumed

Appendix Table VI

Conveyor, Weigh Can, Scales, Receiving Tank
Dumping Accessories
(One-Man Receiving Operation)
Daily Cost of Operation, Dollars--May 28,1952

	Size of Weigh Can, lbs.		
	500	750	1000
I. Fixed Costs			
Insurance, taxes, licenses	0.53	0.59	0.67
Depreciation and interest on building	0.07	0.09	0.10
Depreciation and interest on weigh can	0.24	0.41	0.57
Depreciation and interest on scales	0.20	0.20	0.20
Depreciation and interest on conveyor	0.62	0.62	0.62
Depreciation and interest on receiving tank	0.25	0.28	0.37
Depreciation and interest on accessory	0.07	0.07	0.07
Repairs, maintenance, supplies	0.64	0.70	0.79
Total fixed costs	2.62	2.96	3.39
II. Production Costs			
(a) 50 per cent of milk in less than 500 pound lots			
20,000 pounds per day	3.02	2.99	3.03
40,000 pounds per day	4.72	4.57	4.60
60,000 pounds per day	6.41	6.21	6.22
80,000 pounds per day	8.09	7.73	7.74
100,000 pounds per day	10.09	9.60	9.58
(b) 65 per cent of milk in less than 500 pound lots			
20,000 pounds per day	3.00	3.03	3.04
40,000 pounds per day	4.76	4.73	4.75
60,000 pounds per day	6.67	6.53	6.53
80,000 pounds per day	8.10	7.97	7.93
100,000 pounds per day	10.16	9.93	9.88
(c) 80 per cent of milk in less than 500 pound lots			
20,000 pounds per day	3.09	3.13	3.17
40,000 pounds per day	5.08	5.05	5.09
60,000 pounds per day	6.71	6.65	6.72
80,000 pounds per day	8.49	8.45	8.48
100,000 pounds per day	10.34	10.25	10.28
III. Total Cost			
(a) 50 per cent of milk in less than 500 pound lots			
20,000 pounds per day	5.64	5.95	6.42
40,000 pounds per day	7.34	7.53	7.99
60,000 pounds per day	9.03	9.17	9.61
80,000 pounds per day	10.71	10.69	11.13
100,000 pounds per day	12.71	12.56	12.97

Appendix Table 6 Continued

(b) 65 per cent of milk in less than 500 pound lots			
20,000 pounds per day	5.62	5.99	6.43
40,000 pounds per day	7.38	7.69	8.14
60,000 pounds per day	9.29	9.49	9.92
80,000 pounds per day	10.72	10.93	11.32
100,000 pounds per day	12.78	12.89	13.27
(c) 80 per cent of milk in less than 500 pound lots			
20,000 pounds per day	5.71	6.09	6.56
40,000 pounds per day	7.70	8.01	8.48
60,000 pounds per day	9.33	9.61	10.11
80,000 pounds per day	11.11	11.41	11.87
100,000 pounds per day	12.96	13.21	13.67
IV. Unit cost per 100 pounds, dollars			
(a) 50 per cent of milk in less than 500 pound lots			
20,000 pounds per day	0.028	0.030	0.032
40,000 pounds per day	0.018	0.019	0.020
60,000 pounds per day	0.015	0.015	0.016
80,000 pounds per day	0.014	0.013	0.014
100,000 pounds per day	0.013	0.013	0.013
(b) 65 per cent of milk in less than 500 pound lots			
20,000 pounds per day	0.028	0.030	0.032
40,000 pounds per day	0.019	0.019	0.020
60,000 pounds per day	0.016	0.016	0.017
80,000 pounds per day	0.013	0.014	0.014
100,000 pounds per day	0.013	0.013	0.013
(c) 80 per cent of milk in less than 500 pound lots			
20,000 pounds per day	0.029	0.030	0.033
40,000 pounds per day	0.019	0.020	0.021
60,000 pounds per day	0.016	0.016	0.017
80,000 pounds per day	0.014	0.014	0.015
100,000 pounds per day	0.013	0.013	0.014

Appendix Table VII

Straight-Away Can Washer--Daily Cost of Operation, Dollars
Summary of Data--April 25, 1952

	Size of Can Washer, CPM					
	6	8	10	12	14	16
I. Fixed Costs						
Insurance, taxes, licenses	0.58	0.79	0.89	0.95	1.01	1.35
Depreciation and interest on building	0.34	0.55	0.61	0.66	0.71	0.88
Depreciation and interest on equipment	0.82	0.93	1.11	1.14	1.21	1.74
Repairs, maintenance, supplies	0.43	0.50	0.58	0.60	0.65	0.90
Total	2.17	2.77	3.19	3.35	3.58	4.87
II. Production Costs						
Utilities						
20,000 lb.per day	0.84	0.84	0.84	0.84	0.84	0.84
40,000 lb.per day	1.67	1.67	1.67	1.67	1.67	1.67
60,000 lb.per day	2.51	2.51	2.51	2.51	2.51	2.51
80,000 lb.per day	3.33	3.33	3.33	3.33	3.33	3.33
100,000 lb.per day	4.18	4.18	4.18	4.18	4.18	4.18
Labor						
20,000 lb.per day	1.04	0.73	0.67	0.67	0.67	0.67
40,000 lb.per day	1.59	0.97	0.85	0.85	0.85	0.85
60,000 lb.per day	2.13	1.20	1.02	1.02	1.02	1.02
80,000 lb.per day	2.73	1.49	1.25	1.25	1.25	1.25
100,000 lb.per day	3,30	1.75	1.45	1.45	1.45	1.45
Total Production Costs						
20,000 lb.per day	1.88	1.57	1.51	1.51	1.51	1.5
40,000 lb.per day	3.26	2.64	2.52	2.52	2.52	2.5
60,000 lb.per day	4.64	3.71	3.53	3.53	3.53	3.5
80,000 lb.per day	6.06	4.82	4.58	4.58	4.58	4.5
100,000 lb.per day	7.48	5.93	5.63	5.63	5.63	5.6
III. Total Costs						
20,000 lb.per day	4.05	4.34	4.70	4.86	5.09	6.3
40,000 lb.per day	5.43	5.41	5.71	5.87	6.10	7.3
60,000 lb.per day	6.81	6.48	6.72	6.88	7.11	8.4
80,000 lb.per day	8.23	7.59	7.77	7.93	8.16	9.4
100,000 lb.per day	9.65	8.70	8.82	8.98	9.21	10.5
IV. Unit Cost per 100 pounds						
20,000 lb.per day	0.021	0.022	0.024	0.024	0.026	0.03
40,000 lb.per day	0.014	0.014	0.015	0.015	0.015	0.01
60,000 lb.per day	0.011	0.011	0.011	0.012	0.012	0.01
80,000 lb.per day	0.010	0.010	0.010	0.010	0.010	0.01
100,000 lb.per day	0.010	0.009	0.009	0.009	0.009	0.01

Appendix Table VIII

Rotary Can Washer--Daily Cost of Operation, Dollars
Summary of Data--May 8, 1952

	Washer Size, CPM	
	3	6
I. Fixed Costs		
Insurance, taxes, licenses	0.31	0.37
Depreciation and interest on buildings	0.20	0.20
Depreciation and interest on equipment	0.46	0.62
Repairs, maintenance, supplies	0.22	0.30
Total	1.19	1.49
II. Production Costs		
Labor		
10,000 lb.per day	2.19	1.38
20,000 lb.per day	3.24	2.19
30,000 lb.per day	5.25	3.01
40,000 lb.per day	7.00	3.80
50,000 lb.per day	10.25	4.60
60,000 lb.per day	13.40	5.82
Utilities		
10,000 lb.per day	1.16	1.16
20,000 lb.per day	2.30	2.30
30,000 lb.per day	3.46	3.46
40,000 lb.per day	4.60	4.60
50,000 lb.per day	5.74	5.74
60,000 lb.per day	6.88	6.88
Total		
10,000 lb.per day	3.35	2.54
20,000 lb.per day	5.54	4.49
30,000 lb.per day	8.71	6.47
40,000 lb.per day	11.60	8.40
50,000 lb.per day	15.99	10.34
60,000 lb.per day	20.28	12.70
III. Total Cost		
10,000 lb.per day	4.54	4.03
20,000 lb.per day	6.73	5.98
30,000 lb.per day	9.90	7.96
40,000 lb.per day	12.79	9.89
50,000 lb.per day	17.18	11.83
60,000 lb.per day	21.47	14.19
IV. Unit Cost per 100 pounds		
10,000 lb.per day	0.0454	0.0403
20,000 lb.per day	0.0337	0.0299
30,000 lb.per day	0.0330	0.0265

Appendix Table IX
Clarifier--Daily Cost of Operation, Dollars
Summary of Data--April 26, 1952

