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Donald M. Florence

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Walter M. Carlitz
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SPACE REQUIREMENTS IN
MILK PROCESSING PLANTS

By

Donald M. Florence

THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
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THE'S

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AN ABSTRACT

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Walter M. Carleton

DONALD W. FLOTTING

ABSTRACT

In the design of a milk processing plant many factors must be considered, such as sanitary requirements, labor requirements, initial capital investment, overhead costs, and expected sales volume. Labor costs, building and construction costs, equipment costs, and power costs are all at a premium and the plant must be designed to keep such costs at a minimum. Therefore, the design of the milk plant must provide for a highly efficient operation that will produce a high-quality product at a low selling price.

Preliminary investigations indicated that the space requirements, or the size of the milk plant, had a pronounced effect on the operating efficiency. This study was undertaken to determine a method for estimating or predicting the amount of space required for a milk processing plant to handle a given amount of product. The major points investigated in this study are listed below.

1. Space Required for Milk Handling and Processing Rooms.
2. Space Required for Auxiliary and Service Departments.
3. Space Required for Plant Offices.
4. Space Required for Storage Areas.

For this study, a number of milk plants, handling from 500 to 2,000 gallons of milk daily, were selected which were considered to have an efficient operation. A questionnaire was constructed and mailed to 34 dairy plants and of the 34, seven were returned to the author. The

DONALD L. FLORENCE

ABSTRACT

plants were visited personally and studied by the author, and of these, seven were used in the analysis of data.

The analysis of data was conducted to obtain a relationship between the volume of milk handled daily and the space required in the various rooms of the milk plant. The data acquired from the questionnaire and the plants visited were compiled into one group and the relationship between the two variables analyzed by the least squares method. The average quantity of milk handled daily was taken as a figure which was estimated by the plant operator since it was assumed he should have a fairly accurate knowledge of the amount of milk the plant was processing. The plant operator's opinion was also recorded in determining whether or not the rooms in the milk plant were of sufficient size. Rooms which were considered to be too small were not included in the final analysis.

From the analysis of data, it was found that a general relationship existed between the gallons of milk handled daily by the milk plant and the amount of floor space required for the receiving, processing, bottle washing, milk storage, dry storage, boiler, and office rooms. Because of insufficient and highly variable data, no relationship was found between the amount of milk handled daily and the floor space required for the compressor, plant maintenance, locker, and driver's check rooms.

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INTRODUCTION

The dairy industry is one of the leading industries in the field of food processing. It is of a highly competitive nature and it operates on a narrow margin. Dairy products play a very important part in the food habits of the people of this country. Almost everyone utilizes milk and its products in one form or another. The consuming public is constantly seeking economical and high-quality products. The manufacturer that can produce a high-quality product at a relatively low cost will expand his sales volume, prosper, and survive under present-day competitive conditions.

The modern milk plant is a structure designed for the purpose of housing the equipment and facilities for processing and handling fluid milk. Fluid raw milk is usually bought from individual producers and shipped to the city milk plant where it is inspected, processed, and packaged for sale to retail stores, and directly to individual consumers. In the design of a milk processing plant many factors must be considered, such as sanitary requirements, labor requirements, initial capital investment, overhead costs, and expected sales volume. Labor costs, building and construction costs, equipment costs, and power costs are all at a premium and the plant must be designed to keep such costs at a minimum. Therefore, the design of the milk plant must provide for a highly efficient operation that will produce a high-quality product at a low selling price.

In the initial stages of planning, the investigation was designed to determine some of the desirable basic principles of dairy plant design and layout. The points that were to be determined are listed below.

1. Space Requirements
2. Layout Principles
3. Plant Location
4. Arrangement of Rooms
5. Arrangement of Equipment
6. Ventilating Requirements
7. Lighting Requirements
8. Materials of Construction

Following the review of literature, it was found that some of the principles regarding the above factors had been fairly well established. Also, in conducting the investigation, it was discovered that time limitations would not permit a study of such wide scope.

The information available for determining or estimating the size of a dairy plant for a given volume of milk handled, was quite limited. The review of literature indicated that a few general figures are available for estimating the total plant size and the size of the rooms in the plant. However, there was no indication of any study conducted for the specific purpose of determining space requirements.

It was apparent, however, that space requirements, or the size of the milk plant, had a very pronounced effect on operating costs, overhead costs, and the initial capital investment. The space allotted to the various operations in a milk plant and to the building as a whole,

determines to a large degree the efficiency of the operation. If crowded conditions are prevalent, workers interfere with each other's duties, good housekeeping is impaired, and, in general, there is a resulting loss of efficiency. Excess space, on the other hand, results in additional unnecessary time being consumed by workers in moving to and from their work, higher overhead costs, and higher initial investment. Here again, we evidence an overall reduction in the plant's efficiency.

The space requirements for the milk processing plant appeared to be one of the major factors in a design for efficiency. This study was undertaken to determine a method for estimating or predicting the amount of space required for a milk processing plant to handle a given amount of product. For the most part, the investigation was confined to a study of the smaller plants since it is these that usually are not able to acquire the services of an engineer or architect. However, it is not always the small plant that has an inefficient operation.

The major points investigated in this study are listed below.

1. Space Required for Milk Handling and Processing Rooms.
2. Space Required for Auxiliary and Service Departments.
3. Space Required for Plant Offices.
4. Space Required for Storage Areas.

LITERATURE REVIEW

Value of Effective Design

The modern milk processing plant should be designed to house the facilities of an operation and meet certain sanitary requirements. In the eyes of the consuming public, the physical appearance of the milk plant is an important guide in determining cleanliness and also in determining the quality of the finished product. A properly designed dairy plant will tend to make the job of maintaining cleanliness much easier and will also aid in keeping the employees' morale at a high level. If the milk plant is overcrowded, housekeeping will be more difficult, a more disorderly appearance will result, and employees will find more difficulty in performing their daily tasks. An important factor to consider in the design of a milk plant is the determination of the size of the plant to eliminate overcrowding and the resulting disorderly appearance.

Babcock (2) stated that the milk processing plant should be a modern sanitary structure of durable construction if it is to satisfactorily serve its intended purpose. In order that all operations can be conducted efficiently and economically, it will be essential not only to install sanitary and up-to-date equipment, but also to provide for an efficient layout of the building and equipment. Bartlett (Ref. 3, p. 54) listed the conclusions of Kelly and Clement¹, in which

¹ E. Kelly and C. E. Clement. City Milk Plants, Construction and Arrangement, U.S.D.A. Bul. 849, 1920. pp. 34-35.

they stated that modern milk plants should have a good appearance from an architectural point of view. Broughton (6) contended that the dairy plant of the future will have a sparkling sanitary interior, an attractive modern exterior, and be streamlined for efficient production. A modernistic, attractive plant has a perpetual advertising value; beauty is synonymous with construction materials and designs. Broughton (7) maintained that beauty and efficiency are complementary; the dairy plant must be attractive inside and out. Clarkson (9) declared that for survival under present-day competitive conditions, modern design is a "must" for all buildings.

It was maintained that the physical maintenance of a dairy plant is essential not only to protect the owner's investment in the building, but also to present an attractive looking plant to the public (18). The majority of consumers are inclined to associate a neat, well-kept plant with high-quality products, making the appearance of the plant one of the most effective means of advertisement. Ackerman (1) said that public confidence and acceptance always follow the more efficient operating methods and rigid product controls. Although there are many firms and competition is keen, there will always be a place for the efficient, well-managed plant, whether large or small. The general rule for successful dairy plant operators will be efficient plant operations and narrow operating margins.

Parker (Ref. 21, p. 34) advanced the policy of a streamlined series of operations from the receiving point of the raw material to the warehouse for the finished product. Congestion of equipment and a maze of pipe lines are discouraging to the workers responsible for cleanup and

have an important bearing upon effectiveness and economy. A lack of interest in, and an indifference toward effective sanitary practice will result from tiresome and involved disassembly and assembly of equipment and pipe lines. It is well to keep in mind that congestion, besides being aggravating to employees, is irritating to those officials responsible for approving processing and sanitary practices. Erb (10) acknowledged that the first impression a person gets in entering a dairy plant is the state of housekeeping. Good housekeeping is a very important part of consumer confidence due to rising standards of living and new concepts of cleanliness. The dairy processing plant should be immaculate on the inside, for the state of housekeeping soon becomes public knowledge. Housekeeping is made more difficult by crowded conditions and too much volume for the size of the plant but they do not eliminate its existence.

Parker (Ref. 21, pp 14-15) observed that sometimes reference is made to inadequate washing facilities, improper plant surroundings, badly designed buildings, inadequate lighting, and inadequate ventilation when classifying food establishments as insanitary. Furthermore, aside from the Federal food laws, conditions designed to ensure the comfort and morale, as well as, the health of the employees is included in sanitary codes and legal requirements. A well-lighted, well-designed, well-kept dairy plant is a means of impressing upon employees and visitors that care is being exercised in maintaining clean conditions and surroundings. Farrall (14) declared that we should aim towards a more compact plant design and direct our energies toward making the plant easier to keep clean and sanitary.

Eliminating crowded conditions and maintaining a well-designed plant for milk processing was believed to be one of the major elements in establishing a successful dairy manufacturing enterprise. An efficient and economical operation is realized when housekeeping is carried out with ease, and sanitary requirements are met with little difficulty. An effective advertising medium for building public confidence is made possible by utilizing a well-designed and well-maintained plant. To help insure that the operation will be conducted in an efficient and economical manner, the employee's morale must be maintained at a high level by avoiding overcrowding and providing the necessary comforts for his well-being. A well-designed dairy plant will aid in establishing these desirable characteristics in the milk processing business.

Space Requirements in Relation to Efficiency

The operating efficiency of a milk processing plant will depend to a large measure on the amount of space that is allotted to the various operations.

A limited amount of space will result in excessively crowded conditions. Plant workers will interfere with each other's duties. Extra time and labor will be required for maintaining and cleaning the processing equipment. Time and labor may be wasted because only a limited amount of product can be handled in a given amount of time. Production will not be as flexible as the demand and progress will be hampered, resulting in an eventual loss of business due to keen competition. Extra costs for essential materials and supplies will result from the inability to purchase large quantities at a discount. Time, labor, and costs for maintenance in case of emergencies may be increased because of the in-

ability to provide adequate spare parts storage. Thus, a limited amount of plant space will tend to raise time, labor, and material costs and decrease the operating efficiency.

An excessive amount of plant space will also tend to reduce the overall efficiency of the operation. Time and labor requirements will be excessive because of the extra number of steps required in performing daily tasks. The increase in heating, lighting, refrigerating, and ventilating requirements will raise overhead costs. Excessive lengths of piping, extra pumps, and other needed equipment will increase costs. The added investment in the original building will not be commensurate with the size of the operation. A plant which is excessively large will increase overhead costs and the initial investment to a point where the business may eventually terminate in complete failure.

Farley (12) stated that the common objective in planning dairy plants is "to process the maximum quantity which can be sold of the highest quality products at the lowest possible costs". Bixby (4) believed that in planning a dairy plant one must know (a) the production the plant is required to handle, (b) the number of products to be handled, and (c) the method of packaging the products, because they determine (a) the size of the equipment, (b) the size of the rooms, and (c) the size of the plant, and the operation must be carried out in an economical labor day if lowest costs are to be attained.

Bartlett (Ref. 3, p. 44) made an appraisal of all the factors entering into the price consumers pay for milk. It was found that the real possibilities for savings are to be found in the more efficient distribution of milk for most markets in the country. Analysis of milk

distribution based on the itemized costs on ninety-two wholesale companies and seventy-three home-delivery companies, showed that the low costs of the more efficient group of companies were largely due to the following considerations.

1. Efficient layout of plant and equipment.
2. Limiting the number of items handled.
3. Exclusive stops.
4. Large volume per route.
5. Low prices for high quality milk.
6. Large volume per store.

Shubin and Madeheim (Ref. 23, pp. 312-313) stated that because the floor space of a plant represents an investment, it should be utilized to its fullest extent. This is particularly true when additional floor space is costly. A high output per unit of floor space will usually be the result of an efficient plant layout with a well-integrated and compact floor plan.

Tracy (24) conducted a study of four milk plants in Washington, D.C. in 1943 to determine why plants in that city have shown low margins, as compared with many other cities, for receiving, processing, bottling, selling, and delivery of milk. The results indicated that as the number of square feet of floor space per hundred gallons of milk handled increased, the number of manhours required per hundred gallons milk handled also increased. He concluded that a well-planned layout can reduce the capital cost of milk distribution by minimizing the floor area required per hundred gallons of milk, in addition to bringing about low unit labor costs.

Babcock (2) stated that the economy of operation as well as sanitation must be taken into account when arranging rooms and equipment. The arrangement of rooms and equipment should be such that the men can

carry out their work with the least possible steps and plant space will be utilized most economically. Proper arrangement will reduce expensive lengths of piping and numerous fittings which cause extra labor and also decrease losses which may result from milk sticking to sides of pipes and from leaks at pipe connections. Babcock (2) concluded that in a well-arranged plant it is possible to effect great economies in labor while a poorly planned plant may result in a continual source of added expense due to excessive labor requirements. Bartlett (Ref. 3, p. 54) listed the conclusions of Kelly and Clement.¹ They stated that the rooms in a plant should be arranged to cause the lowest possible expense for machinery and labor, and also, so that the work should be accomplished with the fewest possible steps. Labor requirements are increased with a poorly arranged plant.

Shubin and Madeheim (Ref. 23, p. 72) stated that a reduction of the total plant space required for a given output of products results from conservation of floor space. As a result, overhead costs are lowered and thus, the fixed cost per unit of output is reduced. The extra burden of having a large building for future expansion will increase the overhead and daily operation cost so much that the business will be unable to grow (8). For this reason, the larger sized building that had been planned will not be able to be used at any future date. Babcock (2) stated that the rooms in the plant should be large enough to prevent crowding of machinery and workmen; however, at the same time there should be no unused space.

¹ E. Kelly and C. E. Clement. City Milk Plants, Construction and Arrangement, U.S.D.A. Bul. 849, 1920. pp. 34-35.

Excess space requires unnecessary labor in moving milk from one piece of equipment to another and also requires an added investment.

It was found that a properly designed plant, having the required amount of space, will aid materially in minimizing the capital investment, labor requirements, and overhead costs.

Size of the Plant

It has been found that a well-designed plant, the size being a major factor, has an important bearing on efficiency, cost of operation, overhead costs, capital investment, and sales appeal. The size of the milk processing plant will depend upon a number of related conditions. The most important consideration is, of course, the volume of product handled. The amount of space required will be determined to a lesser extent by the method of operation, the type of equipment utilized, and the method of packaging the finished product. These various factors, however, are usually determined in some degree by the volume of product handled.

Mitten (19) stated that the size of a plant is a function of the amount of milk handled per square foot of floor space. He further stated that the size would depend upon considerations, such as, the type of processing, the storage areas, and other features which are incorporated. Areas which are generally not included are garages and retail stores. Ross (Ref. 22, p. 324) maintained that the size of a processing plant depends entirely on the amount of milk handled and how it is utilized.

Babcock (2) said that the size of the rooms in milk plants and the floor area required per hundred gallons of bottled milk handled daily are widely variable. For the most part, lack of standardization, and construction without due consideration to the important factors which have a bearing on the size of the rooms, is responsible for this variation.

Mortensen (Ref. 20, p. 24) maintained that the requirements for floor space depend not only on the character and volume of business to be conducted, but also on the methods of manufacture. He further stated that there is no definite rule by which the amount of floor space needed to manufacture a particular volume of finished product, can be calculated. The floor space required will depend on the kind of machinery installed, as well as, upon the method of manufacture. One pasteurizer may occupy twice the floor space of another utilizing the same capacity.

Kelly and Clement (Ref. 16, p. 268) found that no uniformity existed between the size of rooms and the volume of milk handled because, in addition to the volume handled, the size required depends on the method of handling. This conclusion was the result of the data given in Table I.

TABLE I¹
FLOOR SPACE IN THE VARIOUS WORKROOMS OF
FIVE WELL-ARRANGED MILK PLANTS

Quantity of Bot- tled Milk Handled Daily (gallons)	Receiv- ing Room (ft. ²)	Bottle Wash- ing Room (ft. ²)	Pasteur- izing Room (ft. ²)	Bottl- ing Room (ft. ²)	Total Area, Handl- ing Rooms (ft. ²)	Milk Storage Room (ft. ²)	Clean Bottle Storage Room (ft. ²)
1,000	400	600	500	300	1,800	450	400
1,500	-	700	500	375	1,625	550	-
3,000	900	1,050	1,300	1,200	4,450	1,200	750
4,000	460	1,886	540	700	3,586	1,426	540
6,000	1,200	1,908	720	720	4,548	1,110	720

¹ E. Kelly and C. E. Clement. City Milk Plants, Construction and Arrangement, U.S.D.A. Bul. 849, 1920.

Kelly and Clement made the following statements regarding the information presented in Table I.

1. The plant handling four-thousand gallons daily had a comparatively small pasteurizing room, although the total area for handling rooms was ample.

2. The plant handling three-thousand gallons daily had space enough to handle considerably more than this quantity.

3. The milk-storage room and clean bottle storage rooms in the plant handling six-thousand gallons daily were hardly large enough for this quantity of milk, but some milk was sent directly onto the delivery wagons and so less storage space was required.

4. The figures in the table, besides giving an idea of the space required, also effectually illustrate the lack of standardization, even in modern plants.

The conclusion made by Kelly and Clement stating that no uniformity existed between the size of rooms and the volume of milk handled appears to be somewhat in error. They stated that the plant handling three-thousand gallons daily had an excess amount of floor space. If this had been taken into consideration, the data given in Table I would tend to show that a direct relationship probably does exist between the floor space and the volume of product handled.

Bixby (4) asserted that in order to plan a dairy plant, one must know (a) the amount of product to be handled, (b) the number of products to be handled, and (c) the method of packaging the product, because they effect (a) equipment size, (b) room sizes, and (c) plant size and in addition the operation must be completed in an economical labor day if the lowest costs are to be realized. Babcock (2) acknowledged that construction requires careful study and planning, since the building represents a large capital investment. Fair (11) advanced the policy of determining the actual size of the plant in order to insure the lowest unit production costs. Furthermore, when planning the layout, have a definite purpose in mind and use models.

Kelly and Clement (Ref. 16, p. 268) believed that rooms should be of adequate size to avoid crowding machinery or workmen; however, there should be no excess or unused space. Unused floor space requires extra labor in moving from one piece of equipment to another. Shubin and Madeheim (Ref. 23, p. 72) contended that bottlenecks resulting from inadequate materials handling, poor locations of work stations; and insufficient capacity of work stations, inspection stations, and cribs, may be eliminated by the use of layout engineering and operation analysis.

Mitten (19) stated that one to two square feet of floor area per gallon of milk handled may be allowed for the total plant area for plants handling over twenty-thousand pounds of milk daily. For plants handling less than twenty-thousand pounds daily, up to three square feet per gallon should be used for the total plant area.

Farrall (13) maintained that the greatest mistake usually made in the construction of a dairy plant is building it too large or too small, or in such a manner that ready expansion is made **difficult**. Ackerman (1) acknowledged that many operations began in small plants with additions being made as needed and, as a result, little attention was given to engineering and future plans.

Shubin and Madeheim (Ref. 23, p. 6), Broughton (7), and Mitten (19) believed that it is necessary to build the plant originally for the present volume with an additional capacity to accomodate any expected increase in sales in the near future. The most important consideration, however, is to plan the building so that future expansion of the plant capacity can be had with a minimum loss of previous investment and without interfering with the operation (18). Broughton (6) and Farrall (13)

emphasized that it is essential to study the building, the lot, and the complete layout and determine if it is possible to expand or add another dairy department. Shubin and Madeheim (Ref. 23, p. 6) and Farrall (13) declared that excess capacity or too large a plant should be avoided. Farrall (13) warned that, particularly in a new business, the overhead costs of a large building and equipment have been a major factor contributing to the bankruptcy of many concerns.

Shubin and Madeheim (Ref. 23, p. 313) found that in a layout with a low percentage of space allocated for the production floor in relation to the total plant area, a large amount of space was occupied by non-productive activities, such as office space, storage areas, and tool cribs. They concluded that for average conditions, a desirable floor-space ratio of thirty percent of the space for nonproductive activities and seventy percent for productive activities may be considered as a rough estimate. This ratio, of course, will vary from industry to industry. It was also stated that in order to eliminate waste areas, mezzanines might be utilized for offices, storerooms, inspection cribs, laboratories, and locker rooms.

Broughton (6) said that hallways and passageways should be avoided in planning small and medium sized plants because they are nonproductive areas. Babcock (2) believed that a mezzanine or balcony is advantageous from the standpoint of providing extra floor space without increasing the ground space or man and labor requirements. Broughton (7), Maguire (17), and Ackerman (1) preferred the use of one-story buildings because they are more flexible, require less supervision, save time and labor, require less space because the equipment is more closely connected, and

permit more floor space per square foot of building. Babcock (2), found that for small plants, the one-story building was the most popular, and the next most popular type was the one-story building with a mezzanine or balcony. Broughton (17) stated that medium and small plants have found that multi-level buildings are more costly in operation.

Broughton (6) proposed that long, narrow rooms should be avoided, because square rooms provide for better arrangement, are the most economical, and are readily adaptable to changing conditions.

The size of a milk processing plant was found to be dependent on the volume of product handled and the amount of space allotted to service and auxiliary departments. Hallways, passageways, and other nonproductive areas should be avoided as much as possible because they increase the capital investment of the building by increasing the floor space, and may increase time and labor requirements. Mezzanines and balconies may be utilized to provide space for nonproductive activities without increasing the total plant space and building size. For small and medium sized plants, the one-story building will require less space, is the most economical, and can be readily expanded to meet changing conditions. The rooms in a plant should be as nearly square as possible to give less expensive construction, to provide a better arrangement, and to allow for ease of expansion. The plant should be built originally for the expected volume with provisions for ready expansion in case of future increases in capacity. Excess capacity should be avoided in order to keep capital investment, overhead costs, and labor requirements to a minimum.

Size of Processing Rooms

The size of the rooms in the milk processing plant will exert a profound effect on the capital investment, overhead costs, and labor requirements. Therefore, it is imperative that the size of the rooms in the milk plant be determined in such a manner that capital investment and operating costs be kept to a minimum.

Mitten (19) found the minimum allowable floor area required for processing rooms (A) could be determined by knowing the area (a) occupied by the equipment. The minimum allowable area, $(A) = \frac{a}{0.20}$. After expansion to twice the original volume, the area obstructed by equipment should not be more than one-third the total area. The New York City receiving station specifications stated that in a milk handling room, the equipment should not occupy more than twenty-five percent of the total floor area (8).

Size of Receiving Room

Babcock (2) stated that a small receiving room will soon become cluttered with milk cans and other objects, and will be difficult to keep clean and attractive. The receiving room in small plants should be of a sufficient size to handle at least one truck load of milk in cans and provide enough space to handle the cans without crowding. The receiving room in larger sized plants should preferably be large enough to handle several truck loads of milk in a short period of time. Enough floor space or conveyor space should be provided to handle this amount of milk until it can be dumped.

It was found that to give maximum efficiency at a minimum cost under a given set of conditions, some of the points to consider in designing the

receiving room were (a) local health board requirements, (b) the volume of milk to be handled, especially during the flush season, (c) the method of delivery, and (d) the amount of floor space, or conveyor space, for incoming and washed cans (18). Furthermore, sufficient space and equipment must be allowed for the inspection of milk and for handling cans of rejected milk.

It was said that in many of the smaller plants, the rotary can washer, which occupies a small space and can be operated by one employee, is used (18).

Farrall (15) announced that one of the latest improvements in milk handling equipment is the bulk handling system as used on California farms. With this particular system of handling milk, the receiving room, as such, would be almost entirely eliminated. However, space would need to be provided for receiving the milk directly from the tanker trucks.

Most milk plants have storage tanks for handling incoming raw milk and also, frequently for skim milk and other products.(18). Vertical tanks, in comparison with horizontal tanks, require less space, but horizontal tanks require less head room. Most storage tanks are cylindrical in shape but some rectangular tanks are used. Rectangular tanks require less floor space, but they are structurally weak and the reinforcement of construction is expensive.