	Size of clarifier, lb/hr		
	7,000	12,000	20,000
I. Fixed Costs			
Insurance, taxes, licenses	0.42	0.49	0.52
Depreciation and interest on building	0.30	0.32	0.32
Depreciation and interest on equipment	1.06	1.26	1.50
Repairs, maintenance, supplies	0.52	0.61	0.74
Total	2.30	2.68	3.08
II. Production Costs			
Utilities			
10,000 lb.per day	0.06	0.04	0.03
20,000 lb.per day	0.11	0.08	0.06
40,000 lb.per day	0.22	0.16	0.12
60,000 lb.per day	0.35	0.24	0.19
80,000 lb.per day	0.43	0.31	0.23
100,000 lb.per day	0.60	0.40	0.30
Labor			
10,000 lb.per day	1.48	1.55	1.59
20,000 lb.per day	1.75	1.71	1.68
40,000 lb.per day	2.24	2.00	1.86
60,000 lb.per day	2.75	2.30	2.08
80,000 lb.per day	3.23	2.56	2.27
100,000 lb.per day	3.75	2.86	2.35
Total			
10,000 lb.per day	1.54	1.59	1.62
20,000 lb.per day	1.86	1.79	1.74
40,000 lb.per day	2.46	2.16	1.98
60,000 lb.per day	3.10	2.54	2.27
80,000 lb.per day	3.66	2.87	2.50
100,000 lb.per day	4.35	3.26	2.65
III. Total Costs			
10,000 lb.per day	3.84	4.27	4.70
20,000 lb.per day	4.16	4.47	4.82
40,000 lb.per day	4.76	4.84	5.06
60,000 lb.per day	5.40	5.22	5.35
80,000 lb.per day	5.96	5.55	5.58
100,000 lb.per day	6.65	5.94	5.73
IV. Unit Cost per 100 pounds			
10,000 lb.per day	0.0384	0.0427	0.0470
20,000 lb.per day	0.0208	0.0223	0.0241
40,000 lb.per day	0.0119	0.0121	0.0126
60,000 lb.per day	0.0090	0.0087	0.0089
80,000 lb.per day	0.0074	0.0069	0.0069
100,000 lb.per day	0.0067	0.0059	0.0057

Appendix Table X

Clarifier--Daily Cost of Operation, Dollars
(When used in one-man receiving room where volume received is controlled by clarifier)

Summary of Data--June 14, 1952

	Size of clarifier, lb/hr		
	7,000	12,000	20,000
I. Total Fixed Costs (See Table IX)	2.30	2.68	3.08
II. Penalty for delaying receiving of milk (add to production costs)			
10,000 lb. per day	1.75	0.77	0.18
20,000 lb. per day	3.50	1.54	0.36
40,000 lb. per day	7.00	3.08	0.72
60,000 lb. per day	10.50	4.62	1.08
80,000 lb. per day	14.00	6.16	1.44
100,000 lb. per day	17.50	7.70	1.80
III. Total Costs			
10,000 lb. per day	5.79	5.04	4.68
20,000 lb. per day	7.66	6.01	5.18
40,000 lb. per day	11.76	7.92	5.78
60,000 lb. per day	15.90	9.84	6.43
80,000 lb. per day	19.96	11.71	7.02
100,000 lb. per day	24.15	13.64	7.53
IV. Unit Cost per 100 pounds			
10,000 lb. per day	0.0580	0.0500	0.0488
20,000 lb. per day	0.0383	0.0301	0.0259
40,000 lb. per day	0.0294	0.0198	0.0145
60,000 lb. per day	0.0265	0.0164	0.0107
80,000 lb. per day	0.0249	0.0146	0.0088
100,000 lb. per day	0.0242	0.0136	0.0075

Appendix Table XI

Filter--Daily Cost of Operation, Dollars
(Including positive pump, motor)--June 16, 1952

	Capacity, lb. per hr.			
	3500	10,000	20,000	30,000
I. Fixed Costs				
Insurance, taxes, licenses	0.11	0.15	0.18	0.20
Depreciation and interest on building	0.02	0.02	0.02	0.02
Depreciation and interest on equipment	0.29	0.40	0.46	0.52
Repairs, maintenance, supplies	0.14	0.20	0.23	0.26
Total	0.56	0.77	0.89	1.00
II. Production Costs				
20,000 lb.per day	1.38	0.94	0.97	1.10
40,000 lb.per day	2.42	1.32	1.17	1.23
60,000 lb.per day	3.46	1.69	1.37	1.36
80,000 lb.per day	4.50	2.06	1.57	1.49
100,000 lb.per day	5.54	2.43	1.77	1.62
III. Total Costs				
20,000 lb.per day	1.94	1.71	1.86	2.10
40,000 lb.per day	2.98	2.09	2.06	2.23
60,000 lb.per day	4.02	2.46	2.26	2.36
80,000 lb.per day	5.06	2.83	2.46	2.49
100,000 lb.per day	6.10	3.20	2.66	2.62
IV. Unit Cost per 100 pounds				
20,000 lb.per day	0.0097	0.0086	0.0093	0.0105
40,000 lb.per day	0.0075	0.0052	0.0051	0.0055
60,000 lb.per day	0.0067	0.0041	0.0037	0.0039
80,000 lb.per day	0.0063	0.0036	0.0031	0.0031
100,000 lb.per day	0.0061	0.0032	0.0027	0.0026

Appendix Table XII

Raw Milk Plate Cooler (with pump and motor)
(including penalty for one-man operation)
Daily Cost of Operation, Dollars

Summary of Data--May 26, 1952

	Capacity, lb. per hr.			
	10,000	20,000	30,000	40,000
I. Fixed Costs				
Insurance, taxes, licenses	0.35	0.42	0.55	0.63
Depreciation and interest on buildings	0.14	0.14	0.14	0.14
Depreciation and interest on equipment	0.68	0.87	1.24	1.47
Repairs, maintenance, supplies	0.32	0.42	0.58	0.70
Total	1.49	1.85	2.51	2.94
II. Production Costs				
Labor (including penalty for rate of rec'g)				
20,000 lb.per day	1.75	1.35	1.44	1.55
40,000 lb.per day	3.50	1.52	1.56	1.64
60,000 lb.per day	5.25	1.70	1.67	1.73
80,000 lb.per day	7.00	1.87	1.80	1.81
100,000 lb.per day	8.75	2.05	1.92	1.91
Total production Cost for 10° F. Cooling				
20,000 lb.per day	2.67	2.27	2.36	2.47
40,000 lb.per day	4.42	2.31	3.35	3.43
60,000 lb.per day	6.17	4.10	4.07	4.13
80,000 lb.per day	7.92	5.07	5.00	5.01
100,000 lb.per day	9.67	5.25	5.12	5.11
III. Total Cost				
20,000 lb.per day	4.16	4.12	4.87	5.41
40,000 lb.per day	5.91	5.16	5.86	6.37
60,000 lb.per day	7.66	5.95	6.58	7.07
80,000 lb.per day	9.41	6.92	7.51	7.95
100,000 lb.per day	11.16	7.10	7.63	8.05
IV. Unit Cost per 100 pound for 10° F. Cooling				
20,000 lb.per day	0.0210	0.0201	0.0240	0.0270
40,000 lb.per day	0.0150	0.0104	0.0146	0.0157
60,000 lb.per day	0.0128	0.0068	0.0068	0.0068
80,000 lb.per day	0.0118	0.0065	0.0062	0.0062
100,000 lb.per day	0.0112	0.0053	0.0051	0.0051

Appendix Table XIII
Horizontal Storage Tank (based on one filling per day)
Summary of Data--Daily Cost of Operation, Dollars, May 1, 1952

	Capacity, Gallons						
	600	1000	2000	3000	4000	5000	6000
I. Insulated Storage Tank							
A. Fixed Costs							
Insurance, Taxes, licenses	0.35	0.38	0.53	0.67	0.78	0.93	1.06
Depreciation and interest on buildings	0.10	0.14	0.25	0.33	0.42	0.50	0.59
Depreciation and interest on equipment	0.67	0.68	0.82	1.05	1.15	1.34	1.51
Repairs, Maintenance, supplies	0.36	0.37	0.45	0.57	0.63	0.73	0.82
Total	1.48	1.57	2.05	2.62	2.98	3.50	3.98
B. Production Costs							
Electricity	0.04	0.05	0.06	0.07	0.08	0.08	0.09
Labor	0.53	0.47	0.74	1.07	1.40	1.61	1.90
Total	0.57	0.52	0.80	1.14	1.48	1.69	1.99
C. Total Costs	2.05	2.09	2.85	3.76	4.46	5.19	5.97
D. Unit Cost per 100 lbs.	.0398	.0232	.0165	.0146	.0130	.0120	.0116
II. Cold Wall Tank (DX)							
A. Fixed Costs							
Insurance, taxes, licenses	0.42	0.46	0.62	0.76	0.91	1.05	1.19
Depreciation and interest on buildings	0.10	0.14	0.25	0.33	0.42	0.50	0.59
Depreciation and interest on equipment	0.85	0.88	1.05	1.25	1.48	1.66	1.84
Repairs, maintenance, supplies	0.46	0.47	0.58	0.68	0.80	0.90	1.00
Total	1.83	1.95	2.50	3.02	3.61	4.11	4.62
B. Production Costs							
Electricity	0.04	0.05	0.06	0.07	0.08	0.08	0.08
Refrigeration	0.64	1.00	1.81	2.05	2.44	2.73	2.88
Labor	0.53	0.47	0.74	1.07	1.40	1.61	1.90
Total	1.21	1.52	2.61	3.19	3.92	4.42	4.86

Appendix Table XIII Continued

	Capacity, Gallons						
	600	1000	2000	3000	4000	5000	6000
C. Total Costs	3.04	3.47	5.11	6.21	7.53	8.53	9.48
D. Unit Cost per 100 lbs.	.0590	.0388	.0297	.0241	.0219	.0198	.0184
III. DX Refrigerated Coils							
A. Fixed Costs							
Insurance, taxes, licenses	0.43	0.47	0.66	0.79	0.92	1.10	1.25
Depreciation, interest on building	0.10	0.14	0.25	0.33	0.42	0.50	0.59
Depreciation and interest on equipment	0.86	0.88	1.16	1.34	1.50	1.75	1.99
Repairs, maintenance, supplies	0.47	0.48	0.63	0.73	0.82	0.97	1.08
Total	1.86	1.97	2.70	3.19	3.66	4.32	4.91
B. Production Costs							
Electricity	0.04	0.05	0.06	0.07	0.08	0.08	0.09
Refrigeration	0.40	0.59	1.00	1.62	2.03	2.19	2.60
Labor	0.70	0.67	0.95	1.38	1.61	1.87	2.17
Total	1.14	1.31	2.01	3.07	3.72	4.14	4.86
C. Total Cost	3.00	3.28	4.71	6.26	7.38	8.46	9.77
D. Unit Cost per 100 lbs.	.0581	.0383	.0272	.0242	.0215	.0197	.0190

Appendix Table XIV
Internal Tube Heater
(heating from 40 to 90° F. for separating)
Summary of Data--Daily Cost of Operation, Dollars, June 4, 1952

	Capacity lb. per hr. 9,000	11,000
I. Fixed Costs		
Insurance, taxes, licenses	0.08	0.09
Depreciation and interest on building	0.06	0.06
Depreciation and interest on heater	0.09	0.11
Repairs, maintenance, supplies	0.05	0.06
Total	0.28	0.32
II. Production Cost		
Labor		
10,000 lb.per day	0.40	0.45
20,000 lb.per day	0.59	0.61
30,000 lb.per day	0.78	0.77
40,000 lb.per day	0.97	0.93
Utilities		
10,000 lb.per day	2.02	2.02
20,000 lb.per day	4.04	4.04
30,000 lb.per day	6.06	6.06
40,000 lb.per day	8.08	8.08
Total Production Cost		
10,000 lb.per day	2.42	2.47
20,000 lb.per day	4.63	4.65
30,000 lb.per day	6.84	6.83
40,000 lb.per day	9.05	9.01
III. Total Cost		
10,000 lb.per day	2.70	2.79
20,000 lb.per day	4.91	4.97
30,000 lb.per day	7.12	7.15
40,000 lb.per day	9.33	9.33
IV. Unit Cost per 100 lb.		
10,000 lb.per day	0.027	0.028
20,000 lb.per day	0.025	0.025
30,000 lb.per day	0.024	0.024
40,000 lb.per day	0.023	0.023

Appendix Table XV

Separator (milk heated to 90° F.)
Summary of Data
Daily Cost of Operation, Dollars, April 26, 1952

	Capacity, lb. per hr. 3,500	7000	11,000
I. Fixed Cost			
Insurance, taxes, licenses	0.42	0.49	0.52
Depreciation and interest on building	0.30	0.32	0.32
Depreciation and interest on equipment	1.06	1.26	1.50
Repairs, maintenance, supplies	0.52	0.61	0.74
Total	2.30	2.68	3.08
II. Production Costs			
Utilities			
5,000 lb.per day	0.06	0.04	0.03
10,000 lb.per day	0.11	0.07	0.06
15,000 lb.per day	0.16	0.11	0.08
20,000 lb.per day	0.22	0.14	0.11
30,000 lb.per day	0.32	0.22	0.16
40,000 lb.per day	0.43	0.27	0.22
50,000 lb.per day	0.56	0.34	0.26
60,000 lb.per day	0.64	0.41	0.31
100,000 lb.per day		0.68	0.51
Labor			
5,000 lb.per day	1.58	1.56	1.60
10,000 lb.per day	1.86	1.78	1.71
15,000 lb.per day	2.10	1.82	1.81
20,000 lb.per day	2.32	1.93	1.85
30,000 lb.per day	2.81	2.19	2.01
40,000 lb.per day	3.33	2.42	2.18
50,000 lb.per day	3.81	2.69	2.33
60,000 lb.per day	4.32	2.95	2.50
100,000 lb.per day		3.95	3.13
Total Production Cost			
5,000 lb.per day	1.64	1.60	1.63
10,000 lb.per day	1.97	1.85	1.77
15,000 lb.per day	2.26	1.93	1.89
20,000 lb.per day	2.54	2.07	1.96
30,000 lb.per day	3.13	2.41	2.17
40,000 lb.per day	3.76	2.69	2.40
50,000 lb.per day	4.37	3.03	2.59
60,000 lb.per day	4.96	3.36	2.81
100,000 lb.per day		4.63	3.64

Continued

Appendix Table XV Continued

	Capacity, lb. per hr.		
	3,500	7,000	11,000
III. Total Cost			
5,000 lb.per day	3.94	4.28	4.71
10,000 lb.per day	4.27	4.53	4.85
15,000 lb.per day	4.56	4.61	4.97
20,000 lb.per day	4.84	4.75	5.04
30,000 lb.per day	5.43	5.09	5.25
40,000 lb.per day	6.06	5.37	5.48
50,000 lb.per day	6.67	5.71	5.67
60,000 lb.per day	7.26	6.04	5.89
100,000 lb.per day		7.31	6.72
IV. Unit Cost per 100 lb.			
5,000 lb.per day	.0788	.0856	.0942
10,000 lb.per day	.0427	.0453	.0485
15,000 lb.per day	.0304	.0307	.0331
20,000 lb.per day	.0242	.0238	.0252
30,000 lb.per day	.0181	.0169	.0175
40,000 lb.per day	.0151	.0134	.0137
50,000 lb.per day	.0133	.0114	.0113
60,000 lb.per day	.0121	.0101	.0098
100,000 lb.per day		.0073	.0067

Appendix Table XVI

Cold Milk Separator--Summary of Data
Daily Cost of Operation, Dollars--June 16, 1952

	Capacity, lb. per hr.		
	2,000	4,000	6,000
I. Fixed Costs (See Table XV)	2.30	2.68	3.08
II. Production Costs			
5,000 lb.per day	1.89	1.74	1.70
10,000 lb.per day	2.51	2.20	1.96
15,000 lb.per day	3.02	2.34	2.05
20,000 lb.per day	3.53	2.61	2.31
30,000 lb.per day	4.63	3.21	2.31
40,000 lb.per day	5.78	3.73	3.12
50,000 lb.per day	6.88	4.34	3.44
III. Total Cost			
5,000 lb.per day	4.19	4.42	4.78
10,000 lb.per day	4.81	4.88	5.04
15,000 lb.per day	5.32	5.02	5.13
20,000 lb.per day	5.83	5.29	5.39
30,000 lb.per day	6.93	5.89	5.77
40,000 lb.per day	8.08	6.41	6.20
50,000 lb.per day	9.18	7.02	6.52
IV. Unit Cost per 100 pounds			
5,000 lb.per day	.0826	.0884	.0956
10,000 lb.per day	.0481	.0488	.0504
15,000 lb.per day	.0355	.0336	.0343
20,000 lb.per day	.0292	.0265	.0269
30,000 lb.per day	.0231	.0197	.0192
40,000 lb.per day	.0202	.0160	.0155
50,000 lb.per day	.0184	.0141	.0130

Appendix Table XVII. Homogenizer--Summary of Data
Daily Cost of Operation, Dollars, April 6, 1952