Size of Pasteurizing Room

It was stated that pasteurizing rooms seldom need to be expanded because increased capacity can be accomplished by installing greater capacity equipment (8). However, Broughton (7) believed that even in the smaller plants the pasteurizing room should never be less than twenty-four by twenty-four feet.

Babcock (2) contended that space may be reduced in plants processing large quantities of milk by utilizing high-temperature short-time pasteurization. Bixby (4) stated that plants using batch pasteurization could change to high-temperature short-time pasteurization and provide great increases in capacity without requiring more floor space, and because of the compact design, could create additional floor space.

According to Maguire (17) floor space requirements may be reduced as much as sixty to seventy percent with the use of high-temperature short-time pasteurization and, in addition, make a straight line flow even more efficient. However, as stated by Babcock (2) and Farley (12), even with high-temperature short-time pasteurization, vat-type pasteurizers are still needed for pasteurizing cream and by-products. Babcock (2) and Farley (12) announced that the line of demarcation for high-temperature short-time pasteurization, is at a plant capacity of 2,500 pounds per hour with a total capacity of ten to twelve thousand pounds daily.

Size of Bottle Washing Room

Broughton (7) stated that the bottle washing room should contain enough floor space to house the bottle washer and the case washer and, in addition, provide enough room to handle the daily run of all sizes of bottles, to allow sorting of crates and bottles, and to provide storage for new bottles and new crates. Mitten (19) and one sales engineering department (8) recommended that the size of the bottle washing room be approximately equal to the total space occupied by the bottle washer, the case washer, and the cold storage rooms. It was also found necessary to allow about seven feet in front of the bottle washer to provide space for stacking cases required for the bottles necessary to fill the bottle

washing machine (8). Babcock (2), however, believed that the size of the bottle washing room would depend on the method of handling the bottles in the plant. If most of the bottles are sent directly from delivery trucks to the washer, only enough space is needed for the bottle washer, conveyors, and workmen. As a rule, however, many of the bottles will have to be stored before being washed and sufficient storage space should be provided.

A sales engineering department (8) recommended that space should be provided for the expansion of the bottle washing room because an increase in capacity must be accommodated by an increase in the size of the room.

Boucher (5) stated that the soaker-type bottle washer is more efficient than the jet-type, however, it requires more floor space for the same capacity.

Size of Milk Storage Room

Babcock (2) and Kelly and Clement (Ref. 16, p. 382) maintained that the milk storage room should provide adequate space for storing all the milk a plant can handle when running at full capacity plus additional space for conveyors, cooling units, emergencies, and passageways between stacks of various kinds of products. It was stated, however, that too large a room is costly and requires additional refrigeration. Babcock (2) further stated that the size of room needed will depend on the proportion of milk held over in storage. Also, if large quantities of milk are stored in cans, more space will be required because it is impractical to stack cans more than two tiers high.

Broughton (7) and Mitten (19) found that the size of cold storage rooms handling round bottles, can be figured on the basis of $5\frac{1}{4}$ gallons

per square foot. Mitten (19) stated that for square bottles, a factor of $7\frac{1}{2}$ gallons per square foot may be used. The above mentioned calculations allow space for aisles and fifty percent excess space.

One sales engineering department (8) recommended using approximately one square foot of space for each case of round bottles or each can shown on the daily processing requirement analysis. With the use of square bottles and bottle cases, one-third less space is required. These figures will allow for aisles and conveyor space when cases are stacked five high. Cases can be stacked seven high, providing for a forty percent expansion in business.

Babcock (2) recommended that full, quart-bottle cases be stacked six tiers high and full, pint-bottle cases be stacked seven tiers high. When cases of round bottles are stacked in this way, approximately two-thousand gallons of bottled milk in cases can be stacked in an area fifteen by sixteen, or 240 square feet, exclusive of space for conveyors, passageways, cooling units, and emergencies. If allowance is made for the men to work and for emergencies, a room approximately eighteen by twenty feet would be needed for storing this quantity of milk. If square bottles are used in place of round bottles, nearly fifty percent more milk can be stored on a given floor area.

Babcock (2) recommended the approximate sizes of milk storage rooms required for plants handling various quantities of bottled milk as shown in Table II.

TABLE II
MILK STORAGE ROOMS REQUIRED
FOR DAIRY PLANTS

Gallons of Bottled Milk Handled	Size of Room, feet
300	8x8
500	10x10
1,000	12x15
2,000	18x20
4,000	24x30

The figures shown in Table II allow space for the men to work and space for emergencies.

Space for Dry Storage Rooms

Babcock (2) declared that all milk plants, regardless of size, should have a place to store washing powders, bottle caps, replacement parts, and other such items. Small plants may provide suitable storage by having cabinets located in the by-products room, but large plants will usually require a separate room.

It was stated that a clean and orderly stock room, easily accessible, and large enough to store all the supplies needed daily in the plant, is one of the first requirements of good housekeeping (18). Adequate shelf and locker space should be allotted for storing parchment wrappers, milk bottle caps, clean cartons, cleaning materials, and other similar items.

Broughton (6) said that very few plants of any size have enough dry storage space. A large dry storage space will effect a saving in

time and aid materially in preventing waste and contamination of bottle caps, washing powder, parchments, and other supplies. Clarkson (9) and the plant operators manual (8) recommended that adequate dry storage be readily accessible to the loading platform and processing rooms. Shubin and Madeheim (Ref. 23, p. 313) maintained that storerooms should be consolidated and overhead space should be utilized for high stacking in order to reduce inventories.

Shubin and Madeheim (Ref. 23, p. 400) proposed that the size of a warehouse be determined from the inventory and the desired provisions for future expansion. The optimum shape is a square building with the maximum ratio of one dimension to another not exceeding three to one. A long building results in extra handling and construction costs are unnecessarily increased.

Broughton (7) and Mitten (19) found the minimum allowable area for dry storage space to be approximately twenty-five percent of the total plant area. Broughton (7) further stated that the storage area may range up to one-hundred percent of the total plant area.

Size of Office Space

Shubin and Madeheim (Ref. 23, p. 216) believed that individual office space requirements should be determined by the area required for the office equipment and the activities conducted. A general standard for the allocation of space for various office activities is given in Table III. The standard requirements shown in Table III would vary according to the size of desk used, the arrangement of desks, and the space required for bulky equipment, such as files and mechanical office equipment.

TABLE III¹
ALLOCATION OF SPACE FOR
OFFICE ACTIVITIES

Office Activity	Area (ft. ²)
Private office for executives	300
Private office for dept. head or technician	250
Space for division head, chief clerk, etc.	150
Space for stenographer-secretary	50
Space for clerical work	40-50

¹ Allocation of Office Space. Management Review, May, 1940. p. 179.

METHOD OF STUDY

The size of a milk processing plant may depend upon a number of related factors. The amount of space required may be determined largely by the volume of product handled, however, the method of handling, the type of equipment employed, and the method of packaging the finished product may also require consideration. Of course, the volume of milk handled will be the foundation for establishing these variables, at least to a certain degree. It would be expected also, that the rate at which the product is processed will regulate the size of the equipment to be employed and thus put its limitations on the necessary space requirements to ensure proper and efficient handling.

This investigation was suggested for the purpose of determining the amount of space required for a milk processing plant to handle a given amount of milk. It was believed that the volume of milk handled daily was the most important element in establishing the space requirements.

For this study, a number of plants were selected which were considered to have an efficient operation. The plants selected ranged in size from 500 to 11,000 gallons of milk handled daily. However, due to the limited amount of information obtained from the larger plants, the only plants considered in this investigation ranged in size from 500 to 8,000 gallons of milk handled daily.

A questionnaire was constructed incorporating the major points of dairy plant design and layout, including both ice cream and milk plants. This form was then sent to 34 dairy plants located in various parts of the United States.

Nine questionnaires, or approximately 27 per cent, were completed and returned to the author. Of the nine, two were received from ice cream plants and not used in the analysis. One of the nine returned questionnaires was not completed in the section referring to room sizes and also the section on the size and kind of equipment used.

The author personally visited nine other plants in the vicinity of Lansing, Michigan and gathered the necessary information as outlined in the questionnaire. Two of the nine plants visited were ice cream manufacturing plants and one milk plant was considered too large to be included and, therefore, were not contained in the final analysis.

A supplementary questionnaire was later formulated to obtain additional information regarding the amount of milk handled daily, the number of units packaged in glass and in paper, the number and kinds of products handled, and the number of personnel required for processing, offices, and routes. This form was mailed to eight of the plants which had supplied information for the original questionnaire. Of the eight, six were completed and returned. Two of the supplementary forms were completed personally by the author.

In this study, an effort was made to obtain a correlation or relationship between the volume of milk handled daily in the milk plant and the space which was required to handle it. The data collected from the various milk plants studied, both by mail and by personal visit, were compiled into one group to obtain an effective sample and statistically analyzed. The average number of gallons of milk handled daily was taken as a figure which was estimated by the plant supervisor since it was assumed that he should have a fairly accurate knowledge of the amount of milk which

his plant was handling daily. The plant supervisor's opinion was also regarded in determining if the rooms throughout the milk plant were of adequate size to carry out the processing operations.

The size of the rooms as reported in the questionnaire was assumed to be accurate on those forms received by mail. In those plants studied by a personal visit, the rooms were measured by the author where floor plans were not available. If floor plans were made available, the measurements were taken directly from the plans.

The gallons of milk handled daily and the area, in square feet, of the several rooms in the milk plant were tabulated and an effort was made to obtain the best equation and representative curve of the relationship between these two variables by the least squares method. In the mathematical analysis, those rooms that were considered too small for efficient production were not included. Only those areas that were considered to be large enough were used in making the calculations.

PRESENTATION OF DATA

Space Required for Receiving Rooms

The receiving room in a milk processing plant is designed to contain the equipment and facilities for handling raw milk which is shipped to the city milk plant, generally by individual producers, for processing and subsequent sale to the public. It must be designed for efficient and rapid handling and also meet rigid sanitary requirements.

The equipment employed in the receiving room varied from plant to plant, but appeared to follow a general trend. (See Appendix II). This variation, in part, would depend upon the original design, the number of producers supplying milk, the amount of milk supplied by each producer, and the rate at which the milk is handled in the plant. Generally, the equipment will include a can washer, a weigh tank with scales and a receiving tank, and conveyors for handling the incoming and outgoing milk cans.

From the data collected on twelve milk plants, some general statements can be made in reference to the equipment needed in the receiving room. It appeared that those plants handling approximately 2,000 to 3,000 gallons of milk daily, or less, would find a rotary can washer quite satisfactory. The capacity of the can washer varied between one can per minute and six cans per minute. The rotary can washer occupies a small amount of space and can be operated by one employee (18). In six of the installations using the rotary can washer, roller conveyors were utilized to aid in the handling of milk cans, while in the seventh plant no conveyors were used in the receiving room.

Milk plants that were handling approximately 3,000 to 8,000 gallons of milk daily required the use of a straight-away can washer. The capacity of these washers ranged from six to ten cans per minute, depending on the rate at which the milk was received. All of the installations utilizing the straight-away can washer had the services of power conveyors for conveying the milk cans to and from the receiving point.

The weigh tank should be of sufficient capacity to handle approximately all of the largest producer's milk at one weighing. Weigh tanks are generally supplied in three sizes; 500, 750, and 1,000 pound capacities, although smaller and larger sizes are available. Five of the plants studied, handling from 500 to 4,000 gallons daily, were using 500 pound weigh tanks, and one plant handling twenty three hundred gallons daily was using a 750 pound weigh tank. One plant handling 700 gallons of milk daily did not use a regular weigh tank, but employed a small dump tank into which the milk was dumped and pumped to the processing room. The capacity given for the weigh tank in the other five plants was given either in gallons or in the number of cans it held so that it was difficult to decide just what size weigh tank was being employed. The size of the weigh tank should, of course, be determined by the amount of milk that is supplied by individual producers. Most plants handling less than 4,000 gallons of milk daily will not require a weigh tank with a capacity greater than 500 pounds.

The size of the receiving tank should be large enough to allow for continuous receiving and will depend on the capacity of the plant and the rate at which milk is received.

Babcock (2) stated that the receiving room in small milk plants should be large enough to handle at least one truck load of milk in cans and provide enough space to handle the cans without crowding. Also, the receiving room in larger plants should preferably be large enough to handle several truck loads of milk in a short period of time. It was further stated that sufficient floor space or conveyor space should be provided to handle the milk until it can be dumped. Sufficient space and equipment must be allowed for the inspection of the milk and for handling cans of rejected milk (18).

In most of the smaller plants, it was observed that only enough conveyor space was required to transport the milk cans between the milk truck and the receiving point. Only this small amount of conveyor space was necessary because the full cans were unloaded and empty cans were reloaded simultaneously at the same point. However, in the larger plants it was necessary to provide enough conveyor space to handle the largest load of milk received, since unloading and loading was done at two different stations. This added convenience allows for rapid and efficient receiving of milk.

One of the latest improvements in milk handling equipment is the bulk handling system as practiced on some farms in California (15). With this system of handling milk, the receiving room is almost entirely eliminated, however, space should be provided for receiving the milk directly from tanker trucks.

The space required for the receiving room was studied in thirteen milk plants. The amount of milk handled daily by these plants ranged from 580 to 7,950 gallons. The size of the rooms and the equipment used,

are listed in Appendix II. Two of the thirteen plants stated that the receiving room was too small and the data was not used in constructing the curve shown in Fig. 1. The plant handling 975 gallons of milk daily and the plant handling 4,190 gallons of milk daily each had one fifteen hundred gallon storage tank located in the receiving room. Ninety-six square feet, the area occupied by the tank, was subtracted from the total area of the room for this analysis.

The required amount of floor space for receiving rooms as shown in Fig. 1 should allow enough area for a can washer, a weigh tank with scales and a receiving tank, in addition to a sufficient amount of space to satisfactorily handle all milk cans.

Referring to Fig. 1, the solid line shows the best estimate of the area, in square feet, for receiving rooms handling from 500 to 8,000 gallons of milk daily. The curve should not be extended beyond the limits of Fig. 1, since another sample containing larger sized plants might possibly produce a much different result. The two broken lines shown in Fig. 1 represent the upper and lower limits of the required area for receiving rooms. This variation should account for differences in the type of equipment employed, variations in conveyor space, layout, and other design features. The variation between the solid line and either broken line is approximately seventy-two square feet measured on a vertical line.

The amount of floor space required for a receiving room can also be calculated from the following equation which was used in constructing Fig. 1.

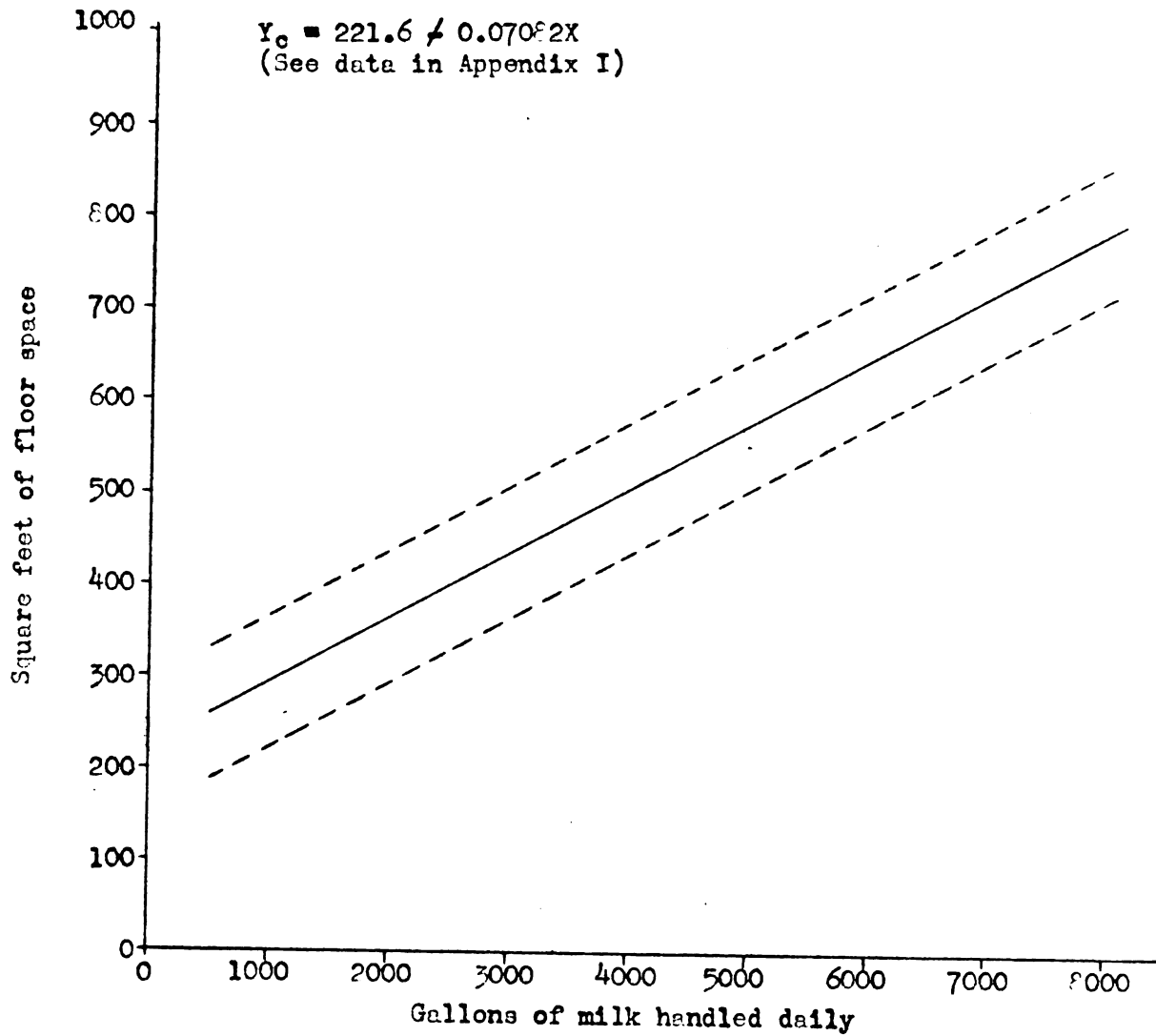


Fig. 1. Floor space required for milk plant receiving rooms.

$$Y_c = 221.6 / 0.07082X$$

Y_c = the required amount of floor space expressed in square feet.

X = gallons of milk handled daily.

The limitations of this equation are the same as those stated above for the curve shown in Fig. 1.

Space Required for Processing Rooms

After the milk has been received and weighed at the milk plant, it is usually pumped to the processing room where it may be stored for a short time and subsequently processed and packaged for sale. The equipment required for processing milk and its byproducts may vary from plant to plant. The type of equipment employed will depend on the size of the operation, the number and kinds of products handled, the method of packaging the finished product, and the method of handling the product. The processing room, however, should be designed to handle the incoming raw milk efficiently with a minimum of time and labor and yet produce a high quality product which will meet rigid sanitary standards.

The data recorded from twelve milk plants ranging in size from 500 to 8,000 gallons daily indicated that the majority of the processing operations are done in one room. Five of the twelve plants had all the processing equipment located in one room. One plant handling 975 gallons of milk daily was equipped with a special byproducts room and the milk storage tank was located in the receiving room. The plant handling 1,100 gallons of milk daily had a separate room for the milk storage tank and the pipe washing tank. A separate room was used for housing the milk storage tank in the plant handling 2,200 gallons of milk daily. A special byproduct room for the manufacture of cottage cheese and butter,

was utilized in the plant handling 4,190 gallons of milk daily, and the milk storage tank was located in the receiving room. The plant handling 4,800 gallons of milk daily had the milk storage tanks located in a separate room. All the processing operations, with the exception of cottage cheese manufacturing, were handled in one room in the plant processing 6,400 gallons of milk daily. The cheese vats were housed in a separate room. Separate rooms were provided for pasteurizing, milk tank storage, byproducts manufacturing, and bottle filling in the plant handling 7,950 gallons of milk daily.

Those plants processing approximately 4,000 gallons of milk daily and less, would probably find one room in which to conduct all processing operations sufficient. As the operation becomes larger, it is advantageous to design separate rooms for tank storage, pasteurizing, bottle filling, and byproducts manufacturing. This type of layout in larger plants will allow a better arrangement, better working conditions, and help to prevent crowding and cluttering of equipment.

The most essential items of equipment that were necessary in all plants appeared to include pasteurizing equipment, a separator, a method for cooling the pasteurized milk prior to bottling, and a bottle filler. It was also obvious that today's milk plant requires the services of a homogenizer. All of the plants studied included a homogenizer in the list of equipment.

Milk storage tanks were generally not found in milk plants handling much less than 1,000 gallons of milk daily; although one plant handling 730 gallons of milk daily was using a 300 gallon storage tank. In the smaller plants where vat-type pasteurizers are used and the total volume of milk handled is relatively small, the pasteurizer supplies most of the necessary storage space.

For larger sized plants, especially those using high-temperature short-time pasteurization, milk storage tanks are usually required since the milk cannot be processed as fast as it is received and must be stored for a period of time. Nine plants handling from 975 gallons to 7,950 gallons of milk daily had total storage tank capacities ranging from fifteen hundred to seven thousand gallons.

The equipment required for pasteurization showed some variation, but seemed to evidence a general trend. The five plants processing between 500 and 1,100 gallons of milk daily utilized vat-type pasteurizers. The total capacity of the pasteurizers for these five plants ranged between 300 and 600 gallons. One plant handling 4,190 gallons daily and another processing 4,800 gallons daily each had vat-type pasteurizers with capacities totaling thirteen hundred gallons. However, it was believed that these two plants could well afford to install the high-temperature short-time system and would find it more satisfactory from the standpoint of efficiency and floor space requirements.

Those plants handling from 1,165 gallons to 7,950 gallons of milk daily, with the exception of the two previously mentioned plants, used the high-temperature short-time method of pasteurization. The capacity of these systems ranged between 3,000 and 8,000 pounds per hour. However, with short-time pasteurization, vat-type pasteurizers were necessary for the processing of cream and byproducts. With this type of pasteurization the amount of floor space required is reduced considerably.

Maguire (17) stated that floor space requirements may be reduced as much as sixty to seventy per cent with the use of high-temperature short-time pasteurization. However, as stated by Babcock (2) and Farley (12), even with this system, vat-type pasteurizers are still needed for past-

eurizing cream and byproducts. They further stated that the line of demarcation for high-temperature short-time pasteurization is at a plant capacity of 2,500 pounds per hour with a total capacity of from ten to twelve thousand pounds daily.

The type of bottle filling equipment used appeared to be uniform throughout all plants. The bottle filling equipment for nine plants handling from 580 to 2,310 gallons of milk daily had capacities ranging from twenty-six to one hundred and twenty quarts per minute. One plant processing 4,190 gallons of milk daily had two fillers with capacities of sixty quarts per minute and eighteen quarts per minute, respectively.

The three largest plants packaged milk in both glass bottles and paper containers. The plant handling 4,800 gallons of milk daily was using an eighty-four quart per minute bottle filler and a thirty-five quart per minute paper carton filler. The bottle filler in this plant was too small. Another plant processing 6,400 gallons of milk daily was utilizing a bottle filler with a capacity of 140 quarts per minute, operated at 110 quarts per minute, and had, in addition, a sixty-five quart per minute paper carton filler. One plant handling 7,950 gallons of milk daily was packaging milk with a ninety-seven quart per minute bottle filler and an eighty-four quart per minute paper carton filler.

Obviously, it would not be feasible nor economical for a small plant to handle a combined operation for both glass and paper containers. However, for larger plants, competition may require the production of milk in both types of containers.

All other minor items of equipment used in the processing rooms for the plants investigated in this study are listed in Appendix II. It

appeared that as the total amount of milk handled increased, there was a definite trend to use equipment with a greater capacity and therefore, increase the space requirements.

Seven plants were used in making the analysis of the space requirements for processing rooms. The sample is somewhat limited in its scope, but it seems to provide a good indication of the amount of floor space required for processing a given amount of milk.