	Capacity, gallons per hour					
	200	500	800	1,000	1,500	2,000
I. Fixed costs						
Insurance, taxes, licenses	0.25	0.43	0.49	0.55	0.69	0.74
Depreciation and interest on building	0.24	0.41	0.51	0.56	0.77	0.77
Depreciation and interest on equipment	0.37	0.60	0.68	0.77	0.93	1.02
Repair, maintenance, supplies	0.29	0.48	0.54	0.61	0.74	0.81
Total	1.15	1.92	2.22	2.49	3.13	3.34
II. Production Costs						
Utilities						
5,000 lb.per day	0.16	0.18	0.18	0.17	0.17	0.16
10,000 lb.per day	0.30	0.35	0.35	0.33	0.33	0.32
20,000 lb.per day	0.60	0.67	0.68	0.66	0.67	0.66
40,000 lb.per day	1.20	1.36	1.38	1.37	1.37	1.36
60,000 lb.per day		2.06	2.07	2.06	2.06	2.06
80,000 lb.per day		2.74	2.76	2.75	2.75	2.74
100,000 lb.per day			3.44	3.26	3.25	3.26
Labor						
5,000 lb.per day	2.65	1.60	1.35	1.42	1.31	1.23
10,000 lb.per day	4.28	2.26	1.76	1.77	1.54	1.44
20,000 lb.per day	7.90	3.50	2.62	2.43	1.99	1.79
40,000 lb.per day	14.80	6.25	4.31	3.80	2.90	2.43
60,000 lb.per day		9.26	7.04	5.10	4.15	3.12
80,000 lb.per day		11.80	7.79	6.50	4.70	3.80
100,000 lb.per day			9.40	7.90	5.65	4.46
III. Total Costs						
5,000 lb.per day	3.96	3.70	3.75	4.08	4.61	4.73
10,000 lb.per day	5.73	4.53	4.33	4.59	5.00	5.10
20,000 lb.per day	9.65	6.09	5.52	5.58	5.79	5.79

Appendix Table XVII Continued

	Capacity, gallons per hour					
	200	500	800	1,000	1,500	2,000
40,000 lb.per day	17.15	9.53	7.91	7.66	7.40	7.13
60,000 lb.per day		13.24	11.31	9.65	9.34	8.52
80,000 lb.per day		16.44	12.77	11.74	10.58	9.88
100,000 lb.per day			15.06	13.65	12.03	11.06
IV. Unit Costs						
5,000 lb.per day	.0790	.0740	.0750	.0820	.0920	.0950
10,000 lb.per day	.0570	.0450	.0430	.0460	.0500	.051
20,000 lb.per day	.0480	.0304	.0276	.0279	.0289	.0289
40,000 lb.per day	.0429	.0238	.0198	.0191	.0185	.0178
60,000 lb.per day		.0220	.0170	.0161	.0156	.0140
80,000 lb.per day		.0205	.0160	.0147	.0132	.0124
100,000 lb.per day			.0151	.0137	.0120	.0111

Appendix Table XVIII. High Temperature Shortime Pasteurizer--Summary of Data
Daily Cost of Operation, Dollars--May 6, 1952

	Capacity, lb. per hr.				
	4,000	8,000	12,000	16,000	20,000
I. Fixed Costs					
Insurance, taxes, licenses	0.73	0.89	1.09	1.37	1.39
Depreciation, interest on building	0.13	0.13	0.16	0.16	0.16
Depreciation, interest on equipment	1.78	2.20	2.76	3.24	3.58
Repairs, maintenance, supplies	0.85	1.06	1.29	1.54	1.70
Total	3.49	4.28	5.30	6.31	6.83
II. Production Costs					
Labor (no delay penalties)					
20,000 lb.per day	4.50	3.92	4.00	4.10	4.31
40,000 lb.per day	7.30	5.50	4.87	4.96	5.01
60,000 lb.per day	10.83	6.89	5.91	5.66	5.55
80,000 lb.per day	13.12	8.30	6.80	6.11	6.06
100,000 lb.per day		9.86	7.85	7.06	6.76
Utilities					
20,000 lb.per day	3.58	3.57	3.57	3.56	3.55
40,000 lb.per day	6.48	6.47	6.46	6.44	6.42
60,000 lb.per day	9.07	9.06	9.05	9.02	8.99
80,000 lb.per day	12.06	12.04	12.03	11.98	11.92
100,000 lb.per day		15.06	15.05	14.99	14.95
Total					
20,000 lb.per day	8.08	7.49	7.57	7.66	7.86
40,000 lb.per day	13.78	11.97	11.33	11.40	11.43
60,000 lb.per day	19.90	15.95	14.96	14.68	14.54
80,000 lb.per day	25.18	20.34	18.83	18.09	17.98
100,000 lb.per day		24.92	22.90	22.05	21.71

Appendix Table XVIII Continued

	Capacity, lb. per hr.				
	4,000	8,000	12,000	16,000	20,000
III. Total Cost					
5,000 lb.per day	5.71	8.04	9.41	9.80	10.77
20,000 lb.per day	11.57	11.77	12.87	13.97	14.69
40,000 lb.per day	17.27	16.25	16.63	17.71	18.26
60,000 lb.per day	23.39	20.13	20.26	20.99	21.37
80,000 lb.per day	28.67	24.62	24.13	24.40	24.81
100,000 lb.per day		29.20	28.20	28.36	28.54
IV. Unit Cost per 100 pounds					
20,000 lb.per day	.0578	.0588	.0644	.0698	.0734
40,000 lb.per day	.0432	.0406	.0416	.0443	.0456
60,000 lb.per day	.0390	.0335	.0338	.0350	.0356
80,000 lb.per day	.0358	.0308	.0302	.0305	.0310
100,000 lb.per day		.0292	.0282	.0284	.0285

Appendix Table XIX. Process Tank (for temperature difference of 120° F., no regeneration; multiply total cost by 0.93 for 100° F.)
Summary of Data--Daily Cost of Operation, Dollars, May 15, 1952

	Capacity, gallons				
	100	200	400	600	1,000
I. Fixed Costs					
Insurance, taxes, licenses	0.12	0.20	0.28	0.43	0.51
Depreciation, and interest on building	0.03	0.09	0.13	0.18	0.18
Depreciation and interest on equipment	0.28	0.37	0.53	0.83	1.06
Total	0.56	0.84	1.19	1.84	2.26
II. Production Costs					
(a) Heating from 40 - 160° F.					
Utilities, daily					
(1) One filling	0.34	0.68	1.36	2.04	3.33
(2) Two fillings	0.68	1.36	2.72	4.08	6.66
(3) Three fillings	1.02	2.04	4.08	6.12	9.99
(4) Four fillings	1.36	2.72	5.44	8.16	13.32
Labor, daily					
(1) One filling	0.66	0.68	0.72	0.77	0.85
(2) Two fillings	0.96	0.98	1.02	1.07	1.15
(3) Three fillings	1.26	1.28	1.32	1.37	1.45
(4) Four fillings	1.56	1.58	1.62	1.67	1.75
(b) Cooling from 160 - 40° F.					
Utilities, daily					
(1) One filling	0.35	0.71	1.41	2.12	3.46
(2) Two fillings	0.71	1.42	2.83	4.25	6.91
(3) Three fillings	1.05	2.13	4.23	6.36	10.38
(4) Four fillings	1.40	2.84	5.64	8.48	13.84
Labor, Daily					
(1) One filling	0.30	0.30	0.30	0.30	0.30
(2) Two fillings	0.60	0.60	0.60	0.60	0.60
(3) Three fillings	0.90	0.90	0.90	0.90	0.90
(4) Four fillings	1.20	1.20	1.20	1.20	1.20

Appendix Table XIX Continued

	Capacity, gallons				
	100	200	400	600	1,000
III. Total Costs					
(a) Heating from 40 - 160° F.					
(1) One filling	1.56	2.20	3.27	4.65	6.44
(2) Two fillings	2.20	3.18	4.93	5.99	10.07
(3) Three fillings	2.84	4.16	6.59	9.33	13.70
(4) Four fillings	3.48	5.14	8.25	11.67	17.33
(b) Additional Cost for Cooling from 160 - 40°F.					
(1) One filling	0.65	1.01	1.71	2.42	3.76
(2) Two fillings	1.31	2.02	3.43	4.85	7.51
(3) Three fillings	1.95	3.03	5.13	7.26	11.28
(4) Four fillings	2.60	4.04	6.84	9.68	15.04
(c) Heating and Cooling					
(1) One filling	2.21	3.21	4.98	7.07	10.20
(2) Two fillings	3.51	5.20	8.36	10.84	17.58
(3) Three fillings	4.79	7.19	11.72	16.59	24.98
(4) Four fillings	6.08	9.18	15.09	21.35	32.37
IV. Unit Cost					
(1) One filling	0.256	0.181	0.145	0.137	0.119
(2) Two fillings	0.205	0.151	0.121	0.111	0.102
(3) Three fillings	0.186	0.139	0.114	0.107	0.097
(4) Four fillings	0.176	0.133	0.110	0.103	0.093

Appendix Table XX. Process Tank (Temperature difference 100° F. Use of regeneration) Summary of Data--Daily Cost of Operation, Dollars, June 17, 1952