The area for the processing room includes that required for all operations in the preparation of raw milk and its byproducts for consumption. This area includes that necessary for milk tank storage, pasteurizing, homogenizing, cooling, bottle filling, byproducts manufacturing, and all other allied operations.

The two plants handling seven hundred gallons and 975 gallons of milk daily produced a small amount of ice cream in addition to the regular products. It was assumed that this would have little effect on the total area required for processing and consequently, the areas were used in making this analysis.

The amount of floor space required for processing rooms for milk plants handling from 500 to 5,000 gallons of milk daily is illustrated in Fig. 2. The curve shown should not be extended beyond these limits, since an analysis including larger plants could possibly give a much different result.

The solid line shown in Fig. 2 indicates the best estimate of the average amount of floor space, in square feet, required for the processing room. This area includes that required for milk tank storage, pasteurizing, cooling, homogenizing, bottle filling, byproducts manufacturing,

and all other allied operations in the processing of bottled milk. The two broken lines on either side of the solid line indicate the upper and lower limits of the area required for the processing room. It should be noted that the variation between the solid and broken lines is less for smaller plants than for larger plants. This could be expected since the small sized operations usually require only a limited amount of additional equipment and floor space for the manufacture of products other than bottled milk.

The area required for the processing room can also be found by use of the following equation which was used in constructing Fig. 2.

$$\text{Log}_{10} Y_c = 1.123181 + 0.621603 \text{ Log}_{10} X$$

$\text{Log}_{10} Y_c$ = logarithm to the base ten of the floor area required, in square feet.

$\text{Log}_{10} X$ = logarithm to the base ten of the gallons of milk handled daily.

The same limitations are required in the use of this equation as was mentioned above for Fig. 2.

Space Required for Bottle Washing Rooms

After the milk has been pasteurized and cooled to approximately 38 to 40 degrees Fahrenheit, it is put into clean, sterile bottles and capped for storage and delivery. A separate room is provided for storing, sorting, and washing the incoming dirty bottles before they are taken to the bottle filler for filling. The bottle washing room should be large enough to accomodate a bottle washer, space for sorting bottles and cases, and provide sufficient storage space for the daily run of all incoming bottles. Additional space may also be required to allow the use of con-

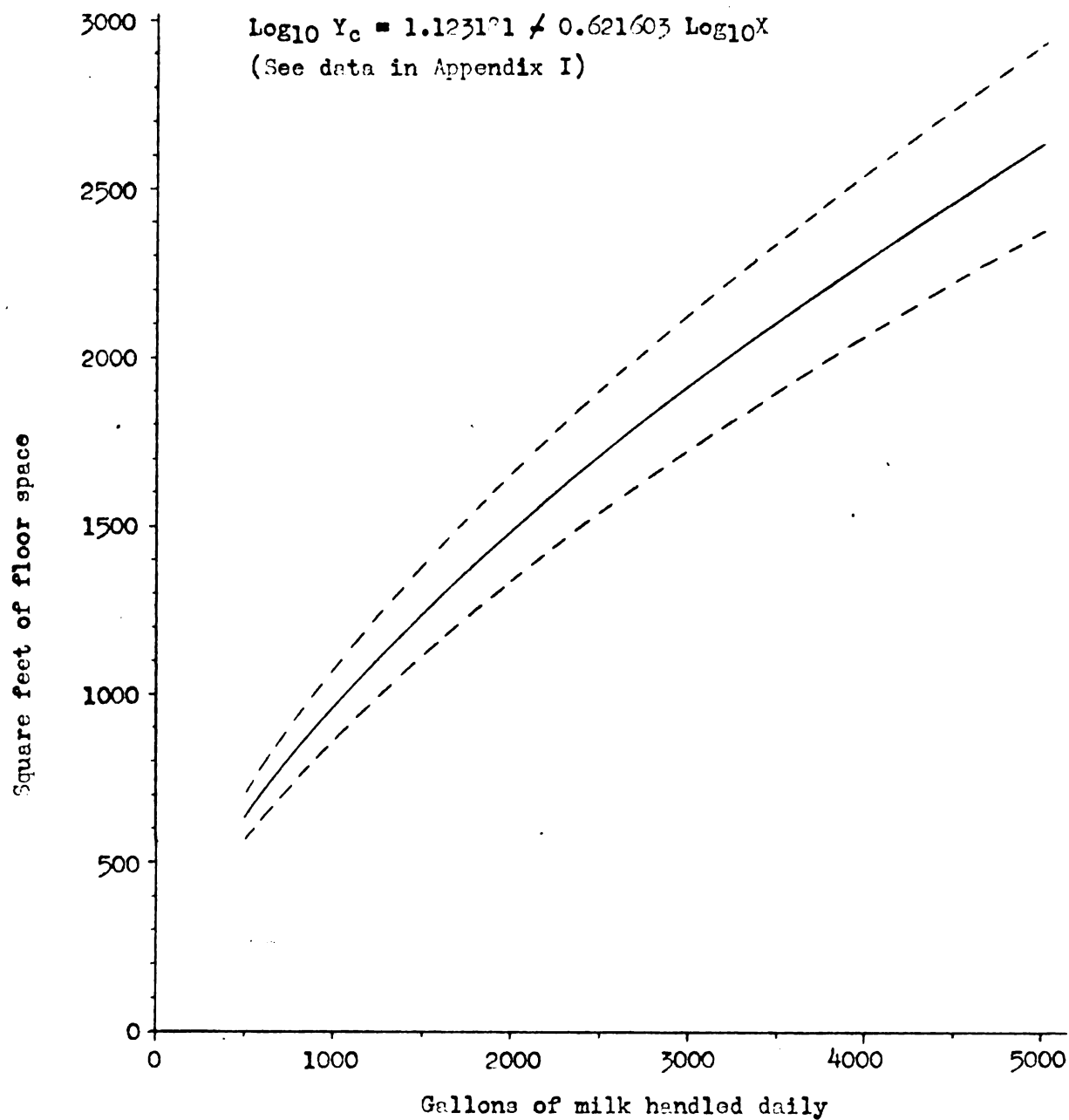


Fig. 2. Floor space required for milk plant processing rooms.

veyors. In plants where a large number of bottles are handled, it is advantageous to provide a loop in the conveyor line entering the bottle washer in order that empty cases, from bottles required to fill the washer, need not be removed and stored until the washer is emptied.

The size of the bottle washing room should be approximately equal to the total space occupied by the bottle washer, case washer, and cold storage rooms (19). In addition, about seven feet should be allowed in front of the bottle washer to stack the cases required for filling the bottle washing machine (8). Babcock (2) stated that the size of the bottle washing room would depend on the method of handling the bottles in the plant. If most of the bottles are sent directly from the delivery trucks to the washer, only enough space is needed for the bottle washer, conveyors, and workmen. As a rule, however, many of the bottles have to be stored before being washed and sufficient storage space should be provided.

The soaker-type bottle washer is more efficient than the jet-type, however, it requires more floor space for the same capacity (5).

The amount of floor space that is required for the bottle washing room will largely depend on the amount of bottled milk handled, the size of the bottle washer, and the styles of bottles used. Ample storage space should be provided for storing cases of bottles and also for the sorting of bottles and cases.

The soaker-type bottle washer was used in all twelve plants studied. (See Appendix II). The amount of bottled milk handled daily by these twelve plants ranged between 500 and 25,100 gallons. The size of the bottle washers used varied from a four-wide washer with a capacity of approximately 32 quarts per minute to a twelve-wide washer with a capacity of

114 quarts per minute. This trend illustrates a general relationship between the size of the bottle washer and the amount of bottled milk handled daily. However, the capacity of the bottle washer is governed entirely by the capacity of the bottle filler.

The method of handling the bottles and cases in the bottle washing room may also affect the floor space requirements. Those plants handling approximately 2,000 gallons of bottled milk daily generally used case dollies for transporting the bottle cases in place of the conveyor systems found in the larger plants. It was assumed that at one time or another during the day, most of the empty bottles were stored in the bottle washing room and were not sent directly to the bottle washer as they came in from the routes.

The square-type milk bottle was used by eleven of the twelve plants investigated. Only one plant was still using the old style round bottle. By using square bottles and bottle cases, one-third less space is required (8).

Six of the 12 plants were used in making the final analysis of the space requirements. The plant handling 730 gallons of milk daily was still using the old style round bottle. Only plants using the square-type bottle were used in making the analysis. Two plants handling 975 to 2,310 gallons of milk daily did not indicate if the room was large enough and were omitted in the calculations. The actual amount of bottled milk handled daily by the two plants handling 1,165 gallons and 4,190 gallons of milk was not known. Also, the bottle washing room for the plant handling 4,800 gallons of milk daily was too small to be considered.

The six plants used in making this analysis were handling approximately 90 per cent of the bottled milk in quart bottles and the other 10

per cent in half-pint bottles. The approximate range was between 85 and 92 per cent for quarts and between 7 and 15 per cent for half-pints. One plant was bottling about 1.3 per cent in pints while another plant was handling approximately 1.7 per cent of the bottled milk in ten-ounce bottles.

Fig. 3 illustrates the amount of floor space required in the bottle washing room for plants handling from 500 to 5,000 gallons of bottled milk daily. When the floor space requirements are estimated by the use of Fig. 3, they should be limited to those plants handling between 500 and 5,000 gallons of bottled milk daily.

The solid line shown in Fig. 3 gives the best estimate of the required amount of floor space for the bottle washing room. The broken line on either side of the solid line indicates the upper and lower limits of the floor space required. The variation between the solid and broken line is equal to approximately 117 square feet. This variation should account for differences in handling methods, and variations in the design and arrangement of the room.

The following equation, which was used in constructing Fig. 3, may also be used for calculating the approximate amount of space required for the bottle washing room.

$$Y_c = 383.2 \div 0.2030X$$

Y_c = square feet of floor space.

X = gallons of bottled milk handled daily.

The same limitations should be placed on the use of this equation as stated above for Fig. 3.

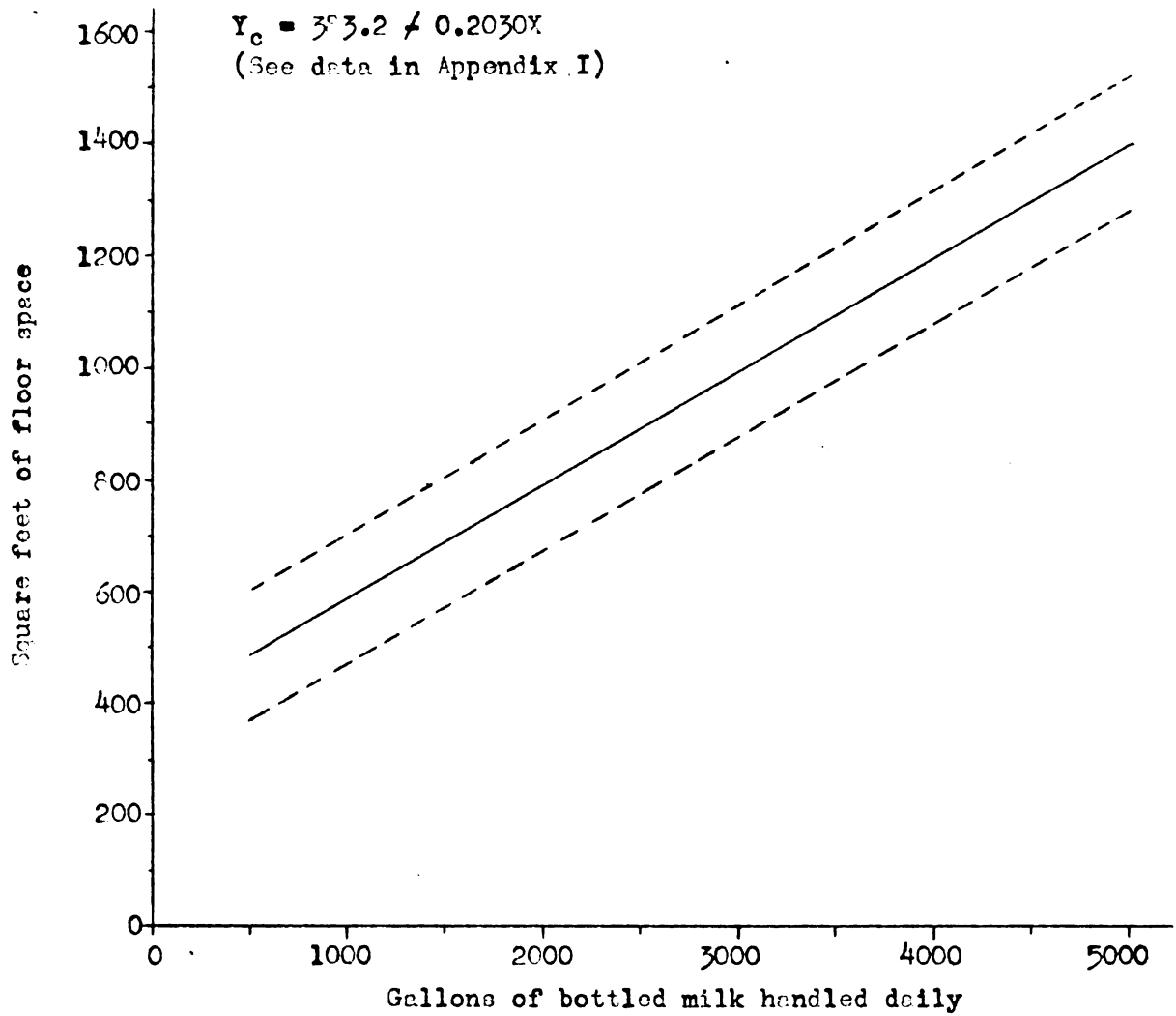


Fig. 3. Floor space required for milk plant bottle washing rooms.

Space Required for Milk Storage Rooms

Milk that has been bottled and capped is usually taken directly to the milk storage room where it is kept refrigerated until delivery. The milk storage room also generally handles bulk milk in five or ten gallon cans, packaged cottage cheese, and many other products that are sold by the dairy. It is good procedure to design the milk storage room sufficiently large enough to accomodate all the products that are processed daily plus enough additional space for aisles and conveyors. Some plants, however, may route their milk directly from the bottle filler to the delivery trucks and less storage space may be required.

Broughton (7) and Mitten (19) found the size of cold storage rooms handling round bottles to be equal to one square foot for each $5\frac{1}{2}$ gallons of milk handled. Mitten (19) used a factor of $7\frac{1}{2}$ gallons per square foot of floor space for square bottles. The above requirements allow space for aisles in addition to 50 per cent excess space.

One square foot of floor space for each case of round bottles or each can shown on the daily processing requirement analysis and two-thirds of a square foot for square bottles and cases was recommended by one sales engineering department (8). When cases are stacked five high, the above method will allow for aisles and conveyors.

Since it is impractical to stack cans more than two tiers high, more space will be required for storing large quantities of milk in cans (2). It was also recommended that full, quart-bottle cases be stacked six tiers high and full, pint-bottle cases seven tiers high.

Seven of the 12 plants investigated indicated that they had sufficient floor space in the milk storage rooms; however, one plant was using

round bottles and was not included in the analysis of data. Only those plants using square bottles were contained in the calculations. The two plants handling 975 and 2,310 gallons of milk daily did not indicate whether the room was large enough. It was assumed that the area allowed for the milk storage room in these two plants was large enough after comparing the floor space and the area per 100 gallons of milk handled daily with that of the other plants studied. Also, the plant handling 2,200 gallons of milk daily stated that there was some room for expansion in the milk storage room. It was assumed not to be excessively large and was contained in the final analysis.

The estimate of the average amount of floor space required for the milk storage room in plants handling between 500 and 5,000 gallons of milk daily is illustrated in Fig. 4. The indicated areas allow enough floor space for storing the daily run of all products in addition to that required for aisles and conveyors.

The solid line shown in Fig. 4 indicates the best estimate of the average amount of floor space required for the milk storage room in plants handling between 500 and 5,000 gallons of milk daily. The broken line on either side of the solid line indicates the upper and lower limits, respectively, of the floor space requirements. Some variation is to be expected due to differences in handling methods and variation in the design and arrangement of the room. Fig. 4 should be used for estimating the floor space requirements in milk storage rooms for only those plants using the square-type milk bottle.

The following equation, which was used in constructing Fig. 4, may also be used to estimate the floor area required for milk storage rooms.

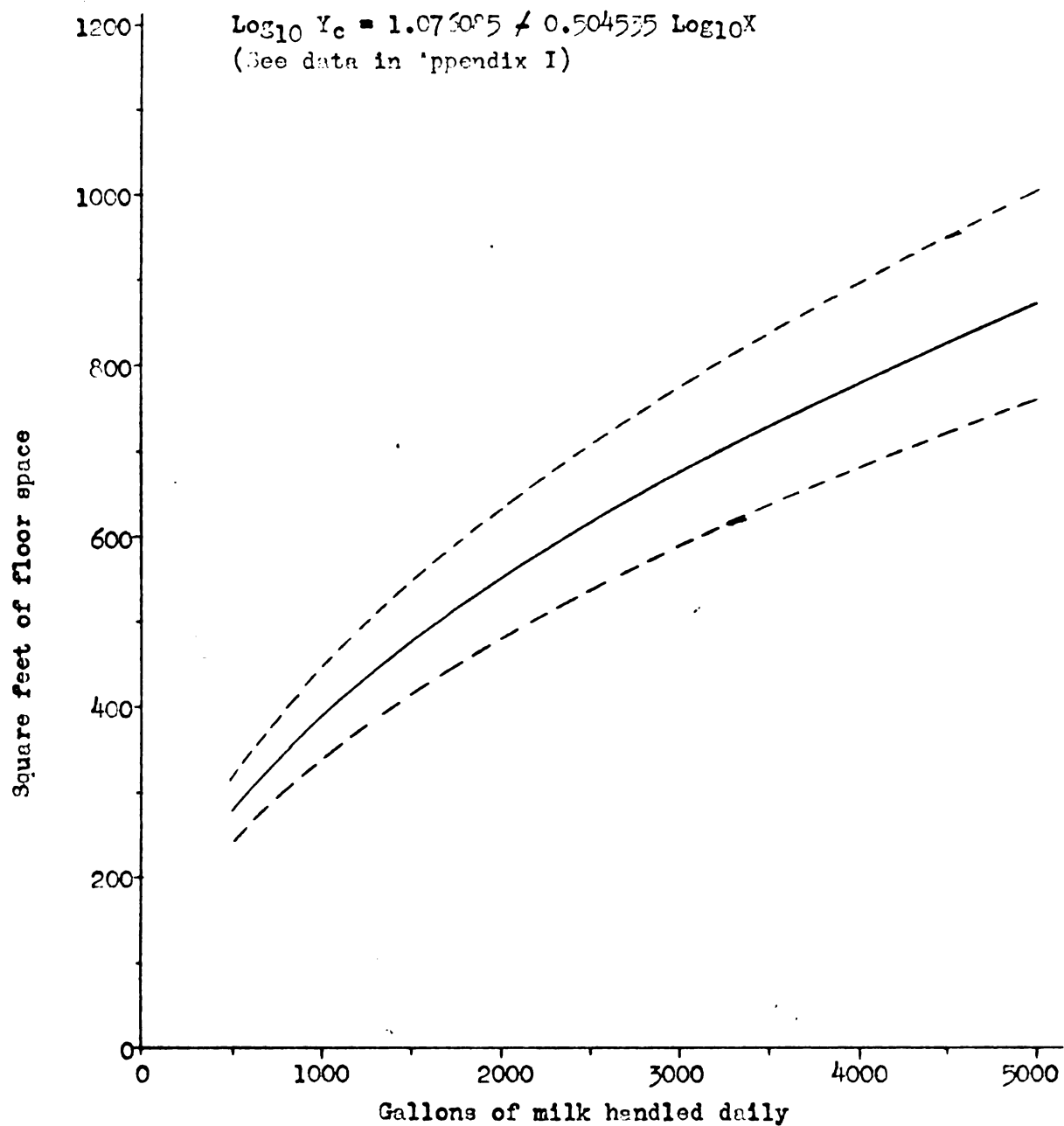


Fig. 4. Floor space required for milk plant bulk milk storage rooms.

$$\text{Log}_{10} Y_c = 1.076085 / 0.504535 \text{ Log}_{10} X$$

$\text{Log}_{10} Y_c$ = logarithm to the base ten of the square feet of floor area required.

$\text{Log}_{10} X$ = logarithm to the base ten of the gallons of milk handled daily.

Space Required for Dry Storage Rooms

The dry storage room should be large enough to supply sufficient storage space for washing compounds, bottle caps, spare parts, and any other supplies that are required in the milk processing plant. The majority of the plants investigated in this study did not have sufficient dry storage space. A separate room should be set aside for the storing of supplies, regardless of the size of the plant. By utilizing a separate room, supplies can be purchased in larger quantities at a reduced cost, inventories are reduced, and waste and contamination are at a minimum. However, small cabinets or shelves may be placed at advantageous positions in the plant to handle most of the supplies for daily requirements.

Babcock (2) emphasized that all milk plants, regardless of size, should have a place to store washing powders, bottle caps, replacement parts, and other such items. He further stated that small plants may provide suitable storage by having cabinets located in the by-products room, but large plants will usually require a separate room.

Only a few plants of any size have adequate dry storage space (6). However, a large dry storage space will affect a saving in time, and aid materially in preventing waste and contamination of bottle caps, washing powders, parchments, and other supplies.

Storerooms should be consolidated and overhead space utilized for high stacking in order to reduce inventories (Ref. 25, p. 315).

Broughton (7) and Mitten (19) found the minimum allowable area for dry storage space to be approximately 25 per cent of the total plant area. Broughton (7) stated that this area may range up 100 per cent of the total plant area.

Of the 12 plants investigated, four indicated that the dry storage area was too small. Three plants did not submit the size of the dry storage area, and one plant did not indicate whether the room was large enough.

The plant handling 4,800 gallons of milk daily stated that the dry storage area was not large enough to handle a 30 day supply of materials. However, it was assumed that had the storage area been equipped with a 12 to 14 feet ceiling, instead of 8 feet, the amount of space would have been adequate. Also, the plant handling 700 gallons of milk daily stated that the storage area was almost large enough. Again it was assumed that if the ceiling height had been 12 to 14 feet, instead of 10 feet 8 inches, the amount of space would have been sufficient. The two plants handling 4,800 and 7,950 gallons of milk daily were packaging milk in paper containers and required more space for dry storage than ordinarily found in a plant handling milk in glass bottles only.