	Capacity, gallons				
	100	200	400	600*	1000
I. Fixed Costs (See Table XIX)	0.56	0.84	1.19	1.84	2.26
Heat exchanger with pump	2.50	2.50	2.50	2.50	2.50
Total	3.06	3.34	3.69	4.34	4.76
II. Production Costs, using regeneration, labor and utilities					
One filling daily	1.27	1.63	2.30	2.98	4.24
Two fillings daily	2.18	2.88	4.18	5.49	7.93
Three fillings daily	3.09	4.13	6.06	8.00	11.62
Four fillings daily	4.00	5.38	7.94	10.51	15.31
III. Total Costs, heating and cooling					
One filling daily	4.33	4.97	5.99	7.32	9.00
Two fillings daily	5.24	6.22	7.87	9.83	12.69
Three fillings daily	6.15	7.47	9.87	12.34	16.38
Four fillings daily	7.06	8.72	11.63	14.85	20.07
IV. Unit Cost per 100 pounds, heating and cooling					
One filling daily	0.500	0.289	0.174	0.142	0.104
Two fillings daily	0.305	0.182	0.114	0.095	0.074
Three fillings daily	0.240	0.145	0.095	0.080	0.063
Four fillings daily	0.205	0.128	0.085	0.072	0.059

* If cooling is done with a compact-type surface cooler, add the fixed costs of the cooler to the total cost of the process tank to obtain the total cost of operation of the two pieces of equipment.

Appendix Table XXI. Square and Rectangular Coil Vat (Heating from 40 - 160° F.) Summary of Data--Daily Cost of Operation, Dollars, May 15, 1952

	Capacity, gallons				
	200	400	600	800	1000
I. Fixed Costs					
Insurance, taxes, licenses	0.39	0.51	0.62	0.69	0.77
Depreciation, interest on buildings	0.18	0.26	0.36	0.40	0.45
Depreciation, interest on equipment	0.59	0.72	0.81	0.89	1.00
Repairs, maintenance, supplies	0.34	0.42	0.47	0.52	0.58
Total	1.50	1.91	2.26	2.50	2.80
II. Production Costs					
(a) Heating from 40 - 160° F.					
Utilities					
One filling daily	0.80	1.60	2.40	3.18	3.98
Two fillings daily	1.60	3.20	4.80	6.36	7.96
Three fillings daily	2.40	4.80	7.20	9.54	11.94
Four fillings daily	3.20	6.40	9.60	12.72	15.92
Labor					
One filling daily	1.25	1.39	1.55	1.74	1.86
Two fillings daily	1.85	1.99	2.15	2.34	2.46
Three fillings daily	2.45	2.59	2.75	2.94	3.06
Four fillings daily	3.05	3.19	3.35	3.54	3.66
Total production cost					
One filling daily	2.05	2.99	3.95	4.92	5.84
Two fillings daily	3.45	5.19	6.95	8.70	10.42
Three fillings daily	4.85	7.39	9.95	12.48	15.00
Four fillings daily	6.25	9.59	12.95	16.26	19.58
(b) Cooling from 160 - 40° F.					
Utilities					
One filling daily	0.83	1.66	2.50	3.31	4.14
Two fillings daily	1.66	3.32	5.00	6.62	8.28
Three fillings daily	2.49	4.98	7.50	9.93	12.42
Four fillings daily	3.32	6.64	10.00	13.24	16.56

	Capacity, gallons				
	200	400	600	800	1000
Labor					
One filling daily	0.60	0.60	0.60	0.60	0.60
Two fillings daily	1.20	1.20	1.20	1.20	1.20
Three fillings daily	1.80	1.80	1.80	1.80	1.80
Four fillings daily	2.40	2.40	2.40	2.40	2.40
Total Production Cost for cooling after heating in coil vat					
One filling daily	1.43	2.26	3.10	3.91	4.74
Two fillings daily	2.86	4.52	6.20	7.82	9.48
Three fillings daily	4.29	6.78	9.30	11.73	14.22
Four fillings daily	5.72	9.04	12.40	15.64	18.96
III. Total Costs					
(a) Heating from 40-160° F.					
One filling	3.55	4.90	6.21	7.42	8.64
Two fillings	4.95	7.10	9.21	11.20	13.22
Three fillings	6.35	9.20	12.21	14.98	17.80
Four fillings	7.75	11.50	15.21	18.76	22.38
(b) Additional cost for cooling same as II(b)					
(c) Heating and cooling					
One filling	4.98	7.16	9.31	11.33	13.38
Two fillings	7.81	11.62	15.41	19.02	22.70
Three fillings	10.64	15.98	21.51	26.71	32.02
Four fillings	13.47	20.54	27.61	34.40	41.34
IV. Unit Cost					
(a) Heating only					
One filling	0.206	0.143	0.121	0.109	0.100
Two fillings	0.144	0.103	0.089	0.082	0.078
Three fillings	0.122	0.089	0.079	0.073	0.069
Four fillings	0.113	0.031	0.074	0.068	0.065

Appendix Table XXI Continued

	Capacity, gallons				
	200	400	600	800	1000
(c) Heating and cooling					
One filling	0.290	0.208	0.181	0.165	0.156
Two fillings	0.227	0.169	0.150	0.139	0.132
Three fillings	0.206	0.155	0.139	0.130	0.124
Four fillings	0.196	0.150	0.134	0.125	0.121

Appendix Table XXII
Compact Type Surface Cooler
(After pasteurizing, cooling from 145 to 40° F.)
Summary of Data--Daily Cost of Operation, Dollars, May 27, 1952

	Capacity, lb. per hr. 20,000	30,000	40,000
I. Fixed Costs			
Insurance, Taxes, licenses	0.95	1.15	1.25
Depreciation, interest on building	0.07	0.11	0.15
Depreciation, interest on equipment	2.40	2.90	4.10
Repairs, maintenance, supplies	0.98	1.16	1.51
Total	4.40	5.32	7.01
II. Production Costs			
Labor			
20,000 lb.per day	0.81	1.08	1.46
40,000 lb.per day	0.83	1.09	1.47
60,000 lb.per day	0.85	1.10	1.48
80,000 lb.per day	0.87	1.11	1.49
100,000 lb.per day	0.89	1.12	1.50
Total Production Cost			
20,000 lb.per day	6.99	7.26	7.64
40,000 lb.per day	12.86	13.12	13.50
60,000 lb.per day	16.80	17.05	17.43
80,000 lb.per day	22.15	22.39	22.77
100,000 lb.per day	27.41	27.64	28.02
III. Total Cost			
20,000 lb.per day	11.39	12.58	14.65
40,000 lb.per day	17.26	18.44	20.51
60,000 lb.per day	21.20	22.37	24.44
80,000 lb.per day	26.55	27.71	29.78
100,000 lb.per day	31.81	32.96	35.03
IV. Unit Cost per 100 pounds, cooling with water down to 80° F., then cooling with DX to 40° F.			
20,000 lb.per day	0.057	0.063	0.073
40,000 lb.per day	0.043	0.045	0.052
60,000 lb.per day	0.035	0.037	0.041
80,000 lb.per day	0.033	0.035	0.037
100,000 lb.per day	0.032	0.033	0.035

Appendix Table XXIII

Refrigerated Storage (with wooden crates)
Summary of Data--Daily Cost of Operation, Dollars, 5/27/52

	Pounds of milk handled daily				
	20,000	30,000	40,000	60,000	80,000
I. Fixed Costs					
Taxes, insurance, licenses	0.20	0.30	0.40	0.57	0.79
Depreciation, interest on building	0.46	0.69	0.91	1.36	1.82
Depreciation, interest on equipment	0.12	0.14	0.17	0.22	0.26
Repairs, maintenance, supplies	0.08	0.11	0.14	0.20	0.26
Total	0.86	1.24	1.62	2.35	3.13
II. Production Costs					
Refrigeration	5.80	7.65	9.35	13.20	17.00
Labor cost (into cooler)	8.22	12.30	16.15	24.50	32.50
III. Total Cost	14.88	21.19	27.12	40.05	52.63
IV. Unit Cost (not including load-out)	0.0744	0.0706	0.0678	0.0665	0.0658

Appendix Table XXIV. Glass Filling and Capping--Summary of Data
Daily Cost of Operation, Dollars, May 21, 1952

	Size		
	No. valves--No. Capping heads		
	10	14-4	28-8
Filling rate in qts. per min.	40	85	135
I. Fixed Costs			
Insurance, taxes, licenses	0.52	0.64	1.00
Depreciation and interest on building	0.15	0.20	0.34
Depreciation and interest on bottler	1.07	1.26	1.94
Repairs, maintenance, supplies	0.56	0.66	1.00
Total	2.30	2.76	4.28
A. Based on 50 trips per milk bottle			
II. Production Costs			
Labor Cost			
1. 100 per cent quarts			
20,000 lbs. per day	7.20	6.02	6.10
40,000 lbs. per day	13.90	10.20	10.40
60,000 lbs. per day	20.60	14.30	14.55
80,000 lbs. per day	27.50	18.60	18.90
100,000 lbs. per day	34.40	22.80	23.00
2. 100 per cent half-pints			
20,000 lbs. per day	22.10	13.90	14.10
40,000 lbs.per day	44.00	26.00	26.25
60,000 lbs. per day	65.50	38.10	38.30
80,000 lbs. per day	87.00	50.10	50.60
100,000 lbs. per day	109.00	61.90	62.50

Appendix Table XXIV Continued--Page 2

	Size		
	No. valves--No. capping heads		
	10	14-4	28-8
Filling rate in qts. per min.	40	85	135
Total Production Cost			
1. 100 per cent quarts			
20,000 lbs. per day	33.74	32.54	32.61
40,000 lbs. per day	66.98	63.24	63.42
60,000 lbs. per day	97.22	93.78	94.08
80,000 lbs. per day	133.66	124.68	124.94
100,000 lbs. per day	167.10	155.40	155.45
2. 100 per cent half-pints			
20,000 lbs. per day	103.12	94.84	95.00
40,000 lbs. per day	206.04	187.88	188.05
60,000 lbs. per day	308.56	280.92	290.00
80,000 lbs. per day	411.08	373.86	374.20
100,000 lbs. per day	514.10	466.60	467.00
III. Total Cost			
1. 100 per cent quarts	36.04		
20,000 lbs. per day	36.04	35.30	36.89
40,000 lbs. per day	69.28	66.00	67.70
60,000 lbs. per day	99.52	96.54	98.36
80,000 lbs. per day	135.96	127.44	129.22
100,000 lbs. per day	169.40	158.16	159.73
2. 100 per cent half-pints			
20,000 lbs. per day	105.42	97.60	99.28
40,000 lbs. per day	208.34	190.64	192.33
60,000 lbs. per day	310.86	283.68	294.28
80,000 lbs. per day	413.38	376.62	378.48
100,000 lbs. per day	516.40	469.36	471.28

	Size		
	No. valves--No. capping heads		
	10	14-4	28-8
Filling rate in qts. per min.	40	85	135
IV. Unit Cost per 100 pounds			
1. 100 per cent quarts			
20,000 lbs. per day	0.180	0.177	0.185
40,000 lbs. per day	0.173	0.165	0.169
60,000 lbs. per day	0.166	0.161	0.164
80,000 lbs. per day	0.162	0.159	0.161
100,000 lbs. per day	0.169	0.158	0.159
2. 100 per cent half-pints			
20,000 lbs. per day	0.527	0.488	0.496
40,000 lbs. per day	0.521	0.477	0.481
60,000 lbs. per day	0.518	0.471	0.474
80,000 lbs. per day	0.516	0.470	0.473
100,000 lbs. per day	0.516	0.469	0.471
B. Based on 25 trips per milk bottle			
Total Cost			
1. 100 per cent quarts			
20,000 lbs. per day	47.31	46.57	48.16
40,000 lbs. per day	91.82	88.54	90.24
60,000 lbs. per day	133.33	130.39	132.17
80,000 lbs. per day	181.04	172.52	174.30
100,000 lbs. per day	225.75	214.51	216.08
2. 100 per cent half-pints			
20,000 lbs. per day	127.80	119.98	121.66
40,000 lbs. per day	253.10	235.40	237.09
60,000 lbs. per day	378.00	350.82	361.42
80,000 lbs. per day	502.90	466.14	468.00
100,000 lbs. per day	628.30	581.26	583.18

	Size		
	No. valves--No. capping heads		
	10	14-4	28-8
Filling rate in qts. per min.	40	85	135
Unit Cost per 100 pounds of milk			
1. 100 per cent quarts			
20,000 lbs. per day	0.237	0.233	0.241
40,000 lbs. per day	0.229	0.221	0.225
60,000 lbs. per day	0.222	0.217	0.220
80,000 lbs. per day	0.226	0.216	0.217
100,000 lbs. per day	0.226	0.215	0.216
2. 100 per cent half-pints			
20,000 lbs. per day	0.639	0.599	0.608
40,000 lbs. per day	0.632	0.589	0.593
60,000 lbs. per day	0.630	0.585	0.602
80,000 lbs. per day	0.629	0.583	0.585
100,000 lbs. per day	0.628	0.581	0.583
C. Data for Figs. 42 and 43--90 per cent of the milk in quarts; 10 per cent in half-pints			
Total Cost			
20,000 lbs. per day	54.36	53.91	55.51
40,000 lbs. per day	107.95	103.23	104.93
60,000 lbs. per day	157.80	152.43	155.09
80,000 lbs. per day	213.23	201.88	203.67
100,000 lbs. per day	266.01	251.69	252.79
Unit Cost			
20,000 lbs. per day	0.272	0.269	0.278
40,000 lbs. per day	0.269	0.258	0.262
60,000 lbs. per day	0.263	0.254	0.260
80,000 lbs. per day	0.264	0.252	0.254
100,000 lbs. per day	0.266	0.252	0.253

Appendix Table XXV
Paper Carton Filling

Summary of Data--Daily Cost of Operation, Dollars, 5/26/52

	Cartons per minute		
	20	35	65
I. When paper carton machine is purchased			
A. Fixed Costs			
Insurance, taxes, licenses	2.48	4.10	6.20
Depreciation, interest on building	0.24	0.30	0.59
Depreciation, interest on filler	5.75	10.80	16.00
Repairs, maintenance, supplies	3.06	5.15	7.70
Total	11.53	20.35	30.49
B. Production Costs			
Utilities			
1. 100 per cent quarts			
5,000 lbs.per day	0.45	0.43	0.40
10,000 lbs.per day	0.86	0.83	0.76
20,000 lbs.per day	1.65	1.57	1.38
40,000 lbs.per day	3.16	2.94	2.60
60,000 lbs.per day	4.60	4.21	3.78
80,000 lbs.per day	7.14	5.58	5.03
100,000 lbs.per day	7.69	6.96	6.29
2. 100 per cent half-pints			
5,000 lbs.per day	0.99	0.95	0.88
10,000 lbs.per day	1.96	1.82	1.69
20,000 lbs.per day	3.92	3.54	3.20
40,000 lbs.per day	7.44	6.68	6.08
60,000 lbs.per day	10.88	9.62	8.88
80,000 lbs.per day	14.52	12.76	11.82
100,000 lbs.per day	18.18	15.92	14.78
Labor			
1. 100 per cent quarts			
5,000 lbs.per day	6.75	3.88	2.15
10,000 lbs.per day	13.50	7.75	4.30
20,000 lbs.per day	27.00	15.50	8.60
40,000 lbs.per day	54.00	31.00	17.20
60,000 lbs.per day	81.00	46.50	25.80
80,000 lbs.per day	108.00	62.00	34.40
100,000 lbs.per day	135.00	77.50	43.00
2. 100 per cent half-pints			
5,000 lbs.per day	27.00	15.55	8.38
10,000 lbs.per day	54.00	31.10	16.75

Appendix Table XXV Continued--Page 2

	Cartons per minute		
	20	35	65
20,000 lbs.per day	108.00	62.20	33.50
40,000 lbs.per day	216.11	124.40	67.00
60,000 lbs.per day	324.00	186.60	100.50
80,000 lbs.per day	432.00	248.80	134.00
100,000 lbs.per day	540.00	311.00	167.50
Total Production Cost, utilities, labor, cases cartons, paraffin, wire			
1. 100 per cent quarts			
5,000 lbs.per day	38.28	35.39	33.63
10,000 lbs.per day	76.51	70.63	67.21
20,000 lbs.per day	152.95	141.37	134.28
40,000 lbs.per day	305.76	282.54	268.40
60,000 lbs.per day	458.50	423.61	402.48
80,000 lbs.per day	612.34	564.78	536.63
100,000 lbs.per day	764.19	705.76	670.79
2. 100 per cent half pints			
5,000 lbs.per day	132.71	121.22	113.98
10,000 lbs.per day	265.40	242.36	227.88
20,000 lbs.per day	530.80	484.62	455.58
40,000 lbs.per day	1061.20	968.84	910.84
60,000 lbs.per day	1591.52	1451.86	1366.03
80,000 lbs.per day	2122.04	1937.08	1821.34
100,000 lbs.per day	2652.58	2421.32	2276.68
C. Total Cost			
1. 100 per cent quarts			
5,000 lbs.per day	49.81	55.74	64.12
10,000 lbs.per day	88.04	90.98	97.70
20,000 lbs.per day	164.48	161.72	164.77
40,000 lbs.per day	317.29	302.89	298.89
60,000 lbs.per day	470.03	443.96	432.97
80,000 lbs.per day	623.87	[illegible]	567.12
100,000 lbs.per day	775.72	726.31	701.28
2. 100 per cent half-pints			
5,000 lbs.per day	144.24	141.57	144.47
10,000 lbs.per day	276.93	262.71	258.37
20,000 lbs.per day	542.33	504.97	486.07
40,000 lbs.per day	1072.73	989.19	941.33
60,000 lbs.per day	1603.05	1472.21	1396.51
80,000 lbs.per day	2133.57	1957.43	1851.83
100,000 lbs.per day	2664.11	2441.67	2307.17
D. Unit Cost per 100 pounds			
1. 100 per cent quarts			
5,000 lbs.per day	0.996	1.114	1.282
10,000 lbs.per day	0.880	0.910	0.977
20,000 lbs.per day	0.822	0.809	0.823