Fig. 5 shows the best estimate of the average amount of floor area required for the dry storage room, as calculated from that found in five milk plants. As indicated by Fig. 5, there was a very high degree of variation between the floor area required for dry storage in the plants investigated. A large amount of variation can be expected due to the wide variation of items carried by various plants. Some milk plants may carry a large supply of replacement parts or handle paper containers and

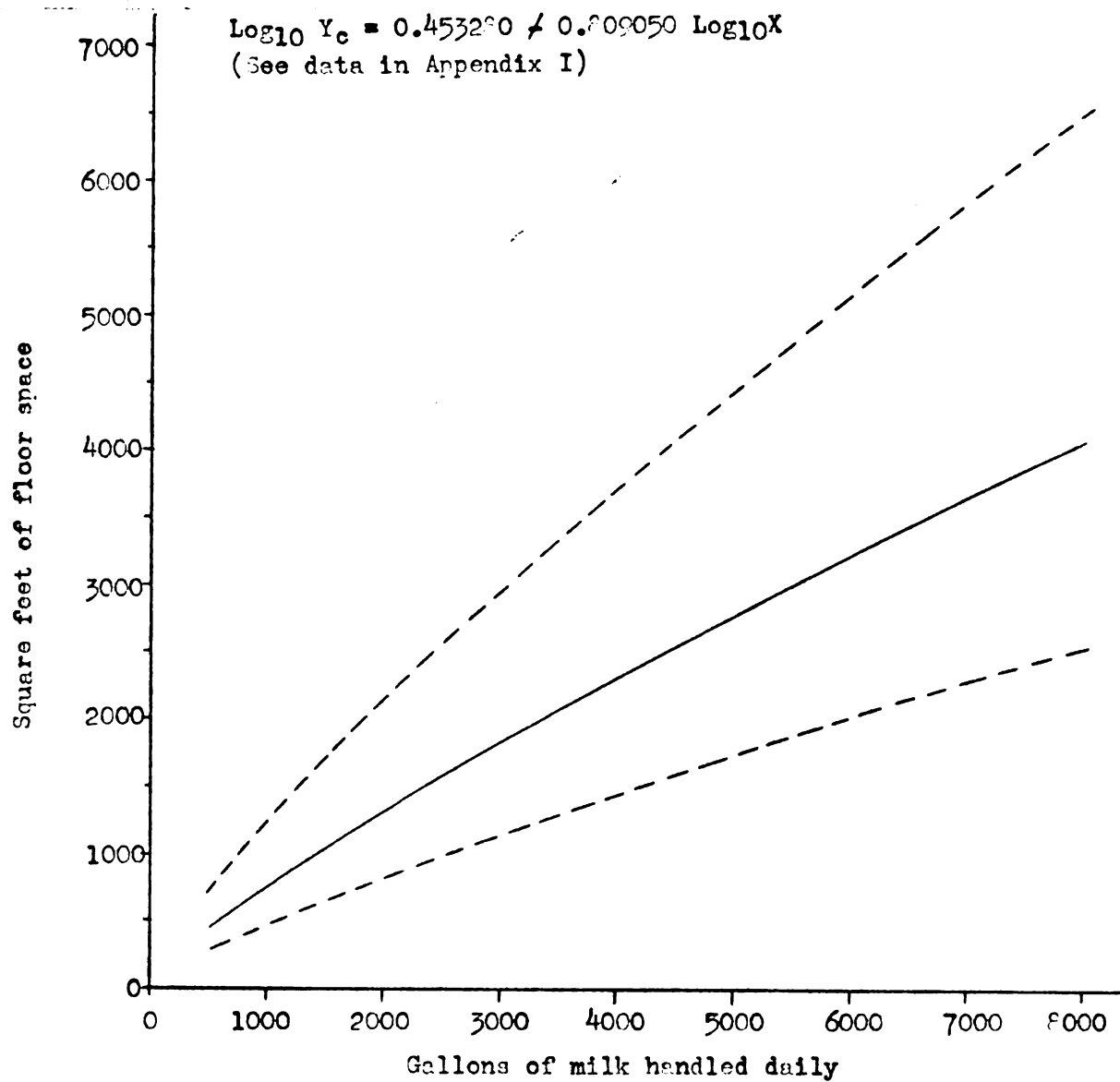


Fig. 5. Floor space required for milk plant dry storage rooms.

others may not. Some plants may be located close to suppliers and not wish to carry a large inventory, while others may find it necessary to provide enough space for at least a 30 day supply and perhaps more. However, the curve shown in Fig. 5 should indicate enough floor space for the average milk plant having a 12 to 14 feet ceiling in the dry storage room.

The solid line shown in Fig. 5 indicates the best estimate of the average amount of floor area required for the dry storage room having a 12 to 14 feet ceiling. The broken line on either side of the solid line locates the upper and lower limits of the floor area required. Fig. 5 was constructed to be used with those plants handling between 500 and 8,000 gallons of milk daily. It should not be used for plants outside this range, since another sample incorporating other plants might produce a different result.

The following equation which was used in constructing Fig. 4 may also be used to calculate the floor space requirements for the dry storage room in milk plants.

$$\text{Log}_{10} Y_c = 0.453280 + 0.809050 \text{ Log}_{10} X$$

$\text{Log}_{10} Y_c$ = logarithm to the base ten of the square feet of floor area.

$\text{Log}_{10} X$ = logarithm to the base ten of the gallons of milk handled daily.

The same limitations should be placed on the use of this equation as stated above for Fig. 5.

Space Required for Boiler Rooms

The boiler room in a milk processing plant should be located in a section of the plant completely isolated from the processing rooms. It

should have adequate floor space for a boiler which will supply the required amount of steam to carry out all processing operations. An adequate supply of steam is usually needed for the bottle washer, the case washer, the can washer, pasteurizing, water for washing and sterilizing equipment, and heating the plant.

The majority of the plants investigated in this study had no problems concerning the size of the boiler room. This room is designed to handle one piece of equipment and is not confronted with the complex problems of expansion that affect processing rooms.

Of the 12 plants investigated in this study, three plants did not make available the size of the boiler room and one plant stated that the boiler room was too small. Those plants handling between 580 and 1,100 gallons of milk daily had boilers with capacities between 20 and 40 horsepower depending upon the daily steam requirements. Plants handling between 2,310 and 7,950 gallons of milk daily had boilers with capacities between 120 and 125 horsepower; although one plant handling 6,400 gallons of milk daily had in addition to a 120 horsepower boiler, a coal-fired boiler with a 150 horsepower capacity for stand-by service. In general, most of the boilers being used today in milk plants are either gas or oil fired, thus reducing the problem of coal dust and ashes usually found with coal-fired boilers.

Fig. 6 illustrates the amount of floor space required for boiler rooms in milk plants handling from 500 to 8,000 gallons of milk daily. The amount of floor space required as indicated in Fig. 6 does not allow for coal bins or fuel storage. The solid line shown in Fig. 6 indicates the best estimate of the average amount of floor space required for boiler

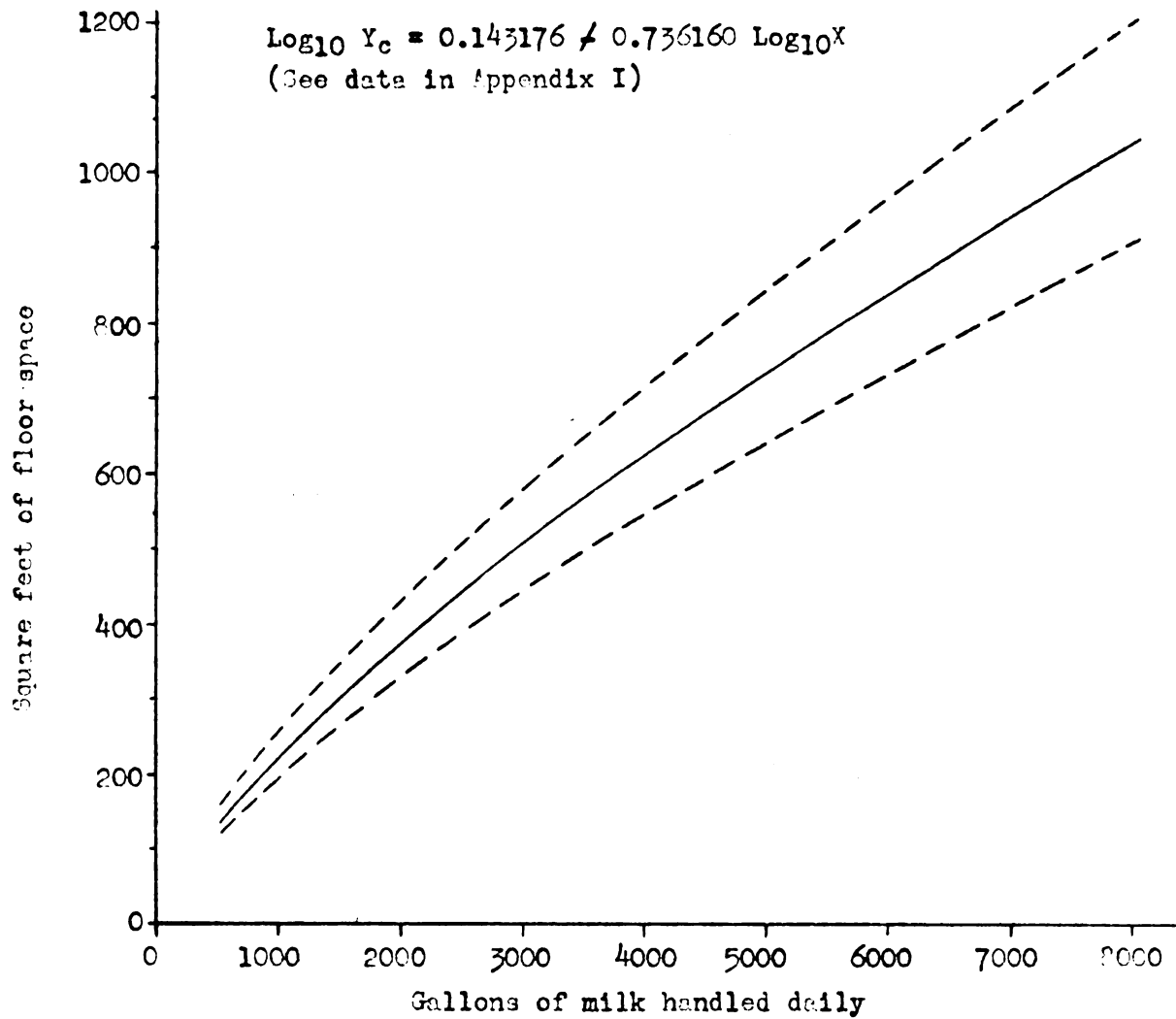


Fig. 6. Floor space required for milk plant boiler rooms.

rooms. The broken line on either side of the solid line gives the upper and lower limits, respectively, of the required amount of floor space. The floor space required for plants outside the range stated above should not be estimated with the use of the curve in Fig. 6, since another sample for other milk plants might yield a different result.

The following equation which was used in constructing Fig. 6 may also be used to estimate the amount of floor space required for milk plant boiler rooms.

$$\text{Log}_{10} Y_c = 0.145176 + 0.736160 \text{ Log}_{10} X$$

$\text{Log}_{10} Y_c$ = logarithm to the base ten of the square feet of floor area required.

$\text{Log}_{10} X$ = logarithm to the base ten of the gallons of milk handled daily.

Space Required for Plant Offices

The milk processing plant requires a certain amount of office space in order to carry out the daily business at hand and keep an orderly file on all records. Records must be kept on all purchases and sales and all other necessary transactions for the operation of a successful enterprise.

The amount of space that is required for plant offices will depend on the number and size of the desks utilized, the amount of space required for files and office equipment, and the arrangement of these items. A general standard for the allocation of space for various office activities is given in Table III, p. 24.

Of the 12 plants studied, four did not report on the amount of floor space available for the plant offices. The plant handling 700 gallons of milk daily combined the office and the driver's check room into one room;

this plant was not used in the analysis. Of the eight plants reporting, seven stated that the space allotted to offices was adequate. It was assumed that the plant handling 975 gallons of milk daily also had adequate office space. Those plants handling up to 1,100 gallons of milk and over should not require more than a one man office force or at the most two, depending on the amount of business transacted.

Fig. 7 indicates the average amount of floor space required for offices in milk plants handling between 500 and 8,000 gallons of milk daily. We should not expect the area to decrease for larger plants as is indicated by Fig. 7. Due to the large variation found in the office space for various milk plants and the fact that we have a limited sample, this has occurred. There is no reason to believe that the area should decrease for larger plants. However, the area as indicated in Fig. 7 should provide a good estimate of the amount of floor space required for offices in milk plants.

The solid line shown in Fig. 7 indicates the best estimate of the average amount of floor space required for offices in milk plants handling between 500 and 8,000 gallons of milk daily. The area for larger plants should not be estimated from this curve. The broken line on either side of the solid line indicates the upper and lower limits of the required area. The variation between either broken line and the solid line is equal to approximately 98 square feet measured on a vertical line.

The following equation which was used in constructing Fig. 7 may be used to calculate the floor space required for milk plant offices.

$$Y_c = -143.2 + 0.4568X - (10^{-7} \times 360.5X^2)$$

Y_c = square feet of floor space required.

X = gallons of milk handled daily.

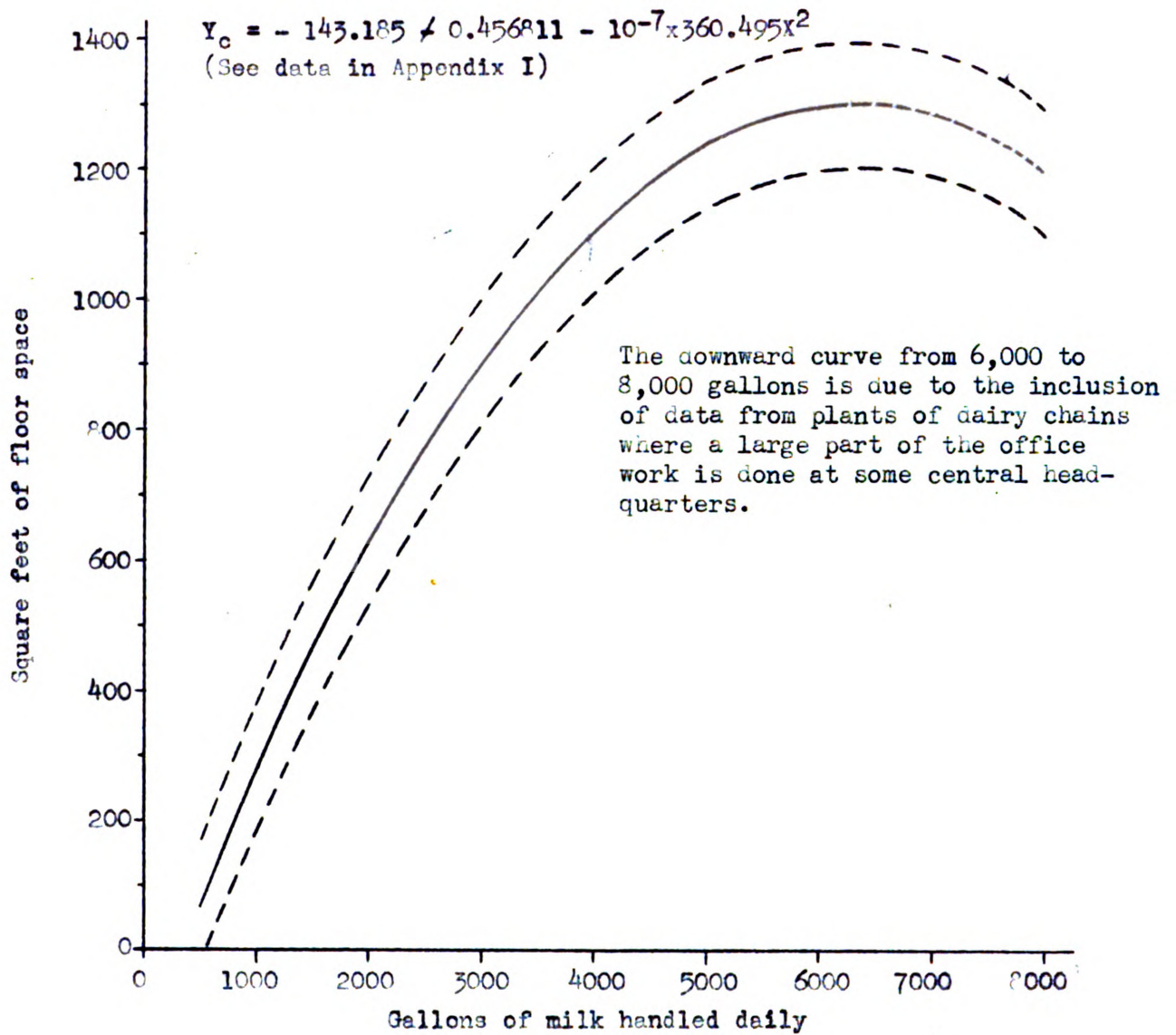


Fig. 7. Floor space required for milk plant offices.

The same limitations apply to the use of this equation as was stated above for Fig. 7.

Space Required for Compressor Rooms

The compressor room is usually located as near as possible to the cold storage rooms so that the length of refrigeration lines are kept to a minimum. It is advisable to provide a separate room for refrigeration machinery so that it may be consolidated for easy maintenance. However, in some of the smaller milk plants no specific room is provided for housing compressors.

The size of the compressor room will depend upon the number and size of compressors necessary to furnish the hourly refrigeration requirements. In most milk plants, compressors are required to maintain the temperature of the cold storage rooms, in addition to supplying the necessary amount of refrigeration for heat exchange equipment. The size of the compressors should be established accurately from the refrigeration load as it occurs through the day. In small plants, two compressors should supply all the refrigeration for plant needs. One is required to maintain the temperature of the milk storage room and the other is used in conjunction with the sweet water system. One compressor would ordinarily supply the refrigeration requirements, however, with two compressors, less trouble is likely to occur in case of a breakdown.

A study of 12 milk plants indicated that no general relationship could be established for the size of the compressor room as determined from the amount of milk handled daily due to variable and insufficient data. Table IV shows the floor space available for compressor rooms in ten milk plants investigated for this study.

TABLE IV
FLOOR SPACE AVAILABLE FOR COMPRESSOR
ROOMS IN TEN MILK PLANTS

Plant	Gals. of Milk Handled Daily	Size of Room (ft.)			Area (sq. ft.)	Large Enough?
		Width	Length	Height		
A	520	None	None	None	None	--
B ¹	700	6.00	14.00	--	84	Not stated
C ¹	730	12.00	12.00	9.00	144	Yes
E	1,100	6.25	8.83	11.67	55	Yes
		11.75	15.67	11.67	180 ²	
H	2,200	20.00	20.00	12.00	400	No
I	2,310	20.00	40.00	14.50	800	Yes
K	4,800	18.00	28.00	8.00	504	No
L ¹	6,400	21.50	15.92	15.00	364	Yes
M	7,950	25.00	30.00	12.00	750	Yes

¹Compressors are used for both milk and ice cream handling.

²Area occupied by a sweet water tank with a 6,000 pound capacity.

Space Required for Plant Maintenance Shops

The maintenance shop for a milk plant may range from a small cabinet, with an adequate supply of tools, in a small plant to a liberal sized machine shop in large plants. Usually in small milk plants, the plant operator conducts most of the maintenance and service work while in large plants, a trained engineer is usually hired. In the modern milk plant, there is a need for continual and periodic maintenance of equipment so that regardless of the size of the plant, some space should be provided for handling a supply of tools and equipment.

The size of the maintenance shop will depend entirely upon the type of service work done in the plant and the tools and machinery required to satisfactorily handle the job. The small milk plant cannot economically afford a complete machine shop, however, tools should be available in case of a breakdown and repairs are needed. A suggested list of tools and equipment for small dairies is recommended by Farrall (Ref. 13, p. 336).

The majority of the plants investigated in this study had some type of maintenance shop available. However, not enough information was available for determining the size required for plants handling various quantities of milk. Table V shows the floor space available for plant shops as found in seven milk plants.

TABLE V
FLOOR SPACE AVAILABLE FOR MAINTENANCE
SHOPS IN SEVEN MILK PLANTS

Plant	Gals. of Milk Handled Daily	Size of Room (ft.)			Area (ft. ²)	Large Enough?
		Width	Length	Height		
A	580	None	None	None	None	--
C ¹	730	8.00	8.00	9.00	64	Yes
E	1,100	None	None	None	None	--
I	2,310	18.00	34.00	14.50	612	Yes
K	4,800	10.00	27.00	8.00	270	No
L ¹	6,400	15.25	60.08	12.67	917	Yes
M	7,950	30.00	35.00	12.00	1,050	Yes

¹Maintaining milk and ice cream equipment.

Space Required for Locker Rooms

Locker rooms should be provided for all plant employees, including bath and toilet facilities. Since it is desirable to have a neat and sanitary appearing plant, it is necessary for employees to have facilities for changing from street clothes into white uniforms.

The size required for locker rooms will depend upon the number of employees needed to handle the processing operations, the type and arrangement of lockers, and the facilities available. In some plants, it was noted that the locker room was also used for a lunch room. However, where employees are required to lunch in the plant, it is much better to have a separate room set aside for this.

Only four of the 12 plants investigated had adequate space for a locker room. The plant handling 6,400 gallons of milk daily stated that the locker room was large enough except at noon when employees utilized it as lunch room. One plant had only toilet facilities available. No conclusion could be drawn stating the amount of space required for locker rooms. Table VI illustrates the floor space available for locker rooms in nine milk plants.

TABLE VI
FLOOR SPACE AVAILABLE FOR LOCKER
ROOMS IN NINE MILK PLANTS

Plant	Gals. of Milk Handled Daily	Size of Room (ft.)			Area (ft. ²)	No. of Personnel	Large Enough?
		Width	Length	Height			
A	580	7.50	13.50	9.00	101	3	Yes
B	700	8.00	8.00	9.00	64	3	Yes
C	730	7.00	7.00	8.00	49	3	Yes
E	1,100	--	--	--	None	--	--
H	2,200	8.00	15.00	9.00	120	3	No
I	2,310	8.50	17.83	12.00	152	7	Yes
K	4,800	12.00	18.00	8.00	216	--	No
L	6,400	15.00	18.00	15.00	270 ^a	20 ^c	No
		15.00	11.00	15.00	165 ^b		
M	7,950	8.00	12.00	8.00	96	25	Yes

^aSpace for lockers.

^bSpace for showers and toilets.

^cEmployees for both milk and ice cream.

Space Required for Driver's Check Room

The driver's check room is designed to provide the facilities to aid the route salesmen in keeping records of their accounts and sales to their customers. The size of the room will depend on the number of salesmen and the available facilities. In most milk plants, tables may be utilized to provide sufficient working space, space for keeping records and route books, and space for handling accounting machines.

The size of the driver's check rooms as found in this investigation was extremely variable. No definite conclusions could be made regarding

the required size. Table VII shows the amount of floor space available for driver's check rooms as found in seven milk plants.

TABLE VII
FLOOR SPACE AVAILABLE FOR DRIVER'S
CHECK ROOMS IN SEVEN MILK PLANTS

Plant	Gals. of Milk Handled Daily	Size of Room (ft.)			Area (ft. ²)	No. of Personnel	Large Enough?
		Width	Length	Height			
A	500	7.00	13.50	9.00	95	4	Yes
B	700	18.00	20.00	10.67	360	6	Yes
C	730	4.00	4.00	8.00	16	5	Yes
D	875	9.00	12.50	--	112	-	--
E	1,100	9.83	5.67	7.42	56	6	No
I	2,510	10.00	10.00	8.00	100	13	Yes
K	7,050	30.00	40.00	8.00	1,200	51	No

Space Required for Total Plant Area

The total amount of floor space required for the milk processing plant will depend upon the individual requirements for each room in the plant. Not enough information was available on the plants investigated to make an estimate of the total plant area required to handle a given amount of milk. However, by using the figures obtained from the estimating equations derived for the individual rooms, we can approximate the amount of floor space required for the more important rooms in the milk processing plant. Table VIII shows the estimate of the floor space required in the important rooms in milk plants handling between 500 and 5,000 gallons of milk daily.

TABLE VIII

FLOOR SPACE REQUIRED IN THE IMPORTANT ROOMS
OF MILK PLANTS HANDLING BETWEEN
500 AND 5,000 GALLONS OF MILK DAILY

Gals. of Milk Handled Daily	Receiv- ing Room (ft. ²)	Process- ing Room (ft. ²)	Bottle Washing Room (ft. ²)	Total, Handling Rooms (ft. ²)	Milk Storage Room (ft. ²)	Dry Storage Room (ft. ²)
500	257	652	485	1,374	274	435
1,000	292	973	586	1,851	389	759
2,000	363	1,485	789	2,647	552	1,330
3,000	434	1,926	992	3,352	677	1,845
4,000	505	2,393	1,195	4,093	782	2,351
5,000	576	2,645	1,398	4,619	876	2,792

CONCLUSIONS

1. The floor space required for milk plant receiving rooms depended largely on the number of gallons of milk handled daily for those plants handling between 500 and 8,000 gallons of milk daily.
2. The amount of floor space required for milk plant bottle washing rooms was directly related to the amount of bottled milk handled daily for plants handling between 500 and 5,000 gallons of bottled milk daily.
3. The gallons of milk handled daily by a milk plant provided a good basis for estimating the size of the boiler room required for milk processing plants handling between 500 and 8,000 gallons of milk daily.
4. The amount of office space required for a milk processing plant was directly related to the volume of milk handled daily for those plants handling between 500 and 8,000 gallons of milk daily. However, some discrepancy was evident in this relationship for larger plants. This could be due to the small number of plants available for the investigation and also to the variability of the space available from plant to plant in the larger plants.
5. The floor space required for dry storage rooms was related to the gallons of milk handled daily by the milk plant. Although a relationship was indicated, due to the limited number of plants available for the analysis, a reliable prediction of the space required could not be made.

6. The size required for milk plant milk storage rooms appeared to be directly related to the gallons of milk handled daily for those plants handling between 500 and 5,000 gallons of milk daily. The estimate of the floor space required for milk storage rooms was not a reliable one, however, due to the small number of plants available for making the analysis.
7. The floor area required for milk plant processing rooms depended largely on the gallons of milk handled daily for those plants handling between 500 and 5,000 gallons of milk. The estimated area for processing rooms provides only a rough approximation of the required area because the area for all processing operations, including byproducts manufacturing, were combined into one figure.
8. A study by questionnaire is not entirely satisfactory for an investigation of dairy plant layout and design. A very small return may be expected, in addition to the fact that the reliability of the information obtained is open to question.
9. The volume of products handled by a given plant should be determined accurately from plant records.
10. An individual study should be made of each processing operation in the milk plant regarding the relationship between the floor area and the quantity of product handled.

RECOMMENDATIONS FOR FUTURE STUDY

1. Obtain the cooperation of a large number of dairies to take part in a study of the layout and design of milk plants.
2. Define a method for estimating the operating efficiency of a milk plant.
3. Determine the amount of excess space which may be included in the original plant design for future expansion without excessively increasing operation and overhead costs.
4. Determine how much increase in capacity can be had in a milk plant by installing greater capacity equipment without increasing the floor space requirements.
5. Determine the total ground space required for milk plants handling various quantities of milk.
6. Determine the number and kinds of products, and the quantity of each, handled by the average milk plant.
7. Construct operation time schedules for milk plants handling various quantities of milk and determine good layouts utilizing models or templates of the equipment.

APPENDIX I

Statistical Analysis of Data

The least squares method of analysis was employed in computing the equation to represent the relationship between the area required for the various rooms in the milk processing plant and the gallons of milk handled daily. Several variations of this method, linear, non-linear, and curvilinear regression, were tested in an effort to obtain the best fitting equation. The data used in the calculations of the space requirements for milk processing plants are shown in Table AI.

Sample calculations are illustrated for the statistical analysis of receiving rooms only. The final results of the statistical analysis for the processing, bottle washing, milk storage, dry storage, boiler, and office rooms are given in Tables AV, AVII, AIX, AXI, AXIII, and AXV respectively.

TABLE AI

DATA USED IN CALCULATIONS OF THE RELATIONSHIP BETWEEN
GALLONS OF MILK HANDLED DAILY AND FLOOR SPACE REQUIRED
FOR THE VARIOUS ROOMS IN THE MILK PROCESSING PLANT

Plant	Gals. of Milk Handled Daily	Gals. of Bottled Milk Handled Daily	Receiv- ing Room (ft. ²)	Pro- cess- ing Room (ft. ²)	Bottle Washing Room (ft. ²)	Milk Stor- age Room (ft. ²)	Dry Stor- age Room (ft. ²)	Boiler Room (ft. ²)	Plant Offices (ft. ²)
A	580	580	270	700	414	349	135 ^a	162	153
B	700	700	200 ^a	700	700	308	360	200	360
C	750	575 ^c	195	720	960	320	820	225 ^a	324
D	875	-	375 ^b	1,162 ^b	608 ^b	302 ^b	235 ^b	-	212 ^b
E	1,100	1,100	172	560 ^a	507	214 ^a	165 ^a	204	121
F	1,165	-	264	1,088	961	102 ^a	416 ^a	-	-
G	1,280	-	400	-	-	-	-	-	-
H	2,200	1,900	400	942	800	600	-	-	-
I	2,510	1,570	503	1,789	888 ^b	691 ^b	-	497	748
J	4,190	-	480	2,152	957	752	5,200	500	-
K	4,800	-	512	1,624 ^a	864 ^a	956 ^a	1,952	704	1,248
L	6,400	4,610	525 ^a	3,006 ^a	1,439	741 ^a	3,872 ^a	1,017	-
M	7,950	4,120	800	2,960 ^a	1,080	1,350 ^a	3,000	1,050	1,200

^aRooms which were too small.

^bAdequacy not stated.

^cUsed round bottles.

Receiving Rooms

The size of the receiving room was investigated in 13 milk plants handling from 580 to 7,950 gallons of milk daily. Two plants handling

700 and 6,400 gallons of milk daily, respectively, stated that the receiving rooms were too small and these data were not used in making this analysis. One plant handling 975 gallons of milk daily did not indicate if the receiving room was large enough, however, it was assumed to be adequate. The two plants handling 975 and 4,190 gallons of milk daily each had a 1,500 gallon storage tank in the receiving room and 96 square feet were subtracted from the area to allow for it.

The data for the receiving room in the 11 milk plants having adequate floor space were compared by four various methods of regression. Sample calculations for the relationship between the gallons of milk handled daily and the floor space required for milk plant receiving rooms is shown in Table AII.

TABLE AII

SAMPLE CALCULATIONS SHOWING THE
RELATIONSHIP BETWEEN THE GALLONS
OF MILK HANDLED DAILY AND THE
AREA OF MILK PLANT RECEIVING ROOMS

Plant	Gals. of Milk Handled Daily X	Area ft. ² Y
A	580	270
C	750	195
D	975	373
E	1,100	172
F	1,165	264
G	1,280	400
H	2,200	400
I	2,510	503
J	4,120	480
K	4,800	512
M	7,950	800

Sample calculations for linear regression. The following sums were calculated for making this analysis: $\Sigma XY = 14,542,115$; $\Sigma X^2 = 120,000,250$; $\Sigma Y^2 = 2,054,887$; $(\Sigma X)^2 = 744,198,400$; $(\Sigma Y)^2 = 19,088,161$; $\bar{\Sigma}Y = 1,735,287$; $\Sigma X = 27,280$; $\Sigma Y = 4,369$; $\bar{Y} = 397.1818$; $\bar{X} = 2,480$

The equation for linear regression is of the form

$$Y_c = a + m (X - \bar{X}).$$

$$a = \frac{\sum Y}{n} = \bar{Y} = 397.182$$

$$m = \frac{n\sum XY - \sum X \sum Y}{\sum X^2 - (\sum X)^2}$$

$$= \frac{(11)(14,542,115) - (27,280)(4,369)}{(120,000,250) - (744,198,400)}$$

$$m = 0.070817361$$

$$Y_c = 397.182 + 0.0708174(X-2,480)$$

$$Y_c = 221.555 + 0.0708174X$$

The explained sums of squares,

$$\sum Y_c^2 = 1,997,808$$

The correlation coefficient,

$$r = \frac{(n)(\sum XY) - \sum X \sum Y}{\sqrt{[n\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2]}}$$

$$= \frac{(11)(14,542,115) - (27,280)(4,369)}{\sqrt{[11(120,000,000,250) - (744,198,400)][(11(2,054,887) - (19,038,161))]}}$$

$$r = 0.9063$$

The standard error of estimate,

$$\sigma_{y_s} = \frac{\sqrt{\sum Y^2 - \sum Y_c^2}}{n}$$

$$= \frac{\sqrt{2,054,887 - 1,997,808}}{11}$$

$$\sigma_{y_s} = \pm 72.035$$

Analysis of Variance for Correlation Coefficient

Source of Variance Variance

Explained: $\sigma^2_{Y_c} = \frac{\sum Y_c^2 - \bar{Y} \sum Y}{m-1} = \frac{1,997,808 - 1,735,287}{1} = 262,521$

Unexplained: $\sigma^2_{y_s} = \frac{\sum Y^2 - \sum Y_c^2}{n-m} = \frac{2,054,887 - 1,997,808}{9} = 6,342$

$$\text{Total: } r^2_y = \frac{\sum Y^2 - \bar{Y}\sum Y}{n-1} = \frac{2,054,887 - 1,735,287}{10} = 31,960$$

$$F_{1,9} = \frac{262,521}{6,342} = 41.394 \quad (F = 22.855 \text{ at } 0.1\% \text{ level})$$

∴ The correlation between the two variables is significant.

Sample calculations for curvilinear regression. The following sums were calculated for making this analysis: $\sum X = 27,280$; $\sum Y = 4,369$; $\sum XY = 14,542,115$; $\sum X^2 = 120,000,250$; $\sum Y^2 = 2,054,887$; $\sum X^2Y = 77,176,580,325$; $\sum X^3 = 716,106,637,480$; $\sum X^4 = 4,892,805,166,191,250$; $\bar{Y}\sum Y = 1,735,287$

The equation for curvilinear regression is of the form

$$Y_c = a + bX + cX^2$$

The normal equations for solution are

$$1. \sum Y = na + b\sum X + c\sum X^2$$

$$4,369 = 11a + 27,280b + 120,000,250c$$

$$2. \sum XY = a\sum X + b\sum X^2 + c\sum X^3$$

$$14,542,115 = 27,280a + 120,000,250b + 716,106,637,480c$$

$$3. \sum X^2Y = a\sum X^2 + b\sum X^3 + c\sum X^4$$

$$77,176,580,325 = 120,000,250a + 716,106,637,480b + 4,892,805,166,191,250c$$

From the simultaneous solution of the normal equations,

$$a = 216.909$$

$$b = 0.07494793$$

$$c = -10^{-9} \times 516.6414$$

$$\therefore Y_c = 216.909 + 0.07494793X - 10^{-9} \times 516.641X^2$$

The explained sums of squares,

$$\sum Y_c^2 = 1,997,600$$

The index of correlation,

$$\rho = \frac{\sqrt{\sum Y_c^2 - \bar{Y}_c^2}}{\sqrt{\sum Y^2 - \bar{Y}^2}}$$

$$= \frac{\sqrt{1,997,600 - 1,735,287}}{\sqrt{2,054,887 - 1,735,287}}$$

$$\rho = 0.906093$$

The standard error of estimate,

$$\sigma_{y_s} = \frac{\sqrt{\sum Y^2 - \sum Y_c^2}}{n}$$

$$= \frac{\sqrt{2,054,887 - 1,997,600}}{11}$$

$$\sigma_{y_s} = \pm 72.115$$

Analysis of Variance for Correlation Coefficient

Source of Variance	Variance
Explained: $\bar{r}^2_{Y_c}$	$= \frac{1,997,600 - 1,735,287}{2} = 131,157$
Unexplained: $\bar{r}^2_{y_s}$	$= \frac{2,054,887 - 1,997,600}{8} = 7,151$
Total: $\bar{r}^2_y$	$= \frac{2,054,887 - 1,735,287}{10} = 31,960$
$F_{2,8}$	$= \frac{131,157}{7,151} = 18.347$ ($F = 18.493$ at 0.1% level)

∴ The correlation between the two variables is significant.

Sample calculations for non-linear regression, $\text{Log}_{10} Y_c = \text{Log}_{10} a + b \text{Log}_{10} X$.

Let $X' = \text{Log}_{10} X$, $Y' = \text{Log}_{10} Y$, and $Y_c' = \text{Log}_{10} Y_c$. The following sums were calculated for making this analysis by using the $\text{Log}_{10} X$ and $\text{Log}_{10} Y$ in place of X and Y respectively: $\sum X'Y' = 92.062108$; $\sum X'^2 = 117.446994$; $\sum Y'^2 = 72.423408$; $(\sum X')^2 = 1,277.386342$; $(\sum Y')^2 = 792.345033$; $\bar{Y}Y' = 72.031367$;

• The first step in the process of creating a new product is to identify a market need.

• This is often done through market research, which involves gathering information about potential customers.

• Once a market need is identified, the next step is to develop a concept for the new product.

• This concept should be based on the market need and should be unique and innovative.

• The next step is to create a prototype of the product, which allows the company to test the concept.

• This is often done through a process called "prototyping," which involves creating a small-scale model of the product.

• Once a prototype is created, the company can test it to see if it meets the market need.

• If the prototype is successful, the company can move forward with developing the final product.

• This often involves creating a detailed design and then manufacturing the product on a large scale.

• Once the final product is created, the company can launch it into the market.

• This is often done through a marketing campaign, which involves promoting the product to potential customers.

• Once the product is launched, the company can monitor its performance and make adjustments as needed.

• This is often done through a process called "product lifecycle management," which involves tracking the product's performance over time.

• Once the product's performance is tracked, the company can decide if it should continue to produce the product or if it should be discontinued.

• This is often done through a process called "product evaluation," which involves assessing the product's performance against its goals.

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$$\Sigma X' = 35.740542; \Sigma Y' = 28.148624; \bar{X}' = 3.249140; \bar{Y}' = 2.558966.$$

The equation for this analysis is

$$Y_c' = a' + m (X' - \bar{X}')$$

$$a = \frac{\Sigma Y'}{n} = \bar{Y}' = 2.558966.$$

$$m = \frac{n \Sigma X'Y' - \Sigma X' \Sigma Y'}{\Sigma X'^2 - (\Sigma X')^2}$$

$$= \frac{(11)(92.062108) - (35.740542)(28.148624)}{(11)(117.446994) - (1,277.386342)}$$

$$m = 0.456699$$

$$\therefore Y_c' = 2.558966 + 0.456699(X' - 3.249140)$$

$$Y_c' = 1.075087 + 0.456699X'$$

$$\text{Log}_{10} Y_c = 1.075087 + 0.456699 \text{Log}_{10} X$$

The explained sums of squares

$$\Sigma Y_c'^2 = 72.306906$$

The correlation coefficient,

$$r_1 = \frac{(n)(\Sigma X'Y') - \Sigma X' \Sigma Y'}{\sqrt{[n \Sigma X'^2 - (\Sigma X')^2][n \Sigma Y'^2 - (\Sigma Y')^2]}}$$

$$= \frac{(11)(92.062108) - (35.740542)(28.148624)}{\sqrt{[(11)(117.446994) - (1,277.386342)][(11)(72.423408) - (792.345033)]}}$$

$$r_1 = 0.8383$$

The standard error of estimate

$$\sigma_{y's} = \sqrt{\frac{\Sigma Y'^2 - \Sigma Y_c'^2}{n}}$$

$$= \sqrt{\frac{72.423408 - 72.306906}{11}}$$

$$\sigma_{y's} = \sqrt{0.102913}$$

Analysis of variance for correlation coefficient

Source of Variance	Variance
Explained: $\sigma_{\bar{y}'_c}^2$	$= \frac{72.306906 - 72.031367}{1} = 0.275539$
Unexplained: $\sigma_{\bar{y}'_s}^2$	$= \frac{72.423408 - 72.306906}{9} = 0.0129447$
Total: $\sigma_{\bar{y}'}^2$	$= \frac{72.423408 - 72.031367}{10} = 0.0392041$

$$F_{1,9} = \frac{0.275539}{0.0129447} = 21.286 \text{ (F = 22.855 at 0.1\% level)}$$

∴ The correlation between the two variables is significant.

Sample calculations for non-linear regression, $Y_c = a + b \text{Log}_{10}X$. Let $X' = \text{Log}_{10}X$. The following sums were calculated for making this analysis by using the $\text{Log}_{10}X$ in place of X : $\Sigma X'Y = 14,767.503818$; $\Sigma X'^2 = 117.446994$; $\Sigma Y^2 = 2,054,887$; $(\Sigma X')^2 = 1,277.386342$; $(\Sigma Y)^2 = 19,088,161$; $\bar{Y}\Sigma Y = 1,735,287$; $\Sigma X' = 35.740542$; $\Sigma Y = 4,369$; $\bar{X}' = 3.249140$; $\bar{Y} = 397.182$

The equation for this analysis is

$$Y_c = a + m (X' - \bar{X}')$$

$$a = \frac{\Sigma Y}{n} = \bar{Y} = 397.182$$

$$m = \frac{n\Sigma X'Y - \Sigma X'\Sigma Y}{n\Sigma X'^2 - (\Sigma X')^2}$$

$$= \frac{(11)(14,767.503818) - (35.740542)(4,369)}{(11)(117.446994) - (1,277.386342)}$$

$$m = 433.025303$$

$$\therefore Y_c = 397.182 + 433.025 (X' - 3.249140)$$

$$Y_c = 433.025X' - 1,009.778$$

$$Y_c = 433.025\text{Log}_{10}X - 1,009.778$$

The explained sums of squares,

$$\Sigma Y_c^2 = 1,982,983$$

The correlation coefficient,

$$\begin{aligned} R_2 &= \frac{(n)(\Sigma X'Y) - \Sigma X' \Sigma Y}{\sqrt{[n\Sigma X'^2 - (\Sigma X')^2][n\Sigma Y'^2 - (\Sigma Y)^2]}} \\ &= \frac{(11)(14,767.504) - (35.740542)(4,369)}{\sqrt{[(11)(117.446994) - (1,277.386342)][(11)(2,054,887 - (19,088,161)]}} \\ R_2 &= 0.8804 \end{aligned}$$

The standard error of estimate,

$$\begin{aligned} \sigma_{ys} &= \sqrt{\frac{\Sigma Y'^2 - \Sigma Y_c^2}{n}} \\ &= \sqrt{\frac{2,054,887 - 1,982,983}{11}} \\ \sigma_{ys} &= 80.850 \end{aligned}$$

Analysis of Variance for Correlation Coefficient

Source of Variance	Variance
Explained: $\bar{\sigma}_{y'_c}^2 = \frac{1,982,983 - 1,735,287}{1} = 247,696$	
Unexplained: $\bar{\sigma}_{y'_s}^2 = \frac{2,054,887 - 1,982,983}{9} = 7,989$	
Total: $\bar{\sigma}_{y'}^2 = \frac{2,054,887 - 1,735,287}{10} = 31,960$	
$F_{1,9} = \frac{247,696}{7,989} = 31.005$ (F = 22.855 at 0.1% level)	

∴ The correlation between the two variables is significant.

Results for receiving rooms. Table AIII lists the results obtained from the calculations for the relationship between the gallons of milk handled daily and the required floor area for milk plant receiving rooms.

TABLE AIII

RESULTS OBTAINED FROM CALCULATIONS
FOR THE RELATIONSHIP BETWEEN GALLONS OF
MILK HANDLED DAILY AND THE FLOOR AREA
FOR MILK PLANT RECEIVING ROOMS

Estimating Equation	Standard Error of Estimate	Correlation Coefficient
1. $Y_c = 221.555 + 0.0708174X$	$\sigma_{y_s} = \pm 72.035$	$r = 0.9063$
2. $Y_c = 216.909 + 0.0749479X - 10^{-9} \times 516.641X^2$	$\sigma_{y_s} = \pm 72.115$	$R = 0.9061$
3. $\log_{10} Y_c = 1.075087 + 0.456699 \log X$	$\sigma_{y's} = \pm 0.102913$	$R_1 = 0.8323$
4. $Y_c = 433.025 \log_{10} X - 1,009.778$	$\sigma_{y_s} = \pm 80.850$	$R_2 = 0.8804$

Equation (1) was assumed to represent the best relationship between the gallons of milk handled daily and the floor area required for milk plant receiving rooms. (See Table AIII).

Equations (1) and (2) indicated almost equally, a satisfactory relationship between the gallons of milk handled daily and the amount of floor space required for the receiving room. The degree of the relationship is expressed by the correlation coefficient which, when equal to 1.00, indicates a line that describes the relationship perfectly. Also, by squaring the coefficient for equations (1) and (2) it was observed that approximately 82 per cent of the variation in the floor space over the range of plants studied was explained by the relationship of square feet to gallons of milk handled daily. The remaining 18 per cent of the variation is due to other factors, such as arrangement of equipment, type of equipment, and method of handling.

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for transparency and accountability, particularly in financial matters. The text suggests that organizations should implement robust systems to track every aspect of their operations, from procurement to sales.

2. The second section focuses on the role of technology in modern business management. It highlights how digital tools can streamline processes, reduce errors, and improve overall efficiency. The author argues that embracing technology is not just a competitive advantage but a necessity for long-term success in today's fast-paced market.

3. The third part of the document addresses the challenges of human resource management. It discusses the importance of attracting and retaining top talent, as well as the need for continuous training and development. The text suggests that organizations should create a supportive work environment that encourages innovation and collaboration among employees.

4. The fourth section explores the impact of market trends and external factors on business performance. It notes that companies must remain vigilant and adaptable to changes in the market, such as shifts in consumer behavior or new regulatory requirements. The author advises that strategic planning and risk management are crucial for navigating these uncertainties.

5. The final part of the document provides a summary of key takeaways and offers practical advice for implementing the discussed concepts. It encourages readers to take a proactive approach to their business management, regularly reviewing and refining their strategies to stay ahead of the competition.

The standard error of estimate indicated that for the 11 plants used in the analysis, the amount of floor space required for receiving rooms could be expected to vary within about ± 72 square feet of the estimated value for approximately 68 per cent of the plants when the area is estimated by either equation (1) or (2). If this range were extended to include about 95 per cent of the plants studied, we could expect to estimate the floor space requirements to within about ± 144 square feet of the actual amount required.

The reliability of the relationship was equally well expressed by either equation (1) or (2). However, by introducing a third constant, as was done for equation (2), the reliability of the results is reduced. This gives the same result as reducing the size of the sample.

The degree of relationship between the floor area and the gallons of milk handled daily was not as well defined by equation (3). Approximately 70 per cent of the variation in the floor area was explained by equation (3) for the relationship of floor area to gallons of milk handled daily. The floor area would be expected to vary between ± 54 and -42 square feet of the true value for about 68 per cent of the plants handling 500 gallons of milk daily and between ± 193 and -152 square feet for about 68 per cent of the plants handling 8,000 gallons of milk daily.

Approximately 71 per cent of the variation in the floor area was explained by the relationship of square feet to gallons of milk handled daily as expressed in equation (4). The estimate of the floor area would be expected to vary between ± 81 square feet of the required amount when estimated by equation (4), for approximately 68 per cent of the plants studied.

Therefore, equation (1) provides the best estimate of the amount of floor space required for milk plant receiving rooms as explained by

the relationship of square feet to gallons of milk handled daily for those plants handling between 500 and 8,000 gallons of milk daily.

Equation (1) indicated that a general relationship existed between the gallons of milk handled daily and the floor space required for milk plant receiving rooms. However, due to variations in arrangement of equipment, type of equipment, and methods of handling, the area required for receiving rooms is quite variable. An estimate of the floor space required, when using equation (1), would be expected to vary within ± 72 square feet of the actual value for approximately 68 per cent of the plants and within ± 144 square feet for approximately 95 per cent of the plants.

Because of the variation in the area required for milk plant receiving rooms, a precise prediction regarding the floor space requirements cannot be made. However, the area required, when calculated from the relationship of square feet of floor space to gallons of milk handled daily, should prove to be a satisfactory estimate.

Table AIV shows the estimate of the average amount of floor space, with upper and lower limits, required for milk plant receiving rooms as calculated from the estimating equation, $Y_c = 221.555 + 0.0708174X$. The upper and lower limits for the required area were determined by adding ± 72 square feet to the estimated area. This amount of variation in the floor area can be expected to include approximately 68 per cent of the plants studied.

TABLE AIV
ESTIMATE OF FLOOR AREA REQUIRED
FOR MILK PLANT PROCESSING ROOMS
USED IN CONSTRUCTING FIG. 1

Gals. of Milk Handled Daily	Floor Area Required (ft. ²)		
	Avg.	Max.	Min.
500	257	329	185
1,000	292	364	220
2,000	363	435	281
3,000	434	506	362
4,000	505	577	433
5,000	576	648	504
6,000	647	719	574
7,000	717	789	645
8,000	788	860	716

Processing Rooms

The size of the processing room was investigated in 12 milk plants handling from 500 to 7,950 gallons of milk daily. Those plants handling 1,100; 4,800; 6,400, and 7,950 gallons of milk daily, respectively, had processing rooms which were too small and were not included in the analysis. One plant handling 975 gallons of milk daily did not indicate if the processing room was large enough, however, it was assumed to be adequate. The two plants handling 975 gallons and 4,190 gallons of milk daily each had a 1,500 gallons storage tank in the receiving room and 96 square feet were subtracted from the receiving room area and added to that of the processing room.

The area for the processing room includes the area for pasteurizing, milk tank storage, bottle filling, byproducts manufacturing, cooling the milk prior to bottle-filling, homogenizing, and all other allied operations.