	Cartons per minute 20	35	65
40,000 lbs.per day	0.793	0.757	0.747
60,000 lbs.per day	0.783	0.739	0.722
80,000 lbs.per day	0.779	0.731	0.709
100,000 lbs.per day	0.776	0.726	0.701
2. 100 per cent half pints			
5,000 lbs.per day	2.88	2.83	2.89
10,000 lbs.per day	2.76	2.63	2.58
20,000 lbs.per day	2.71	2.52	2.43
40,000 lbs.per day	2.68	2.49	2.35
60,000 lbs.per day	2.67	2.48	2.33
80,000 lbs.per day	2.66	2.45	2.31
100,000 lbs.per day	2.66	2.44	2.31
II. Values for Fig. 45 and 46, Ninety per cent of the milk in quarts, ten per cent in half-pints			
A. Total Cost			
5,000 lbs.per day	59.25	64.33	72.16
10,000 lbs.per day	106.93	107.93	113.77
20,000 lbs.per day	202.26	196.05	196.90
40,000 lbs.per day	392.83	371.52	363.13
60,000 lbs.per day	583.33	546.78	529.32
80,000 lbs.per day	774.84	722.35	695.59
100,000 lbs.per day	964.56	897.85	861.22
B. Unit Cost per 100 pounds			
5,000 lbs.per day	1.181	1.287	1.403
10,000 lbs.per day	1.069	1.080	1.138
20,000 lbs.per day	1.011	0.980	0.935
40,000 lbs.per day	0.982	0.929	0.908
60,000 lbs.per day	0.972	0.911	0.882
80,000 lbs.per day	0.968	0.903	0.869
100,000 lbs.per day	0.965	0.898	0.861
III. When paper carton machine is rented			
A. Fixed Cost			
Insurance, taxes, licenses	2.48	4.10	6.20
Depreciation, interest on building	0.24	0.30	0.59
Repairs, maintenance, supplies	3.06	5.15	7.70
Total	5.78	9.55	14.49

	Cartons per minute		
	20	35	65
B. Production Costs			
Base plus production rental less discount) for carton machine			
1. 100 per cent quarts			
5,000 lbs.per day	11.56	19.70	27.70
10,000 lbs.per day	15.50	19.70	27.70
20,000 lbs.per day	16.90	23.65	30.24
40,000 lbs.per day	26.20	28.30	41.40
60,000 lbs.per day	34.50	37.60	44.70
2. 100 per cent half-pints			
5,000 lbs.per day	15.52	19.70	27.70
10,000 lbs.per day	17.85	23.69	29.35
20,000 lbs.per day	26.25	30.22	35.88
40,000 lbs.per day	44.90	47.00	50.80
60,000 lbs.per day	63.55	65.65	69.45
Total Production Costs			
1. 100 per cent quarts			
5,000 lbs.per day	49.84	55.09	61.33
10,000 lbs.per day	92.01	90.33	94.91
20,000 lbs.per day	169.85	165.02	164.52
40,000 lbs.per day	331.96	310.84	309.80
60,000 lbs.per day	493.00	461.21	447.18
2. 100 per cent half pints			
5,000 lbs.per day	148.23	140.92	141.68
10,000 lbs.per day	283.25	266.05	257.23
20,000 lbs.per day	557.05	514.84	491.46
40,000 lbs.per day	1106.10	1015.84	961.64
60,000 lbs.per day	1655.07	1517.51	1435.47
C. Total Cost			
1. 100 per cent quarts			
5,000 lbs.per day	55.62	64.64	75.82
10,000 lbs.per day	97.79	99.88	109.40
20,000 lbs.per day	175.63	174.57	179.01
40,000 lbs.per day	337.74	320.39	324.29
60,000 lbs.per day	498.78	470.76	461.67
2. 100 per cent half-pints			
5,000 lbs.per day	154.01	150.47	156.17
10,000 lbs.per day	289.03	275.60	271.72
20,000 lbs.per day	562.83	524.39	505.95
40,000 lbs.per day	1111.88	1025.39	976.13
60,000 lbs.per day	1660.85	1527.06	1449.96

	Cartons per minute 20	35	65
D. Unit Cost per 100 pounds			
1. 100 per cent quarts			
5,000 lbs.per day	1.110	1.292	1.516
10,000 lbs.per day	0.978	0.999	1.094
20,000 lbs.per day	0.878	0.873	0.895
40,000 lbs.per day	0.844	0.801	0.811
60,000 lbs.per day	0.825	0.785	0.768
2. 100 per cent half-pints			
5,000 lbs.per day	3.08	3.01	3.12
10,000 lbs.per day	2.89	2.76	2.72
20,000 lbs.per day	2.814	2.622	2.529
40,000 lbs.per day	2.78	2.56	2.44
60,000 lbs.per day	2.76	2.545	2.417
IV. When 90 per cent of milk in quarts, 10 per cent in half-pints, machine rented			
A. Total Cost			
5,000 lbs.per day	65.46	74.12	83.86
10,000 lbs. per day	116.91	117.45	125.63
20,000 lbs.per day	214.35	209.55	211.70
40,000 lbs.per day	415.85	390.86	389.47
60,000 lbs.per day	615.11	576.39	560.50
B. Unit Cost per 100 pounds			
5,000 lbs.per day	1.309	1.582	1.677
10,000 lbs.per day	1.169	1.175	1.256
20,000 lbs.per day	1.072	1.048	1.059
40,000 lbs.per day	1.039	0.977	0.973
60,000 lbs.per day	1.025	0.961	0.934

Appendix Table XXVI. Soaker Bottle and Case Washer--Summary of Data
Daily Cost of Operation, Dollars--May 20, 1952

	Capacity, BPM					
	24	60	100	140	200	240
I. Fixed Costs						
Insurance, taxes, licenses	1.89	2.77	3.96	5.50	7.76	8.80
Depreciation, interest on building	1.43	2.04	2.81	3.19	5.54	5.80
Depreciation, interest on bottle washer	2.74	2.95	4.60	5.71	9.49	11.80
Depreciation, interest on case washer	0.47	0.59	0.62	0.67	0.69	0.72
Repair, maintenance, supplies	1.10	1.67	2.48	3.03	4.81	5.81
Total	7.63	10.02	14.47	18.10	28.29	32.93
II. Production Costs						
A. Labor						
1. 100 per cent quarts						
20,000 lbs.per day	9.45	9.89	10.33	10.77	11.21	11.65
40,000 lbs.per day	16.80	17.24	17.68	18.12	18.56	19.00
60,000 lbs.per day	23.40	23.84	24.28	24.72	25.16	25.60
80,000 lbs.per day	30.84	31.24	31.68	32.12	32.56	33.00
100,000 lbs.per day	37.30	37.74	38.18	38.62	39.06	39.50
2. 100 per cent half-pints						
20,000 lbs.per day	30.80	31.24	31.68	32.12	32.56	33.00
40,000 lbs.per day	59.00	59.44	59.88	60.32	60.76	61.20
60,000 lbs.per day	81.40	81.84	82.28	82.72	83.16	83.60
80,000 lbs.per day	115.00	115.44	115.88	116.32	116.76	117.20
100,000 lbs.per day	148.00	148.44	148.88	149.32	149.76	150.20
B. Utilities						
1. 100 per cent quarts						
20,000 lbs.per day	2.84	2.64	2.17	2.08	2.01	1.96
40,000 lbs.per day	5.68	5.28	4.34	4.16	4.02	3.92
60,000 lbs.per day	8.52	7.92	6.51	6.24	6.03	5.88
80,000 lbs.per day	11.36	10.56	8.68	8.32	8.04	7.84
100,000 lbs.per day	14.20	13.20	10.85	10.40	10.05	9.80