Results for processing rooms. Table AV lists the results obtained from the calculations for the relationship between the gallons of milk handled daily and the required floor area for milk plant processing rooms.

TABLE AV

RESULTS OBTAINED FROM CALCULATIONS
FOR THE RELATIONSHIP BETWEEN GALLONS
OF MILK HANDLED DAILY AND THE FLOOR
AREA FOR MILK PLANT PROCESSING ROOMS

Estimating Equation	Standard Error of Estimate	Correlation Coefficient
1. $Y_c = 551.610 + 0.417415X$	$\sigma_{y_x} = \pm 164.156$	$r = 0.9516$
2. $\log_{10} Y_c = 1.127181 + 0.621603 \log_{10} X$	$\sigma_{y'_x} = \pm 0.045749$	$r = 0.9691$

Equation (2) was assumed to more nearly represent the relationship between the gallons of milk handled daily and the floor area required for milk plant processing rooms. (See Table AV).

Equation (2) gave a slightly better measure of the degree of relationship between the area required for milk plant processing rooms and the gallons of milk handled daily. The correlation coefficients were 0.9516 and 0.9691 for equations (1) and (2), respectively. A coefficient of 1.00 indicates a perfect relationship. Also, approximately 91 and 94 per cent of the variation in the floor area, over the range of plants studied, was explained by the relationship of square feet to gallons of milk handled daily, by equations (1) and (2), respectively.

The required amount of floor space, when estimated by equation (1), could be expected to vary between ± 154 square feet of the actual value for 60 per cent of the plants studied. If this range were extended to include approximately 95 per cent of the plants studied we should expect this estimate to vary between ± 328 square feet of the actual value.

When equation (2) is used, the estimate of the required amount of floor space would be expected to vary within approximately ± 70 and $- 63$ square feet of the actual value for 60 per cent of the plants handling 500 gallons of milk daily and within ± 294 and $- 265$ square feet of the actual value for 60 per cent of those plants handling 5,000 gallons of milk daily. If these limits are extended to include approximately 95 per cent of the plants studied, those plants handling 500 gallons of milk daily would be expected to show a variation of from ± 140 to $- 126$ square feet from the correct amount while plants handling 5,000 gallons of milk daily would be expected to vary between ± 594 and $- 530$ square feet of the actual amount of floor area required.

Equation (2) was selected as the one best representing the relationship between the square feet of floor space required for milk plant processing rooms and the gallons of milk handled daily. This equation appeared to show a better representation of the data.

A large amount of variation between the size of processing rooms for milk plants was quite evident due to variations in the number of products handled, and also variations in the type and arrangement of the equipment employed. There is considerable doubt as to the reliability of the estimate of the area for processing rooms, since the area includes that required for all processing operations, including byproducts manufacturing and milk tank

storage. Also the plants used in this study included some which had high-temperature short-time pasteurization in addition to vat pasteurization, and some which did not. Therefore, the estimate of the area required for the processing rooms can only be used as a very rough approximation. It does show, however, that a general relationship exists between the amount of product handled daily and the floor area required for milk plant processing rooms.

Table AVI shows the estimate of the average amount of floor space, with upper and lower limits, required for milk plant processing rooms as calculated from the estimating equation, $\log_{10} Y_c = 1.1251^{\circ}1 \pm 0.621603 \log_{10} X$. The upper and lower limits for the required area were determined by adding ± 0.045749 , the logarithm of the error of estimation, to the logarithm of the estimated area and then obtaining the anti-logarithm. This amount of variation in the floor area can be expected to include approximately 6% per cent of the plants studied.

TABLE AVI

ESTIMATE OF FLOOR AREA REQUIRED
FOR MILK PLANT PROCESSING ROOMS
USED IN CONSTRUCTING FIG. 2

Gals. of Milk Handled Daily	Floor Area Required (ft. ²)		
	Avg.	Max.	Min.
500	632	702	569
1,000	973	1,061	875
2,000	1,407	1,663	1,347
3,000	1,826	2,140	1,733
4,000	2,203	2,559	2,072
5,000	2,645	2,939	2,381

Bottle Washing Rooms

The size of the bottling washing room was investigated in 12 milk plants handling from 580 to 7,950 gallons of milk daily. One plant handling 4,800 gallons of milk daily indicated that the bottle washing room was too small and was not included in the analysis. In addition, the amount of bottled milk handled daily was not known for three other plants and consequently they were omitted from the analysis. Also, the plant handling 2,510 gallons of milk daily did not indicate if the bottle washing room was large enough and this plant was not included in the analysis of the data. The plant handling 730 gallons of milk daily was using round bottles and only those plants using square bottles were included in the calculations. This analysis was based on the gallons of bottled milk handled daily.

Results for bottle washing rooms. Table AVII shows the results obtained from the calculations for the relationship between the gallons of bottled milk handled daily and the required area for milk plant bottle washing rooms.

TABLE AVII

RESULTS OBTAINED FROM CALCULATIONS
FOR THE RELATIONSHIP BETWEEN GALLONS OF
BOTTLED MILK HANDLED DAILY AND THE FLOOR
AREA FOR MILK PLANT BOTTLE WASHING ROOMS

Estimating Equation	Standard Error of Estimate	Correlation Coefficient
1. $Y_c = 563.151 + 0.203005X$	$\sigma_{y's} = \pm 117.4^{\circ}1$	$r = 0.9414$
2. $\text{Log}_{10}Y_c = 1.35521 + 0.475328\text{Log}_{10}X$	$\sigma_{y's} = \pm 0.100447$	$\rho = 0.9060$

Equation (1) was assumed to give the best estimate of the floor area required for milk plant bottle washing rooms. (See Table AVII).

The degree of relationship between the floor area and the gallons of bottled milk handled daily was explained more satisfactorily when using equation (1) than when using equation (2) for estimating. The correlation coefficients, which are a measure of this degree of relationship, were 0.9414 and 0.9060 for equations (1) and (2), respectively. A perfect relationship is indicated by a coefficient of 1.00. Also, by squaring the coefficient, it was observed that approximately 89 and 82 per cent of the variation in the floor space for bottle washing rooms was explained in the relationship of square feet of area to gallons of bottled milk handled daily by equations (1) and (2), respectively.

The amount of variation in the estimated results was much greater when expressed by equation (2) than when expressed by equation (1). For equation (1), the estimated amount of floor space would be expected to vary within ± 117 square feet of the actual value for 69 per cent of the plants studied. This variation in the estimated amount of floor space would be increased to ± 234 square feet if approximately 95 per cent of the plants were to be included within the limits of variation.

When equation (2) is used, the variation to be expected between the actual and the estimated amount of floor space required for bottle washing rooms would be within ± 259 and -154 square feet for 69 per cent of the plants handling 500 gallons of bottled milk daily and within ± 601 and -388 square feet for 69 per cent of the plants handling 5,000 gallons of bottled milk daily. If the range of variation is extended to include approximately 95 per cent of all plants, the above variations would be doubled.

Equation (1) was selected to represent the best estimate of the floor area required for milk plant bottle washing rooms because the error of estimation was much smaller than for equation (2).

There appeared to be a general relationship between the size of milk plant bottle washing rooms and the gallons of bottled milk handled daily. A variation of ± 117 square feet for the estimated floor area is not excessively large when considering the size of bottle washing rooms. This amount of variation is due to differences in methods of handling bottle cases in the bottle washing room and also due in part to the limited size of the sample. However, the area as estimated by equation (1) in this section should provide a bottle washing room of adequate size handling the square-type milk bottle.

Table AVIII shows the estimate of the average amount of floor space, with upper and lower limits, required for milk plant bottle washing rooms as calculated by the estimating equation, $Y_c = 383.151 + 0.00005X$. The upper and lower limits for the required area were determined by adding ± 117 square feet to the estimated area. This amount of variation in the floor area would be expected to include approximately 6% per cent of the plants studied.

TABLE AVIII

ESTIMATE OF FLOOR AREA REQUIRED
FOR MILK PLANT BOTTLE WASHING
ROOMS USED IN CONSTRUCTING FIG. 3

Gals. of Bottled Milk Handled Daily	Floor Area Required (ft. ²)		
	Avg.	Max.	Min.
500	485	602	357
1,000	526	704	469
2,000	729	907	672
3,000	902	1,110	875
4,000	1,105	1,313	1,078
5,000	1,308	1,516	1,281

Milk Storage Rooms

The size of the milk storage room was investigated in 12 milk plants handling from 500 to 7,950 gallons of milk daily. Five of the plants indicated that the milk storage room was too small and these were not included in the analysis of data. The two plants handling 975 and 2,510 gallons of milk daily did not indicate whether the milk storage room was large enough, however, they were both assumed to be adequate in size. The plant handling 730 gallons of milk daily was using round bottles and was also handling a small amount of milk in paper containers. Only those plants handling milk in square bottles were included in the analysis.

Results for milk storage rooms. Table AIX shows the results obtained from the calculations for the relationship between the gallons of milk handled daily and the required area for milk storage rooms.

TABLE AIX

RESULTS OBTAINED FROM CALCULATIONS
FOR THE RELATIONSHIP BETWEEN GALLONS
OF MILK HANDLED DAILY AND THE FLOOR
AREA REQUIRED FOR MILK PLANT
MILK STORAGE ROOMS

Estimating Equation	Standard Error of Estimate	Correlation Coefficient
1. $Y_c = 251.046 + 0.136571X$	$\sigma_{y_s} = \pm 72.015$	$r = 0.9214$
2. $\text{Log}_{10}Y_c = 1.076085 + 0.504535\text{Log}_{10}X$	$\sigma_{y'_s} = \pm 0.060596$	$\rho = 0.9322$

Equation (2) was assumed to represent the best relationship between the gallons of milk handled daily and the floor area required for milk storage rooms. (See Table AIX).

The degree of relationship between the floor area and the gallons of milk handled daily was more satisfactorily explained when using equation (2) than when using equation (1), however, the difference was small, as indicated by the correlation coefficients. It was also observed that approximately 85 and 87 per cent of the variation in the floor space for milk storage rooms was explained by the relationship of square feet of area to gallons of milk handled daily when estimated by equations (1) and (2), respectively.

The amount of floor space, when estimated by equation (1), may be expected to vary between ± 72 square feet of the actual value for approximately 95 per cent of the plants studied.

The range of variation to be expected between the actual and the estimated amount of floor space required for milk storage rooms would be

within ± 41 and $- 36$ square feet for approximately 66 per cent of the plants handling 500 gallons of milk daily, and within ± 131 and $- 114$ square feet for 68 per cent of those plants handling 5,000 gallons of milk daily, when the areas are estimated by equation (2). If the range of variation were extended to include approximately 95 per cent of all plants, the variations stated above would be doubled.

Equation (2) indicated a slightly better relationship between the floor area and the gallons of milk handled for milk storage rooms than did equation (1). Equation (2) also showed a lesser amount for small plants and a greater amount for larger plants in the variation between the actual and the estimated amount of floor space required. A larger variation, however, would be expected for the larger plants. Therefore, equation (2), probably provides the best estimate of the floor area.

The size of the milk storage room appeared to be directly related to the gallons of milk handled daily by the milk plant. The variation of the estimate was probably due to differences in the number of products handled, the method of handling the finished products, the arrangement of the room, and the height at which cases of milk are stacked. Also, some of the variation is undoubtedly due to the small number of plants available for making this analysis. The area as estimated by equation (2) should provide sufficient floor space for the milk storage room handling milk in the square-type milk bottle.

Table AX shows the estimate of the average amount of floor space, with upper and lower limits, required for milk plant, milk storage rooms as calculated from the estimating equation, $\text{Log}_{10}Y_c = 1.076085 \pm 0.504535\text{Log}_{10}X$. The upper and lower limits for the estimated area were determined by adding

± 0.060596 to the logarithm of the estimated value and then determining the anti-logarithm. This variation in the floor area would be expected to give a range of area which would include that for approximately 68 per cent of the plants studied.

TABLE AX

ESTIMATE OF FLOOR AREA REQUIRED
FOR MILK PLANT MILK STORAGE ROOMS USED
IN CONSTRUCTING FIG. 4

Gals. of Milk Handled Daily	Floor Area Required (ft. ²)		
	Avg.	Max.	Min.
500	274	315	238
1,000	389	447	338
2,000	552	634	480
3,000	677	778	582
4,000	782	900	681
5,000	876	1,007	762

Dry Storage Rooms

The size of the dry storage room was investigated in ten milk plants handling from 500 to 7,950 gallons of milk daily. Four of the plants indicated that the dry storage room was too small and these were not included in the analysis of data. The plant handling 975 gallons of milk daily did not indicate whether the milk storage room was large enough and was omitted from the calculations.

Results for dry storage rooms. Table AXI shows the results obtained from the calculations for the relationship between the gallons of milk handled daily and the required area for milk plant dry storage rooms.

TABLE AXI

RESULTS OBTAINED FROM CALCULATIONS
FOR THE RELATIONSHIP BETWEEN GALLONS
OF MILK HANDLED DAILY AND THE FLOOR
AREA REQUIRED FOR MILK PLANT
DRY STORAGE ROOMS

Estimating Equation	Standard Error of Estimate	Correlation Coefficient
1. $Y_c = 864.461 + 0.370495X$	$\sigma_{y_s} = \pm 3,095$	$r = 0.6005$
2. $\log_{10} Y_c = 0.453280 + 0.009050 \log_{10} X$	$\sigma_{y'_s} = \pm 0.204513$	$\rho = 0.8677$

Equation (2) was the only equation showing a satisfactory relationship between the gallons of milk handled daily and the floor area required for milk plant dry storage rooms. (See Table AXI).

The difference between the reliability of the two estimates, as shown by the correlation coefficients, was so extreme that selection could be made on the basis of this alone, recalling that a coefficient of 1.00 indicates a relationship which is perfect. Approximately 56 and 75 per cent of the variation in the floor space for milk plant dry storage rooms, when estimated by equations (1) and (2), respectively, was explained by the relationship of square feet of area to gallons of milk handled daily. The other 44 and 25 per cent of the variation was due to other factors. Therefore, equation (2) was the only one showing any degree of relationship between the two variables.

Equation (2), however, does not provide a very reliable relationship. The amount of floor space, when estimated by equation (2), may be expected to vary within ± 261 and -164 square feet of the actual value for approximately 68 per cent of those plants handling 500 gallons of milk daily and within $\pm 2,456$ and $-1,554$ square feet of the actual value for approximately 68 per cent of those plants handling 8,000 gallons of milk daily. This large amount of variation was due to the extreme difference in the size of the dry storage rooms found in milk plants and also, to the limited number of plants included in the analysis.

Because of the large amount of variation found in milk plant dry storage rooms, a reliable estimate of the space requirements cannot be made.

Table A'II shows the estimate of the average amount of floor space, with upper and lower limits, required for milk plant dry storage rooms as calculated from the estimating equation, $\log_{10} Y_c = 0.455280 \pm 0.809050 \log_{10} X$. The upper and lower limits for the required area were determined by adding ± 0.204515 , the logarithm of the estimating error, to the logarithm of the estimated area and then determining the anti-logarithm. The range of area contained within these limits would be expected to include that required for approximately 68 per cent of all plants.

TABLE AXII

ESTIMATE OF FLOOR AREA REQUIRED
FOR MILK PLANT DRY STORAGE
ROOMS USED IN CONSTRUCTING FIG. 5

Gals. of Milk Handled Daily	Floor Area Required (ft. ²)		
	Avg.	Max.	Min.
500	435	604	271
1,000	732	1,216	474
2,000	1,330	2,151	851
3,000	1,847	2,958	1,153
4,000	2,311	3,753	1,456
5,000	2,722	4,471	1,744
6,000	3,086	5,122	2,021
7,000	3,506	5,770	2,269
8,000	4,004	6,540	2,550

Boiler Rooms

Data were available for boiler rooms from nine milk plants handling from 500 to 7,050 gallons of milk daily. The plant handling 750 gallons of milk daily stated that the size of the boiler room was too small and was not used in this analysis.

Results for boiler rooms. Table AXIII shows the results obtained from the calculations for the relationship between the gallons of milk handled daily and the required area for milk plant boiler rooms.

TABLE AXIII

RESULTS OBTAINED FROM CALCULATIONS
FOR THE RELATIONSHIP BETWEEN GALLONS
OF MILK HANDLED DAILY AND THE FLOOR
AREA REQUIRED FOR MILK PLANT
BOILER ROOMS

Estimating Equation	Standard Error of Estimate	Correlation Coefficient
1. $Y_c = 98.210 + 0.126028X$	$\sigma_{Y_s} = \pm 74.008$	$r = 0.9751$
2. $\log_{10} Y_c = 0.143176 + 0.736160 \log_{10} X$	$\sigma_{Y'_s} = \pm 0.059744$	$\rho = 0.9905$

Equation (2) was assumed to represent the most satisfactory relationship between the gallons of milk handled daily and the floor area required for milk plant boiler rooms. (See Table AXIII).

The difference between the reliability of the two estimates was practically negligible, as explained by the correlation coefficient. When estimated by equations (1) and (2), respectively, approximately 95 and 96 per cent of the variation in the floor space for milk plant boiler rooms was explained by the relationship of square feet to gallons of milk handled daily, indicating a very reliable relationship.

The amount of floor space, when estimated by equation (1), may be expected to vary between ± 74 square feet of the actual value for the space required in approximately 68 per cent of all plants and between ± 148 square feet in approximately 95 per cent of all plants.

The range of variation to be expected between the actual and the estimated amount of floor space required for milk plant boiler rooms would be within ± 20 and -17 square feet for approximately 68 per cent of all

plants handling 500 gallons of milk daily, and within ± 155 and -154 square feet for approximately 68 per cent of those plants handling 8,000 gallons of milk daily, when the areas are estimated by equation (2). If this range of variation were extended to include approximately 95 per cent of all plants, the variations stated above would be doubled.

The size of the boiler room was found to be directly related to the gallons of milk handled daily by milk plants. The variation in the estimated floor area was probably due to some differences in the original design, and also, in part, to the small size of the sample available for making this analysis.

Table AXIV shows the estimate of the average amount of floor space, with upper and lower limits, required for milk plant boiler rooms as calculated from the estimating equation, $\text{Log}_{10}Y_c = 0.145176 \pm 0.736160\text{Log}_{10}X$. The upper and lower limits for the required area were determined by adding ± 0.059744 , the logarithm of the estimating error, to the logarithm of the estimated value, and then determining the anti-logarithm. Approximately 68 per cent of all plants would be expected to be included in the range of area bounded by these limits.

TABLE AXIV

ESTIMATE OF FLOOR AREA REQUIRED
FOR MILK PLANT BOILER ROOMS USED
IN CONSTRUCTING FIG. 6

Gals. of Milk Handled Daily	Floor Area Required (ft. ²)		
	Avg.	Max.	Min.
500	135	155	118
1,000	225	252	196
2,000	374	430	326
3,000	505	579	440
4,000	624	716	543
5,000	735	843	641
6,000	841	964	732
7,000	941	1,080	820
8,000	1,039	1,192	905

Plant Offices

Data were available for plant offices from eight milk plants handling from 520 to 7,950 gallons of milk daily. The plant handling 975 gallons of milk daily did not indicate if the space allotted to plant offices was large enough, however, it was assumed to be adequate. The plant handling 700 gallons of milk daily included the driver's check room in the space allotted to offices and this plant was omitted from the analysis.

Results for plant offices. Table AXV shows the results obtained from the calculations for the relationship between the gallons of milk handled daily and the required area for milk plant offices.

TABLE AXV

RESULTS OBTAINED FROM CALCULATIONS
FOR THE RELATIONSHIP BETWEEN GALLONS
OF MILK HANDLED DAILY AND THE FLOOR
AREA REQUIRED FOR MILK PLANT OFFICES

Estimating Equations	Standard Error of Estimate	Correlation Coefficient
1. $Y_c = 151.976 + 0.159190X$	$\sigma_{y_s} = \pm 196.854$	$r = 0.9014$
2. $\log_{10} Y_c = -0.204774 + 0.867218 \log_{10} X$	$\sigma_{y'_s} = 0.179797$	$r_1 = 0.9875$
3. $Y_c = -143.185 + 0.456211X$ $-10^{-7} \times 360.495X^2$	$\sigma_{y_s} = \pm 98.066$	$r_2 = 0.9765$

Equation (3) was assumed to represent the most satisfactory relationship between the gallons of milk handled daily and the floor area required for milk plant offices. (See Table XV).

The degree of relationship between the floor area and the gallons of milk handled daily was much better explained by equation (3) as indicated by the correlation coefficients. Approximately 81 and 79 per cent of the variation in floor space for plant offices was explained by equations (1) and (2), respectively, by the relationship of square feet to gallons of milk handled daily, while about 95 per cent of the variation was explained by equation (3).

When estimated by equation (1), the amount of floor space required for plant offices may be expected to vary between ± 197 square feet of the actual value for approximately 68 per cent of all plants. The difference between the actual and the estimated amount of floor space for plant offices, when estimated by equation (2), may be expected to vary within ± 70 and -46

square feet for 68 per cent of all plants handling 500 gallons of milk daily and within ± 776 and $- 513$ square feet for 68 per cent of all plants handling 2,000 gallons of milk daily. The variation expected in the floor area when estimated by equation (2), would be within ± 93 square feet of the actual value when approximately 68 per cent of all plants are included. If the above ranges were extended to include approximately 95 per cent of all plants, the amount of variation in the floor area between the actual and the estimated values would be doubled. Since the relationship between the floor area and the gallons of milk handled daily was much more satisfactorily explained by equation (3) and also, the estimating error was smaller, especially for the larger plants, this equation was selected as the one providing the best estimate of the office space required for milk plants.

Due to the small number of plants used in the analysis, and also the variability in the floor space available for offices in the larger plants, the relationship established does not give a very reliable indication of the office space requirements for the larger plants. The estimated values indicated that the floor space required for plant offices increased with an increasing plant capacity for plants handling up to approximately 6,000 gallons of milk daily. For plants handling over 6,000 gallons of milk daily, the area required decreased with an increasing plant capacity. It might be expected that the area would increase at a decreasing rate, but it is impractical to expect the required area to decrease with an increased plant capacity. Therefore, the upper limits of this estimate, probably beyond a plant capacity of approximately 5,000 gallons daily, cannot be depended upon to produce a very reliable estimate.

Table XVI shows the estimate of the average amount of floor space, with upper and lower limits, required for milk plant offices as calculated from the estimating equation, $Y_c = -143.125 + 0.456811X - 10^{-7} \times 360.495X^2$. The upper and lower limits for the required area were determined by adding ± 96 square feet to the estimated area. This amount of variation in the estimated area should give a range which would be expected to include the areas for approximately 68 per cent of all plants.

TABLE XVI
ESTIMATE OF FLOOR AREA REQUIRED
FOR MILK PLANT OFFICES USED
IN CONSTRUCTING FIG. 7

Gals. of Milk Handled Daily	Floor Area Required (ft. ²)		
	Avg.	Max.	Min.
500	75	174	-22
1,000	273	376	180
2,000	626	724	528
3,000	905	1,001	805
4,000	1,107	1,205	1,009
5,000	1,240	1,338	1,142
6,000	1,300	1,398	1,202
7,000	1,288	1,386	1,190
8,000	1,204	1,302	1,106

APPENDIX II

List of Plant Descriptions

Plant A

Plant A, constructed in 1949 to handle approximately 3,500 gallons of milk daily, was a one-story structure processing 500 gallons of milk daily. Milk was bottled in the square-type bottle with approximately 1,000 quarts and 1,500 half-pints of milk produced daily. In addition, approximately 80 pounds of cottage cheese were processed daily.

The products handled were whole milk, homogenized vitamin D milk, chocolate milk, chocolate drink, cereal mix, coffee cream, whipping cream, buttermilk, cottage cheese, and skim milk.

The employees consisted of one man for the office, four route men, and three men handling the processing operations.

The following information lists the size of the various rooms and the equipment required for the milk plant.

Receiving room. The receiving room was 15¹/₂ ft. wide x 20 ft. long x 14 ft. high and was considered to be large enough. The following equipment was listed for the receiving room.

1. Weigh tank, (50 gals.)
2. Rotary can washer, (4 cpm.)
3. Poller conveyors for receiving and returning cans

Processing room. The dimensions for the processing room were 20 ft. wide x 35 ft. long x 14 ft. high. This room was assumed to be sufficiently large.

The equipment required for processing is listed as follows.

1. Preheater, (4,000 lbs. per hr.)
2. Pasteurizers, (2 at 200 gals. each)
3. Homogenizer, (200 gal. per hr.)
4. Surface cooler, (2,500 lbs. per hr.)
5. Bottle filler, (26 qts. per min.)
6. Cheese vat, (50 gal.)
7. Separator-clarifier, (1,000 lbs. per hr.)

Bottle washing room. The size of the bottle washing room was 18 ft. wide x 25 ft. long x 14 ft. high and was considered to be adequate in size. The equipment indicated for the bottle washing room was as follows.

1. Soaker-type bottle washer, (4-wide, 32 bpm)
2. Compressors, (2 at 2 hp)
3. Cases of bottles handled on dollies

Milk storage room. The milk storage room was $15\frac{1}{2}$ ft. wide x $22\frac{1}{4}$ ft. long x 9 ft. high and was assumed to be large enough. Milk was stored in square-type milk bottles.

Dry storage room. The dry storage room was approximately one-third as large as necessary and was 10 ft. wide x $13\frac{1}{2}$ ft. long x 14 ft. high.

Office space. This plant had an office $8\frac{1}{2}$ ft. wide x 18 ft. long x 9 ft. high and was considered to be large enough.

Driver's check room. A sufficiently large driver's check room was available which measured 7 ft. wide x $13\frac{1}{2}$ ft. long x 14 ft. high.

Boiler room. A 40 horsepower oil-fired boiler was located in a 12 ft. wide x $13\frac{1}{2}$ ft. long x 14 ft. high room. This room was considered to be adequate in size.

Locker room. A small room $7\frac{1}{2}$ ft. wide x $13\frac{1}{2}$ ft. long x 9 ft. high was available as a lavatory and shower room, and was sufficiently large.

Plant B

Plant B, processing approximately 700 gallons of milk daily, was a one-story plant constructed in 1947 to handle 750 gallons of milk daily. Milk was bottled in square-type bottles with approximately 2,400 quarts and 1,200 half-pints being bottled daily. In addition, approximately 80 pounds of cottage cheese per day and 10,000 gallons of ice cream per year were being processed.

The products handled were grade A and B milk, raw milk, homogenized vitamin D milk, chocolate milk, buttermilk, light cream, heavy cream, and orangeade.

This operation required three men for processing, two office workers, and six route salesmen.

The following information gives the size of the rooms for this plant and the equipment required to carry out the processing operations.

Receiving room. The size of this room was stated as being 10 ft. wide x 20 ft. long x $10\frac{2}{3}$ ft. high. The operator indicated that this room should probably be 15 ft. wide. The list of equipment for the receiving room was as follows.

1. Rotary can washer, ($1\frac{1}{2}$ cpm)
2. Dump tank

Processing room. An adequate sized room for processing was available which measured $17\frac{1}{2}$ ft. wide x 40 ft. long x $10\frac{2}{3}$ ft. high. The equipment required for processing included:

1. Clarifier, (6,000 lbs. per hr.)
2. Separator, (5,500 lbs. per hr.)
3. Pasteurizers, (3 at 150 gal. each)
4. Cheese vats, (80 gal.)
5. Homogenizer, (400 gal. per hr.)
6. Cabinet cooler, (4,000 lbs. per hr.)
7. Bottle filler, (2,000 qts. per hr.)
8. Batch freezer, (5 gal.)
9. Ice cream package filler, hand operated

Bottle washing room. The bottle washing room was $17\frac{1}{2}$ ft. wide x 40 ft. long x $10\frac{2}{3}$ ft. high and was assumed to be large enough. The following equipment was located in this room.

1. Soaker-type bottle washer, (4 wide; 2,200 bph)

Milk storage room. The milk storage room was sufficiently large and measured 14 ft. wide x 22 ft. long x $8\frac{1}{2}$ ft. high. Milk was handled in square bottles.

Dry storage room. This room was indicated as being just about large enough. The dimensions were 12 ft. wide x 20 ft. long x $10\frac{2}{3}$ ft. high.

Office and driver's check room. The size of this room was 18 ft. wide x 20 ft. long x $10\frac{2}{3}$ ft. high and was considered to be large enough.

Boiler room. A 30 horsepower horizontal, package unit boiler was located in a sufficiently large room measuring 10 ft. wide x 20 ft. long x 10 $\frac{2}{3}$ ft. high.

Compressor room. This room measured 6 ft. wide x 14 ft. high and was adequate in size. The following compressors were located in this room.

1. One, 3 hp. (Freon-12)
2. Two, 2 hp. (Freon-12)
3. One, 2 hp. (Methyl-chloride)
4. One, 1 $\frac{1}{2}$ hp. (Freon-12)

Locker room. The size of the locker room was 8 ft. wide x 8 ft. long x 9 ft. high and was of sufficient size.

Plant C

Plant C was a one-story built originally in 1942 to handle 400 gallons of milk daily. In 1950, a new building was erected, additions were made to the original plant, and the complete layout was rearranged to handle 750 gallons of milk daily. The majority of the milk was bottled in the round-type bottle with approximately 2,000 quarts, 100 pints, and 1,000 half-pints being bottled daily. Approximately 400 quarts were handled in paper containers. In addition, about 10,000 gallons of ice cream were processed yearly.

The products handled were market milk, cottage cheese, buttermilk, ice cream, orange drink, and chocolate milk.

Three men were employed to handle processing, one was required for the office, and five were needed as route salesmen.

The information listed below states the size of the the various rooms found in the plant and the equipment required.

Receiving room. The receiving room was 15 ft. wide x 15 ft. long x 20 ft. high and was considered to be large enough. The equipment required included.

1. Weigh tank, (500 lb.)
2. Roller conveyors

Processing room. The dimensions of the processing room were 15 ft. wide x 40 ft. long x 15 ft. high and it was assumed to be sufficiently large. The equipment required for processing is listed as follows.

1. Plate pre-heater, (4,000 lbs. per hr.)
2. Separator-clarifier, (4,000 lbs. per hr.)
3. Milk storage tank, (500 gal.)
4. Pasteurizers, (2 at 150 gal. each)
5. Cheese vat, (100 gal.)
6. Homogenizer, (200 gal. per hr.)
7. Plate cooler, (5,000 lbs. per hr.)
8. Bottle filler, (30 to 40 sts. per min.)

Bottle washing room. The size of the bottle washing room was 50 ft. wide x 52 ft. long x 15 ft. high and it was considered to be adequate in size. The equipment indicated for the bottle washing room was as follows.

1. Soaker-type bottle washer, (32 to 40 sts. per min.)
2. Roller conveyor for cases from washer to filler.
3. Power conveyor for bottles from washer to filler.

Milk storage room. The milk storage room was sufficiently large and measured 15 ft. wide x 20 ft. long x 8 ft. high. Milk was handled in round bottles with a small amount handled in paper containers.

Dry storage room. There were two rooms for dry storage and the total area was considered to be too small. One room measured 20 ft. wide x 25 ft. long x 10 ft. high, while the other room was 16 ft. wide x 20 ft. long x 9 ft. high.

Boiler room. This room, which was large enough, was 15 ft. wide x 15 ft. long x 9 ft. high. It contained a 20 horsepower boiler which was assumed to be too small.

Compressor room. This room measured 12 ft. wide x 12 ft. long x 9 ft. high and was considered to be sufficiently large. The following compressors were used for both milk and ice cream handling.

1. One 10 hp. compressor
2. One 20 hp. compressor

Maintenance shop. The size of this room was 8 ft. wide x 8 ft. long x 9 ft. high and it was adequate in size.

Locker room. The locker room was large enough and measured 7 ft. wide x 7 ft. long x 8 ft. high.

Office space. This plant had an office 10 ft. wide x 12 ft. long x 8 ft. high which was considered to be sufficiently large.

Driver's check room. A check room considered to be adequate in size was available which measured 4 ft. wide x 4 ft. long x 8 ft. high.

Plant D

Plant D was a two-story plant, basement and ground floor, built in 1950 to handle 2,000 gallons of milk daily. At the time of this study

975 gallons of milk daily was being processed. In addition, this plant was processing approximately 50,000 gallons of ice cream per year.

The information listed below indicates the size of the various rooms found in the plant and the equipment required. No response was given indicating whether or not the rooms were large enough.

Receiving room. The receiving room was 16 ft. wide x 29 $\frac{1}{3}$ ft. long.

The following equipment was listed for this room.

1. Rotary can washer, (6 cpm.) too small
2. Weigh tank, (500 lb.)
3. Clarifier, (800 gal. per hr.)
4. Milk storage tank, (1,500 gal.)
5. Roller conveyors for receiving and returning cans

Processing room. This room was 20 $\frac{1}{2}$ ft. wide x 52 ft. long. The equipment required included.

1. Separator, (120 gal. per hr.) too small
2. Pasteurizers, (3 at 500 gal. and 1 at 100 gal.)
3. Homogenizer, (400 gal. per hr.)
4. Plate cooler, (500 gal. per hr.)
5. Bottle filler, (50 cts. per min.)

Byproducts room. This room was measured in two sections because of the shape. The dimensions were 11 $\frac{2}{3}$ ft. wide x 12 $\frac{1}{2}$ ft. long plus 11 $\frac{1}{2}$ ft. wide x 23 ft. long. The only equipment listed for this room was.

1. Batch freezer, (10 gal.)
2. Ice cream package filler, hand operated

Bottle washing room. The size of the bottle washing room was 19 ft. wide

x 32 ft. long. The equipment listed for this room was as follows.

1. Soaker-type washer, (6 wide)
2. Case washer

Milk storage room. The dimensions listed for this room were 12 $\frac{1}{3}$ ft. wide x 24 $\frac{1}{3}$ ft. long. Roller conveyors were used for loading delivery trucks.

Dry storage rooms. The dry storage room measured 12 $\frac{1}{6}$ ft. wide x 19 $\frac{1}{6}$ ft. long.

Office space. This plant had an office 13 $\frac{1}{2}$ ft. wide x 16 $\frac{1}{2}$ ft. long.

Driver's check room. The room available measured 9 ft. wide x 12 $\frac{1}{2}$ ft. long.

Basement. The basement was utilized for refrigeration, boiler room, maintenance shop, and truck storage. Some of the equipment listed was as follows.

1. One, 5 hp. compressor
2. Two, 10 hp. compressors
3. One, 15 hp. compressor
4. One, 20 hp. boiler

Plant E

Plant E was a one-story plant handling approximately 1,100 gallons of milk daily. All milk was handled in the square-type milk bottle.

Four men were employed to handle the processing, while one was required for the office and six were required to handle the milk routes.

The information listed below indicates the size of the rooms in the plant and the equipment available to handle the processing operations.

Receiving room. The receiving room was $11\frac{1}{2}$ ft. wide x 15 ft. long x $11\frac{2}{3}$ ft. high and was considered to be large enough. The equipment required included.

1. Rotary can washer, (3 cpm.)
2. Weigh tank, (500 lbs.)
3. Roller conveyor for receiving cans

Tank storage room. This room was $14\frac{1}{2}$ ft. wide x 15 ft. long x $11\frac{2}{3}$ ft. high and was adequate in size. The equipment used was as follows.

1. Milk storage tank, (1,500 gal.)
2. Pipe washing tank

Processing room. The processing room was smaller than required and was $14\frac{1}{2}$ ft. wide x $24\frac{1}{6}$ ft. long x $11\frac{2}{3}$ ft. high. The equipment required included.

1. Separator, (7,000 lbs. per hr.)
2. Pasteurizers, (1 each at 100, 200, & 300 gal.)
3. Homogenizer, (400 gal. per hr.)
4. Plate Cooler (6,000 lbs. per hr.)
5. Bottle filler, (48 qts. per min.)

Bottle washing room. The size of this room was given as being 15 ft. wide x $21\frac{1}{2}$ ft. long x 9 ft. high plus a section $11\frac{1}{2}$ ft. wide x 16 ft. long x 9 ft. high. This L-shaped room was considered to be sufficiently large to handle all incoming bottles. The following equipment was listed for this room.

1. Soaker-type bottle washer, (8 wide, 55 bpm)
2. Cases of bottles handled on dollies

Milk storage room. The milk storage room was too small and cases of milk could not be stored on dollies. This room measured 14 ft. wide x $15\frac{1}{4}$ ft. long x $8\frac{1}{2}$ ft. high.

Dry storage room. The dry storage room was too small and measured $11\frac{1}{4}$ ft. wide x $14\frac{1}{4}$ ft. long x $11\frac{2}{3}$ ft. high.

Office space. This plant had an office 11 ft. wide x 11 ft. long and it was considered to be sufficiently large.

Driver's check room. The room available measured $5\frac{2}{3}$ ft. wide x $9\frac{5}{6}$ ft. long x $7\frac{1}{2}$ ft. high and was not adequate in size.

Boiler room. A 30 horsepower gas-fired boiler was located in a room $11\frac{1}{3}$ ft. wide x 18 ft. long x $11\frac{2}{3}$ ft. high which was assumed to be large enough.

Compressor room. This room measured $6\frac{1}{2}$ ft. wide x $8\frac{5}{6}$ ft. long x $11\frac{2}{3}$ ft. high and was ample in size. One $7\frac{1}{2}$ horsepower compressor was available. In addition, a space $11\frac{1}{3}$ ft. wide x $16\frac{2}{3}$ ft. long x $11\frac{2}{3}$ ft. high was occupied by a 6,000 lb. capacity sweet water tank.

Plant F

Plant F, a one-story structure built in 1949 to handle approximately 2,325 gallons per day, was processing 1,165 gallons per day. This plant was still in the process of remodeling. Milk was handled in the square-type milk bottle. In addition, approximately 20,000 gallons of ice cream

were processed yearly and 500 pounds of cottage cheese were processed weekly.

Four men were required to handle the processing operations.

The following information lists the size of the various rooms and the equipment required for handling all processing operations.

Receiving room. The receiving room was 14 $\frac{1}{2}$ ft. wide x 18 $\frac{1}{2}$ ft. long x 9 ft. high and was considered to be large enough. The following equipment was listed for the receiving room.

1. Rotary can washer, (5 cans)
2. Wash tank
3. Balance tank, (200 gal.)
4. Roller conveyors for receiving and returning cans

Processing room. This room was measured in three sections because of the variable shape. The sections measured were 20 ft. wide x 30 ft. long x 12 $\frac{1}{3}$ ft. high, 7 ft. wide x 27 ft. long x 12 $\frac{1}{3}$ ft. high, and 6 ft. wide x 10 $\frac{5}{6}$ ft. long x 12 $\frac{1}{3}$ ft. high and were considered to be sufficiently large. The equipment required for processing is listed as follows.

1. Milk storage tank, (1,500 gal.)
2. Separator, (250 gal. per hr.)
3. H.T.S.T. pasteurizer, (5,000 lbs. per hr.)
4. Pasteurizer, (5 at 200 gal. each, 1 at 60 gal.)
5. Homogenizer, (2,700 lbs. per hr.)
6. Cheese vat, (100 gal.)
7. Bottle filler, (40 gts. per min.)
8. Wash tank with power brush
9. Dry storage cupboard

10. Power conveyor from washer to filler for bottles
11. Foller conveyor from washer to filler to storage for cases

Bottle washing room. The size of the bottle washing room was given in two sections because of the variable shape of the room. One section was 22 $\frac{2}{3}$ ft. wide x 23 $\frac{5}{6}$ ft. long x 12 $\frac{1}{3}$ ft. high and the other was 14 ft. wide x 30 ft. long x 12 $\frac{1}{3}$ ft. high. This room was considered to be adequate in size. The equipment indicated for the bottle washing room was as follows.

1. Beaker-type bottle washer, (8 wide, 60 bpm)
2. Bottle cases handled on **dollies**

Milk storage room. The milk storage room was 12 ft. wide x 16 ft. long x 6 $\frac{1}{2}$ ft. high and was much too small. Milk was handled in the square-type bottle.

Dry storage room. The dry storage room was also too small and was 16 ft. wide x 26 ft. long x 8 ft. high. It was necessary to have most of the paper supplies stored by the supplier and have them ordered as needed.

Other rooms. This plant was in the process of remodeling and had planned a new boiler room which would contain the compressor room and the maintenance shop. In addition, the new plans called for larger storage rooms, new locker rooms, offices, and retail store. The other equipment is listed below.

1. One 5 hp. compressor
2. One, 25 hp. coal-fired boiler, standby
3. One, 50 hp. oil-fired boiler

Plant G

Plant G, processing approximately 1,200 gallons per day of milk, was a two-story plant built in 1920. Now additions have been made since that time to accommodate an expanding business. In addition to handling milk, this plant processed approximately 125,000 gallons of ice cream yearly plus some cottage cheese. Six men were required to handle all processing operations.

The only information available from this plant was that for the receiving room. This room measured 20 ft. wide x 20 ft. long x 10 ft. high and was considered to be sufficiently large.

Plant H

Plant H, processing approximately 2,200 gallons of milk daily, was a one-story plant constructed in 1947 to handle 2,000 gallons of milk daily. Since that time, a change has been made in the pasteurization equipment and raw milk storage to accommodate the increase in production. Milk was bottled in square-type bottles with approximately 6,940 quarts, 200 pints, and 2,500 half-pints being bottled daily.

The products handled in addition to milk were buttermilk, chocolate milk, heavy cream, light cream, cereal mix, cottage cheese, and skim milk.

Three men were employed to handle processing, two were required for the office, and six were needed as route salesmen.

The information listed below states the size of the various rooms found in the plant and the equipment required.

Receiving room. The receiving room was 20 ft. wide x 20 ft. long x 12 ft. high and was considered to be large enough. The equipment required included.

1. Rotary can washer, (3 cans)
2. Weigh tank, (5 cans)
3. Roller conveyors for receiving and returning cans

Tank storage room. The dimensions for this room were 12 ft. wide x 16 ft. long x 10 ft. high. It was considered to be sufficiently large enough to provide space for one, 5,000 gallons storage tank. Provisions were being made to add another tank.

Processing room. An adequate sized room for processing was available which measured 25 ft. wide x 30 ft. long x 12 ft. high. The equipment required for processing included.

1. Clarifier, (800 gal. per hr.)
2. Separator, (air tight)
3. H.T.S.T. pasteurizer, (600 gal. per hr.)
4. Homogenizer, (600 gal. per hr.)
5. Bottle filler

Bottle washing room. The bottle washing room was 20 ft. wide x 40 ft. long x 12 ft. high and was assumed to be large enough. The following equipment was located in this room.

1. Soaker-type bottle washer, (8 wide)
2. Power conveyor from washer to filler for bottles
3. Roller conveyor from washer to filler for cases
4. All cases of bottles are handled on dollies from trucks to the washer

Milk storage room. The milk storage room had space for expansion and measured 20 ft. wide x 30 ft. long x 8 ft. high. Milk was handled in square bottles.

Compressor room. This room measured 20 ft. wide x 20 ft. long x 12 ft. high and was considered to be too small. The following compressors were located in this room.

1. One ammonia compressor, (4x4)
2. One ammonia compressor, (5x5)

Locker room. The size of the locker room was 8 ft. wide x 15 ft. long x 9 ft. high and it was too small.

The boiler room, dry storage room, and offices were located in a separate building constructed since the plant was originally built. A 25 horsepower gas-fired boiler was available as a steam generator.

Plant I

Plant I, a two-story plant constructed in 1949 to handle 750 gallons of milk per hour, was processing approximately 2,310 gallons of milk daily. The second floor of this plant was used for dry storage and offices. Milk was bottled in square-type bottles with approximately 9,820 quarts, 1,790 third-quarts, 265 pints, 3,100 half-pints, and 575 quarts in bulk being handled daily.

The products handled were grade A milk, homogenized milk, skim milk, buttermilk, light and heavy cream, and chocolate milk.

The employees consisted of six men for the office, thirteen route men, and seven men handling the processing operations.

Receiving room. The receiving room was 15 ft. wide x $38 \frac{2}{3}$ ft. long x $14 \frac{1}{2}$ ft. high and was considered to be large enough. The following equipment was listed for the receiving room.

1. Strainy-away can washer, (8 cpm)
2. Weigh tank, (750 lbs.)

Processing room. The dimensions for the processing room were $38 \frac{2}{3}$ ft. wide x $46 \frac{1}{3}$ ft. long x $14 \frac{1}{2}$ ft. high. This room was assumed to be sufficiently large. The equipment required for processing is listed as follows.

1. Pre-heater, (11,000 lbs. per hr.)
2. Clarifier, (6,500 lbs. per hr.)
3. Storage tanks, (2 at 3,000 gal. each)
4. H.T.S.T. Pasteurizer, (6,500 lbs. per hr.)
5. Pasteurizers, (2 at 200 gal. each)
6. Homogenizer, (4,200 lbs. per hr.)
7. Milk cooler, (25,000 lbs. per hr.)
8. Bottle filler and hooder, (120 qts. per min.)

Bottle washing room. The size of the bottle washing room was 25 ft. wide x $35 \frac{1}{2}$ ft. long x 10 ft. high and it was considered to be adequate in size. The equipment indicated for the bottle washing room was as follows.

1. Soaker-type bottle washer, (90 bpm)
2. Case washer, (120 cases per min.)

Milk storage room. The milk storage room was 19 ft. wide x $36 \frac{1}{2}$ ft. long x 8 ft. high. It was not indicated whether the room had adequate space.

Boiler room. A 125 horsepower oil-fired boiler was located in a room 14 ft. wide x $35\frac{1}{2}$ ft. long x $14\frac{1}{2}$ ft. high which was considered to be adequate in size.

Compressor room. This room measured 20 ft. wide x 40 ft. long x $14\frac{1}{2}$ ft. high and was adequate in size. The following compressors were located in this room.

1. Two 5x5 compressors
2. Two $6\frac{1}{2}$ x $6\frac{1}{2}$ compressors

Maintenance shop. The shop occupied a space 18 ft. wide x 34 ft. long x $14\frac{1}{2}$ ft. high and was sufficiently large.

Locker room. The locker room was of adequate size and measured $8\frac{1}{2}$ ft. wide x $17\frac{5}{6}$ ft. long x 12 ft. high and provided facilities for seven men.

Office space. This room measured 22 ft. wide x 34 ft. long x $8\frac{1}{2}$ ft. high and was considered to be large enough.

Driver's check room. Adequate space was available in a room 10 ft. wide x 19 ft. long x 8 ft. high.

Plant J

Plant J, a two-story plant constructed in 1950, was handling approximately 4,190 gallons of milk daily. The second floor was utilized for dry storage and locker rooms. In addition to milk, this plant was producing approximately 500 gallons of ice cream per day, 3,000 to 3,600 pounds of butter per week, and cottage cheese.

The information listed below gives the size of the rooms and the equipment required for handling the milk.

Receiving room. The receiving room was 15 ft. wide x 32 ft. long x 12 ft. high and was considered to be large enough. The equipment required included.

1. Straight-away can washer, (6 cpm)
2. Weigh tank, (500 lbs.)
3. Storage tank, (1,500 gal.)
4. Power conveyor for receiving and returning cans

Processing room. The dimensions for the processing room were 32 ft. wide x 44 ft. long x 12 ft. high and it was assumed to be sufficiently large. The equipment required for processing is as follows.

1. Preheater
2. Separator, (7,000 lbs. per hr.)
3. Pasteurizers, (3 at 300 gal. and 2 at 200 gal. each)
4. Cream vat, (200 gal., coil)
5. Balance tank, (100 gal. on hydraulic lift)
6. Plate cooler, (10,000 lbs. per hr.)
7. Homogenizer, (800 gal. per hr.)
8. Bottle filler, (18 qt. per min.)
9. Paper machine, (60 qt. per min.)

Byproducts room. The size of this room was 17 ft. wide x 36 ft. long x 12 ft. high and it was large enough. The equipment included:

1. Cheese vats, (2 at 300 gal. each)
2. Butter churn, (600 lbs.)

Bottle washing room. The bottle washing room measured 20 ft. wide x 35 ft. long x 12 ft. high and was considered to be adequate in size. The equipment indicated was as follows:

1. Bocker-type bottle washer, (8 wide)
2. Case washer

Milk storage room. The milk storage room handled approximately 3,500 gallons of milk daily, measured 16 ft. wide x 47 ft. long x 9 ft. high and was assumed to be large enough. Milk was handled in both glass bottles and paper containers.