	Capacity, BPM					
	24	60	100	140	200	240
2. 100 per cent half-pints						
20,000 lbs.per day	3.78	3.50	2.90	2.77	2.69	2.64
40,000 lbs.per day	7.56	7.00	5.80	5.54	5.38	5.28
60,000 lbs.per day	11.34	10.50	8.70	8.31	8.07	7.92
80,000 lbs.per day	15.12	14.00	11.60	11.08	10.76	10.56
100,000 lbs.per day	21.00	17.50	14.50	11.75	13.45	11.20
C. Total production costs, including bottle breakage						
1. 100 per cent quarts						
20,000 lbs.per day	14.58	14.73	14.79	15.15	15.51	15.90
40,000 lbs.per day	27.08	27.12	26.62	26.88	27.18	27.12
60,000 lbs.per day	37.82	38.66	37.69	37.86	38.09	38.38
80,000 lbs.per day	50.59	51.00	49.56	49.64	49.60	50.04
100,000 lbs.per day	63.00	62.44	60.53	60.52	60.61	60.80
2. 100 per cent half-pints						
20,000 lbs.per day	36.78	36.94	36.78	37.09	37.25	37.84
40,000 lbs.per day	70.96	70.84	70.08	70.26	70.54	70.88
60,000 lbs.per day	99.34	98.94	97.58	97.63	97.83	97.52
80,000 lbs.per day	138.92	138.24	136.28	136.20	136.28	136.56
100,000 lbs.per day	180.00	176.94	174.38	172.07	174.21	172.40
III. Total Costs						
1. 100 per cent quarts						
20,000 lbs.per day	22.21	24.75	29.26	33.24	43.80	48.83
40,000 lbs.per day	34.71	37.14	41.09	44.98	56.47	60.05
60,000 lbs.per day	45.45	48.68	52.16	55.96	66.38	71.31
80,000 lbs.per day	58.22	61.02	64.03	67.74	77.89	82.97
100,000 lbs.per day	70.63	72.46	75.00	78.62	88.90	93.73

	Capacity, BPM					
	24	60	100	140	200	240
2. 100 per cent half-pints						
20,000 lbs.per day	44.41	46.96	51.25	55.19	65.54	70.77
40,000 lbs.per day	78.59	80.86	84.55	88.36	98.83	103.81
60,000 lbs.per day	107.27	108.76	112.05	115.73	126.12	130.45
80,000 lbs.per day	146.55	148.26	150.75	154.30	164.57	169.49
100,000 lbs.per day	187.63	186.96	188.85	190.17	202.50	205.33
3. 90 per cent of milk in quarts; 10 per cent in half-pints						
20,000 lbs.per day	23.40	27.07	31.46	35.44	45.97	51.02
40,000 lbs.per day	39.10	40.50	45.44	49.32	60.71	64.43
60,000 lbs.per day	51.63	54.69	58.15	61.94	72.35	77.22
80,000 lbs.per day	67.05	69.74	72.70	76.40	86.56	91.62
100,000 lbs.per day	82.33	83.91	86.39	87.78	100.26	104.89
IV. Unit Costs per 100 pounds						
1. 100 per cent quarts						
20,000 lbs.per day	0.111	0.123	0.146	0.166	0.219	0.244
40,000 lbs.per day	0.087	0.092	0.103	0.112	0.141	0.150
60,000 lbs.per day	0.076	0.081	0.085	0.093	0.111	0.119
80,000 lbs.per day	0.073	0.076	0.080	0.085	0.097	0.104
100,000 lbs.per day	0.071	0.072	0.075	0.079	0.089	0.094
2. 100 per cent in pints						
20,000 lbs.per day	0.222	0.234	0.256	0.276	0.327	0.354
40,000 lbs.per day	0.196	0.202	0.211	0.222	0.247	0.259
60,000 lbs.per day	0.180	0.181	0.187	0.193	0.210	0.217
80,000 lbs.per day	0.183	0.185	0.189	0.193	0.206	0.212
100,000 lbs.per day	0.187	0.187	0.189	0.190	0.203	0.205

	Capacity, BPM					
	24	60	100	140	200	240
3. 90 per cent of milk in quarts						
20,000 lbs.per day	0.117	0.135	0.157	0.177	0.229	0.255
40,000 lbs.per day	0.098	0.101	0.114	0.123	0.152	0.161
60,000 lbs.per day	0.086	0.091	0.097	0.103	0.121	0.128
80,000 lbs.per day	0.084	0.087	0.091	0.096	0.108	0.116
100,000 lbs.per day	0.082	0.084	0.086	0.088	0.100	0.105

Appendix Table XXVII. Pipe Line--Summary of Data
Daily Cost of Operation, June 4, 1952

	Pounds of milk per day				
	20,000	40,000	60,000	80,000	100,000
I. Stainless Steel					
A. Fixed Costs					
Taxes, insurance, licenses	0.06	0.08	0.11	0.13	0.15
Depreciation, interest on pipe	0.18	0.25	0.32	0.40	0.48
Repairs, maintenance, supplies	0.08	0.11	0.14	0.18	0.22
Total	0.32	0.44	0.57	0.71	0.85
B. Production Cost					
Labor	6.90	9.90	12.90	15.90	18.90
C. Total Cost	7.22	10.34	13.47	16.61	19.75
D. Unit Cost per 100 pounds	0.036	0.026	0.022	0.021	0.020
II. Glass Lines Cleaned in Place by Circulation					
A. Fixed Costs, same as above					
B. Production Cost					
Labor	2.90	3.57	4.00	4.80	5.18
C. Total Cost	3.32	4.01	4.57	5.51	6.03
D. Unit Cost per 100 pounds	0.0166	0.0100	0.0076	0.0069	0.0060

XIII. GLOSSARY

Batch or holding process- a method of pasteurization in which the milk is held in batches at a temperature of 143° F. for 30 minutes to destroy the bacteria. This method is being replaced rapidly by the HTST method of pasteurization.

BHP represents boiler horsepower. A boiler is rated on the basis of the quantity of water it will evaporate. A boiler horsepower is equivalent to the evaporation of 34.5 pounds of water per hour at 212° F.

BPM represents bottles per minute. It is a term used to designate the capacity of a bottle washer or bottle filler, or rate of handling bottles.

Capital recovery- The uniform annual payment necessary to recover an investment with interest. The capital recovery is calculated on the basis of the following relationship:

Capital recovery= (first cost - salvage value)(CRF) + (salvage value)(interest rate)

Clarifier- A centrifugal device which is used for removing foreign material from milk in much the same manner in which cream is removed from milk. Many clarifiers and separators have interchangeable parts.

Cold wall- A type of storage tank in which the cooling is done by circulating the coolant in the walls of the tank.

CPM represents cans per minute. The term is used for designating the speed of operation of a can washer, and other operations where cans must be handled. It is also used to designate the capacity of a carton filler in cartons per minute. CPM is also used to designate the capacity of a case washer in cases per minute.

CRF represents capital recovery factor. It is a value which multiplied by the investment gives the annual uniform payment plus interest required to repay an investment.

DX represents direct-expansion. It is used to describe a method of refrigeration in which the refrigerant changes state from a liquid to a gas to accomplish cooling. Most large systems use ammonia as a refrigerant.

Fixed costs- Those costs which remain relatively constant regardless of the plant production. Interest, depreciation, taxes, and insurance are examples of fixed costs.

Gallons per hour- It is a term which represents the equipment capacity, such as a homogenizer. However, most continuous flow equipment is rated in pounds per hour. One gallon of milk weighs 8.59 pounds.

HTST represents high-temperature short-time. The HTST is a continuous method of pasteurization. Pasteurization is carried out by heating to 160° F. and maintaining the temperature for 15 seconds.

Insulated storage tank- A type of storage tank which contains three to four inches of insulating material in the wall. Milk is cooled before it is placed in the tank, usually with a plate cooler.

Operational cost - The same as the production cost in this dissertation.

P. D. pump - represents positive displacement pump, often expressed as positive pump. The P. D. pump is used for moving milk whenever it is necessary to move a fixed volume of milk per unit time.

Processing cost- the cost of putting the product in a saleable form. It does not include the cost of the raw material for the product.

Production costs -These costs which depend on the volume of milk processed in the plant. Labor, utility, and bottle costs are included in production costs.

Sweet water-The term is used to designate water that has been refrigerated which has no salt content. Sweet water can be used to cool a product down 34° F. If there is salt in the refrigerated water, the solution is known as brine, which can be used for cooling below the freezing point of water.

Tons of refrigeration -This term is used to designate the capacity of refrigeration equipment. A ton is the amount of refrigeration accomplished by melting one ton of ice. If cooling is accomplished at the rate of 200 Btu. per minute, the equipment is said to have one ton refrigeration capacity.

Total cost- Sum of fixed and production costs.

Unit cost- The cost of an operation (or process) expressed in terms of a standard unit quantity of milk, such as cost per pint, per quart, or per 100 pounds. The unit cost was expressed in dollars per 100 pounds in this dissertation. The cost per 100 pounds can be conveniently calculated on a quart basis by dividing by fifty.

U value- represents the over-all heat transfer coefficient expressed in British Thermal Units per hour-square foot-degree Fahrenheit.

Variable costs- Those costs which are obtained by adding the cost of production and the cost of the milk.

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