Dry storage room. The dry storage room was large enough and measured 52 ft. wide x 100 ft. long x 12 ft. high. The area occupied by this room was equal to the total area of the processing plant.

Boiler room. A 125 horsepower oil-fired boiler was located in a room 20 ft. wide x 25 ft. long which was assumed to be adequate in size.

Plant K

Plant K, a two-story plant with a mezzanine, was originally built in 1918 and expanded by rearrangement in 1937 to handle approximately 2,900 gallons of milk per day. At the time of this investigation this plant was handling 4,000 gallons of milk per day.

Milk was handled in both the square-type bottle and paper containers.

The following information gives the size of the rooms for this plant and the equipment required to carry out the processing operations.

Receiving room. This room was triangular in shape and measured 32 ft. wide x 32 ft. long x 11 ft. high and was considered to be large enough. The list of equipment for the receiving room was as follows.

1. Straight-away can washer, (6 cpm)
2. Weigh tank
3. Power conveyor for receiving and returning cans

Tank storage room. This room measured 18 ft. wide x 24 ft. long x 13 ft. high and was considered to be adequate in size. The equipment required was as follows.

1. Storage tanks, (1 at 2,000 gal.; 2 at 1,000 gal. each)
2. Surface cooler, (4,000 lbs. per hr.)

Processing room. The processing room was 26 ft. wide x 36 ft. long x 16 ft. high and, in addition, contained a balcony measuring 16 ft. wide x 16 ft. long x 9 ft. high. The area available for processing was too small. The equipment used included:

1. Clarifier, (12,000 lbs. per hr.)
2. Separator, (5,000 lbs. per hr.)
3. Preheaters, (15,000 lbs. per hr.)
4. Pasteurizers, (6 at 200 gals. each; 1 at 100 gal.)
5. Balance tank, (400 gal.)
6. Homogenizer, (1,100 gal. per hr.)
7. Surface cooler, (9,000 lbs. per hr.)
8. Bottle filler, (2 $\frac{1}{2}$ qts. per min.)
9. Paper carton filler, (35 qts. per min.)
10. Cheese carton filler, hand operated

Bottle washing room. The bottle washing room did not have sufficient area and measured 24 ft. wide x 36 ft. long x 15 ft. high. The equipment included:

1. Tocker-type bottle washer, (12 wide, 100 per min.)
2. Case washer
3. Power conveyors for cases and bottles from washer to filler

Milk storage room. The milk storage room was 26 ft. wide x 36 ft. long x 9½ ft. high and did not have sufficient capacity.

Dry storage room. The dry storage room was located in the basement and was not large enough to handle a 30 day supply of material. This room measured 24 ft. wide x 38 ft. long x 8 ft. high plus an area 30 ft. wide x 34 ft. long x 8 ft. high.

Boiler room. The boiler room was adequate in size and measured 22 ft. wide x 32 ft. long.

Office space. The offices were located on a mezzanine measuring 26 ft. wide x 48 ft. long x 7 ft. high and were considered to be sufficiently large.

Locker room. The locker room was 12 ft. wide x 18 ft. long x 8 ft. high and was assumed to be too small.

Maintenance shop. This room measured 10 ft. wide x 27 ft. long x 8 ft. high and did not contain sufficient space.

Plant L

Plant L was a one-story plant handling approximately 6,400 gallons of milk daily in addition to processing between 100,000 and 150,000 gallons of ice cream per year and 1,800 pounds of cottage cheese per week. Milk was processed in both square-type bottles and paper containers with approximately 16,000 quarts and 8,900 half-pints handled in glass bottles daily, and 5,800 quart, 1,500 pint, and 1,800 10-ounce paper containers handled daily.

The products handled in the milk plant were premium milk, regular milk, homogenized milk, homogenized vitamin D milk, skim milk, chocolate milk, light and heavy cream, buttermilk, orange drink, and cottage cheese.

Twenty men were employed to handle processing, twelve were required for the office, and approximately forty-five were needed as route salesmen.

The information listed below states the size of the various rooms found in the plant and the equipment required.

Receiving room. The receiving room was $17\frac{1}{2}$ ft. wide x 30 ft. long x 15 ft. high and was considered to be too small. The equipment required included:

1. Straight-away can washer, (10 cpm)
2. Weigh tank, (500 lbs.)
3. Clarifier, (20,000 lbs. per hr.)
4. Power conveyors for receiving and returning cans

Processing room. The dimensions for the processing room were $26\frac{1}{2}$ ft. wide x $52\frac{1}{2}$ ft. long x $12\frac{1}{2}$ ft. high plus a balcony measuring $17\frac{1}{2}$ ft. wide x $17\frac{1}{2}$ ft. long x 8 ft. high. In addition, an area $16\frac{1}{2}$ ft. wide x $44\frac{1}{2}$ ft. long x $12\frac{1}{3}$ ft. high was available for the cottage cheese packing and bottle

filling operations. The total area was too small for a satisfactory operation.

The equipment required for processing is as follows:

1. Storage tanks, (1 at 3,000 gal. and 1 at 2,000 gal.)
2. Separator, (12,000 lbs. per hr.)
3. H.T.S.T. pasteurizer, (20,000 lbs. per hr.)
4. Pasteurizers, (1 at 1,000 gal.; 5 at 500 gal.; 4 at 200 gal. each)
5. Cabinet cooler, (15,000 lbs. per hr.)
6. Homogenizers, (1 at 20,000 lbs. per hr.; 1 at 600 gal. per hr.)

Byproducts room. This room, used for manufacturing cottage cheese, measured 18 ft. wide x 28 ft. long x 14 ft. high and was sufficiently large. The equipment located in this area consisted of two, 800-gallon cheese vats.

Bottle washing room. The size of the bottle washing room was 26 $\frac{1}{3}$ ft. wide x 54 $\frac{2}{3}$ ft. long x 12 $\frac{2}{3}$ ft. high and it was considered to be large enough for the present operation. The equipment listed was as follows:

1. Soaker-type bottle washer, (12 wide, 114 bpm)
2. Case washer
3. Power conveyor for receiving cases from trucks

Milk storage room. The milk storage room was too small to satisfactorily handle all products. This room, divided into two areas due to the variable shape, measured 17 $\frac{1}{2}$ ft. wide x 43 $\frac{1}{2}$ ft. long x 7 $\frac{5}{6}$ ft. high plus 5 ft. wide x 14 ft. long x 7 $\frac{5}{6}$ ft. high. A cold diffuser located in this room occupied approximately 24 square feet. A power conveyor was used to handle milk cases into and from this room.

Dry storage room. The area allotted to dry storage was considered to be too small. For milk processing, the following areas were available for dry storage: (a) $29\frac{1}{2}$ ft. wide x $69\frac{2}{3}$ ft. long x $12\frac{2}{3}$ ft. high, (b) $45\frac{1}{6}$ ft. wide x $80\frac{1}{2}$ ft. long x 12 ft. high, and (c) 14 ft. wide x 17 ft. long x 16 ft. high.

Boiler room. A 120 horsepower gas-fired boiler and a 150 horsepower coal-fired standby boiler were located in a room $26\frac{1}{2}$ ft. wide x $38\frac{3}{4}$ ft. long, which was adequate in size.

Compressor room. The compressor room was 17 ft. wide x $21\frac{1}{2}$ ft. long x 16 ft. high and was sufficiently large. The following compressors, for both the milk and ice cream operations, were located in this room.

1. Three 50 hp. compressors
2. One 20 hp. compressor

Maintenance shop. The room for maintenance work was of adequate size and measured $15\frac{1}{2}$ ft. wide x 60 ft. long x $12\frac{2}{3}$ ft. high.

Locker room. The area allowed for lockers was $15\frac{1}{6}$ ft. wide x 18 ft. long x 15 ft. high, and that allotted to showers and a lavatory measured 11 ft. wide x $15\frac{1}{6}$ ft. long x 15 ft. high. This room was considered to be too small to provide adequate facilities for 24 men.

Plant M

Plant M, processing approximately 7,050 gallons of milk daily, was a two-story plant originally constructed in 1928 to handle 4,000 gallons of milk daily. Since that time, additions, new buildings, and rearrangements have been made to handle the increased production. Milk was handled in

both square-type glass bottles and paper containers with approximately 14,100 quarts, 820 10-ounce bottles, and 4,300 half-pints handled in glass and 5,200 quarts, 460 pints, and 2,000 10-ounce handled in paper containers. In addition, approximately 350 pounds of cottage cheese were processed daily.

Twenty-five men were employed to handle processing, seven were required for the office, and fifty-one were needed as route salesmen.

The following information gives the size of the rooms for this plant and the equipment required to carry out the processing operations.

Receiving room. The size of this room was stated as being 20 ft. wide x 40 ft. wide x 8 ft. high and was considered to be large enough. The list of equipment for the receiving room was as follows:

1. Straight-away can washer, (8 cpm)
2. Weigh tank
3. Power conveyors for handling cans

Tank storage room. This room measured 20 ft. wide x 36 ft. long x 8 ft. high and contained sufficient floor space. Four storage tanks were located here with a total capacity of 7,000 gallons.

Pasteurizing room. The pasteurizing room was sufficiently large and measured 15 ft. wide x 36 ft. long x 12 ft. high. The equipment required for processing was indicated as follows:

1. Clarifier, (12,000 lbs. per hr.)
2. H.T.S.T. Pasteurizer (8,000 lbs. per hr.)
3. Homogenizer, (800 gal. per hr.)

4. Plate cooler

5. Balance tank

Bottle filling room. This room did not have adequate space and measured 20 ft. wide x 25 ft. long x 16 ft. high. The equipment located here was as follows:

1. Paper carton machine
2. Bottle filler, (97 cts. per min.)
3. Power conveyors from fillers to cooler

Byproducts room. The byproducts room was 20 ft. wide x 60 ft. long x 12 ft. high and was too small for efficient production. The equipment used included:

1. Cheese vats, (3 at 400 gal. each)
2. Separator, (7,000 lbs. per hr.)

Bottle washing room. Sufficient space was available for bottle washing in a room 30 ft. wide x 36 ft. long x 8 ft. high. The following equipment was located in this room:

1. Soaker-type bottle washer, (34 to 98 bpr)
2. Case washer

Milk storage room. Adequate floor area was not provided in a space 30 ft. wide x 45 ft. long x 8 ft. high to effectively handle all products.

Dry storage room. The rooms available for dry storage measured 40 ft. wide x 45 ft. long x 10 ft. high and 20 ft. wide x 60 ft. long x 10 ft. high and provided a sufficient amount of space.

Boiler room. A 120 horsepower oil-fired boiler was located in an adequate size room measuring 30 ft. wide x 35 ft. long x 12 ft. high.

Compressor room. The compressor room was 25 ft. wide x 30 ft. long x 12 ft. high, was sufficiently large, and contained one compressor.

Maintenance shop. Sufficient space was provided in a room 30 ft. wide x 35 ft. long x 12 ft. high.

Locker room. This room measured 8 ft. wide x 12 ft. long x 8 ft. high and was considered large enough to provide facilities for twenty-five men.

Office space. A room 30 ft. wide x 40 ft. long x 8 ft. high provided ample office quarters.

Driver's check room. The main office was also utilized as a driver check room and sufficient space was not available for this.

APPENDIX III

QUESTIONNAIRE FOR THE STUDY OF DAIRY PLANTS

1. Name of plant_____
2. Location of plant_____
3. Plant manager_____
4. Give location in relation to the nearest city or town.
5. What is the average daily production of your plant?
 - A. Milk - gals. per day_____, or lbs. per day_____
 - B. Ice Cream - gal. per year_____
 - C. Other (Cheese, butter, etc.)_____
6. What is the present maximum daily capacity of your plant?
 - A. Milk - gals. per day_____, or lbs. per day_____
 - B. Ice cream - gals. per year_____
 - C. Other (cheese, butter, etc.)_____
7. What was the maximum output on any one day in 1950?
 - A. Milk - gals. per day_____, or lbs. per day_____
 - B. Ice cream - gals. per year_____
 - C. Other_____
8. For what capacity was the plant originally built?_____
Date built_____. Did it handle the amount designed for?_____
9. Has the plant ever expanded?_____. How was it expanded? (Addition, new building, rearrangement, etc.)
10. Was the above method of expansion satisfactory?_____. Please explain.
11. Do you believe that a plant should be built large enough originally, to accomodate an increase in production, or should it be built just large enough to handle the known capacity with provisions to permit additions as needed?

12. Is the present plant site large enough to allow for a building expansion?
_____. Draw a simple sketch of the plant and plant site showing its limitations.
13. Do you believe that the plant site should be large enough to permit ready expansion on a one floor level?_____. Please explain.
14. Are the rooms arranged to obtain efficient use of labor and efficient operating conditions?_____. Please explain.
15. Can the plant operation, as a whole, be easily supervised?_____. If not, why not?
16. What type of delivery schedule do you maintain (every other day, three day week, etc.)?_____. How many days per week is the plant in operation?
17. Is the storage tank capacity large enough for normal operating conditions?_____. Does the storage tank capacity provide enough flexibility to take care of emergencies, such as, a decline in sales or a breakdown? Do you think that the tank capacity should provide for such emergencies?
18. How much space, in general, is left between pieces of processing equipment?_____. Is this sufficient for proper maintenance and cleaning?_____
19. At what distance from the walls is processing equipment?_____ Is this satisfactory?_____
20. What methods are used for the mechanical cleaning of sanitary pipe lines? Are they satisfactory?_____
21. What methods are used for holding milk lines in place?
22. Where are the water, steam, and refrigeration lines located? (In walls, tunnels, suspended from the ceiling, etc.) Is this method satisfactory?_____. How would you change?

23. Size of rooms

Type of room	Length	Width	Height	Amt. prod. handled or stored	Large enough? Yes or No
Receiving					
Tank storage					
Pasteurizing					
Byproducts					
Filling					
Milk storage (cooler)					
Bottle washing					
Mix room					
Freezer room					
Hardening room					
Dry storage					
Boiler room					
Compressor room					
Laboratory					
Shop					
Locker rooms					
Office space					
Retail store					
Driver's check-in					
Garage					
Loading docks					
Unloading docks					
Other					

24. List major items of equipment

Item	Size or capacity	Type	Large enough? Yes or No
Can washers			
Weigh tanks			
Pre-heaters			
Clarifiers			
Storage tanks			
Separators			
Pasteurizers			
Cheese vats			
Homogenizers			
Coolers			
Fillers			
Bottle washers			
Case washers			
Freezers			
Flavor vats			
Fruit feeders			
Ice cream pkg. fillers			
Specialty tanks			
Compressors			
Boilers			
Other			

25. Are conveyors used?_____. Do you feel that they are efficient and economical?_____. Where are they used? (State whether powered or roller).
26. Give the location of floor drains in processing rooms.
27. How many floors does the plant have?_____. Is this layout satisfactory? Explain. What is each floor used for?
28. What type of ventilation is employed? Is this satisfactory? Explain.
29. What type of lighting is used in processing rooms? Is this satisfactory?
30. What type of window construction is used in processing rooms?
- A. Glass block_____
 - B. Steel sash and frame_____
 - C. Wood sash and frame_____
 - D. Aluminum_____
31. What materials are used for floor construction?
- A. Processing rooms_____
 - B. Milk storage_____
 - C. Bottle washing rooms_____
 - D. Freezing rooms_____
32. What materials are used for wall construction?
- A. Exterior walls_____
 - B. Interior walls_____
33. Draw a simple sketch indicating the flow pattern for products and packages (label the various stations).
34. Do you have a retail store?_____. Is it desirable?_____. Explain
35. If you were to build now, in order to obtain maximum operating efficiency, what suggestions do you have relative to the following items?

A. Building materials

Floors_____

Exterior walls_____

Interior walls_____

Window construction_____

B. Placement of drains in processing rooms.

C. Type of electric lighting.

D. Use of conveyors.

E. Refrigeration system and layout.

F. Number of floors for the plant.

G. Ventilation.

H. Arrangement of rooms in relation to each other.

I. Other suggestions.

36. What questions would you like to have answered?

37. If it is possible, would you provide us with detailed floor plans of your plant layout? If this is not possible, would you provide us with a simple sketch of the layout; label individual rooms and give the dimensions. Any plans will be returned to you after a reasonable period of time.

38. Number of men handling processing?_____

39. Number of hours worked per day?_____

40. If you feel that it is not too confidential, could you state the cost of processing alone per 100 lbs. of milk?_____. Per 100 gals. of ice cream?_____

DAIRY PLANT STUDY
SUPPLEMENTARY QUESTIONNAIRE

Please indicate the average daily amounts for the following items.

1. Milk received daily, _____ gals. or _____ lbs.
2. Total products pasteurized daily, _____ gals. or _____ lbs.
3. Total products held in storage tanks daily, _____ gals. or _____ lbs.
4. Total products handled in milk storage (cooler) daily, _____ gals.

a. Please indicate the total number of units handled in the milk storage daily for the following.

1. Paper containers

2. Glass bottles

quarts _____

quarts _____

pints _____

pints _____

half-pints _____

half-pints _____

5. Total products bottled daily.

a. Paper containers _____ gals.

b. Glass bottles _____ gals.

1. Please indicate the total number of units bottled daily.

a. Paper containers

b. Glass bottles

quarts _____

quarts _____

pints _____

pints _____

half-pints _____

half-pints _____

6. Total number of bottles washed daily, _____ units. Round _____ Square _____

7. Please list the various products that you process. _____

8. Number of men handling processing _____

9. Approximate number of office personnel _____

10. Number of route men utilizing the driver check-in room _____

11. Name of plant _____

12. Address _____

13. Plant manager _____

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• The first step in the process of creating a new product is to identify a market need. This involves conducting market research to determine what consumers want and need. Once a need is identified, the next step is to develop a concept for a product that meets that need.

• The second step is to develop a business plan. This involves determining the costs of production, the pricing strategy, and the marketing strategy. The business plan also includes a financial forecast and a break-even analysis.

• The third step is to create a prototype. This involves building a small-scale version of the product to test its design and functionality. The prototype is used to gather feedback from potential customers and to make any necessary adjustments.

• The fourth step is to conduct a pilot run. This involves producing a small batch of the product to test the production process and to gather feedback from customers. The pilot run is used to identify any problems and to make any necessary adjustments.

• The fifth step is to launch the product. This involves marketing the product to potential customers and making it available for purchase. The launch is the final step in the process of creating a new product.

• The sixth step is to monitor the product's performance. This involves tracking sales, customer feedback, and other metrics to determine how well the product is performing in the market. This information is used to make any necessary adjustments to the product or the marketing strategy.

• The seventh step is to evaluate the product's success. This involves comparing the product's performance to the goals set in the business plan. This evaluation is used to determine if the product is a success and if it should be continued or discontinued.

• The eighth step is to plan for the future. This involves identifying opportunities for growth and expansion, and developing a strategy to pursue those opportunities. This planning is essential for the long-term success of the product.

• The ninth step is to implement the future plan. This involves putting the strategy into action and making any necessary adjustments. This implementation is essential for the long-term success of the product.

• The tenth step is to review the product's performance. This involves reviewing the product's performance over time and making any necessary adjustments. This review is essential for the long-term success of the product.

• The eleventh step is to continue to improve the product. This involves making any necessary adjustments to the product or the marketing strategy to keep the product competitive in the market. This improvement is essential for the long-term success of the product.

• The twelfth step is to celebrate the product's success. This involves acknowledging the hard work and dedication that went into creating the product and celebrating the success. This celebration is essential for the long-term success of the product.

• The thirteenth step is to plan for the future. This involves identifying opportunities for growth and expansion, and developing a strategy to pursue those opportunities. This planning is essential for the long-term success of the product.

• The fourteenth step is to implement the future plan. This involves putting the strategy into action and making any necessary adjustments. This implementation is essential for the long-term success of the product.

• The fifteenth step is to review the product's performance. This involves reviewing the product's performance over time and making any necessary adjustments. This review is essential for the long-term success of the product.

• The sixteenth step is to continue to improve the product. This involves making any necessary adjustments to the product or the marketing strategy to keep the product competitive in the market. This improvement is essential for the long-term success of the product.

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• 1. The first step in the process of creating a new product is to identify a market need. This involves conducting market research to determine what consumers want and need. Once a need is identified, the next step is to develop a concept for a product that meets that need. This is often done through brainstorming and sketching ideas. The third step is to create a prototype of the product. This can be done using various materials and techniques, depending on the nature of the product. The fourth step is to test the prototype with a small group of consumers to gather feedback. This feedback is used to make improvements to the product. The fifth step is to create a business plan for the product, which includes details about the manufacturing process, distribution, and marketing. The final step is to launch the product into the market and monitor its performance. This process is iterative, meaning that it can be repeated as needed to improve the product over time.

• 2. The second step in the process of creating a new product is to develop a concept for the product. This involves brainstorming ideas and sketching out a rough design. The third step is to create a prototype of the product. This can be done using various materials and techniques, depending on the nature of the product. The fourth step is to test the prototype with a small group of consumers to gather feedback. This feedback is used to make improvements to the product. The fifth step is to create a business plan for the product, which includes details about the manufacturing process, distribution, and marketing. The final step is to launch the product into the market and monitor its performance. This process is iterative, meaning that it can be repeated as needed to improve the product over time.

• 3. The third step in the process of creating a new product is to create a prototype of the product. This can be done using various materials and techniques, depending on the nature of the product. The fourth step is to test the prototype with a small group of consumers to gather feedback. This feedback is used to make improvements to the product. The fifth step is to create a business plan for the product, which includes details about the manufacturing process, distribution, and marketing. The final step is to launch the product into the market and monitor its performance. This process is iterative, meaning that it can be repeated as needed to improve the product over time.

• 4. The fourth step in the process of creating a new product is to test the prototype with a small group of consumers to gather feedback. This feedback is used to make improvements to the product. The fifth step is to create a business plan for the product, which includes details about the manufacturing process, distribution, and marketing. The final step is to launch the product into the market and monitor its performance. This process is iterative, meaning that it can be repeated as needed to improve the product over time.

• 5. The fifth step in the process of creating a new product is to create a business plan for the product. This includes details about the manufacturing process, distribution, and marketing. The final step is to launch the product into the market and monitor its performance. This process is iterative, meaning that it can be repeated as needed to improve the product over time.

• 6. The final step in the process of creating a new product is to launch the product into the market and monitor its performance. This process is iterative, meaning that it can be repeated as needed to improve the product over time.

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• The first step in the process of creating a new product is to identify a market need. This involves conducting market research to determine what consumers want and what problems they are trying to solve. Once a need is identified, the next step is to develop a concept for a product that addresses that need. This often involves brainstorming and sketching out ideas for the product's design and features.

• After a concept has been developed, the next step is to create a prototype. This is a physical model of the product that allows designers to test and refine their ideas. Prototyping can be done in a variety of ways, from simple hand-drawn sketches to more complex 3D printed models. The goal of prototyping is to identify any potential issues or improvements before moving forward with full-scale production.

• Once a prototype has been created, the next step is to conduct a feasibility study. This involves assessing the technical, financial, and market viability of the product. Technical feasibility involves determining whether the product can be manufactured using current technology. Financial feasibility involves estimating the costs of production and determining whether the product can be sold at a price that allows for a profit. Market feasibility involves determining whether there is a sufficient market for the product.

• If the feasibility study is positive, the next step is to develop a business plan. This document outlines the company's goals, strategies, and financial projections. It also serves as a tool for securing funding from investors or lenders. The business plan should include information about the company's management team, its competitive advantage, and its marketing strategy.

• Once a business plan has been developed, the next step is to secure funding. This can be done in a variety of ways, from seeking venture capital investment to crowdfunding. The goal is to raise enough money to cover the costs of production and marketing. Once funding has been secured, the next step is to begin full-scale production of the product.

• The final step in the process is to launch the product and begin marketing it. This involves creating a marketing plan that outlines the company's strategies for reaching its target audience. Marketing can be done in a variety of ways, from traditional advertising to social media marketing. The goal is to create awareness of the product and generate sales.

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