TIME STUDY OF ICE CREAM PLANTS BY WORK SAMPLING TECHNIQUE

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY
Richard A. Keppeler

1957

This is to certify that the

thesis entitled

THE STUDY OF ICE CREAM PLANTS BY

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presented by

Richard A. Keppeler

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Carl W. Hall
Major professor

Date Feb. 25, 1957

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By

Richard A. Keppeler

AN ABSTRACT

Submitted to the College of Agriculture of Michigan
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ABSTRACT

The study was conducted to establish production standards of six ice cream manufacturing plants. Six different size categories were studied. The sizes were 0-20,000 gallons per year; 20,001 to 50,000; 50,001 to 100,000; 100,001 to 250,000; 250,001 to 700,000; and 700,001 gallons per year and up, and were designated as Plants I through VI, respectively.

The form of time study known as work sampling was used as the data gathering technique. Work sampling can be used for analyzing either repetitive or non-repetitive work of humans or machines, either singly or in groups.

The results include basic times for elements of pint, quart, half-gallon, gallon and bulk filling operations, elapsed time ratios, machine utilization factors, gallons per man hour for each plant. A check list is included in the thesis.

ACKNOWLEDGEMENTS

It gives me great pleasure to thank Dr. Carl W. Hall for his excellent and subtle guidance on this project. Without his encouragement I am certain it would never have taken form. Also, I thank Professor Philip Thorson, at whose suggestion and with whose guidance the work sampling technique was used. To Dr. Joseph Meiser goes my thanks for his advice and suggestions.

To Dr. Arthur W. Farrall goes my deep gratitude for encouragement and making financial assistance available to finish this project. Also, I am deeply indebted to the supervisors and workers of the various companies surveyed for the openhanded generosity with which they answered questions and gave information.

Thanks also go to Mr. F. M. Skiver of the Bureau of Dairying, Michigan Department of Agriculture, for his help in setting up the size categories and recommending of companies for study.

Last but not least, a great debt of gratitude which can be experienced, but much less easily expressed, goes to my wife, Betty. Her spiritual strength and physical support have contributed immeasurably to the accomplishment of this task.

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INTRODUCTION

"For production men, cost control is of paramount importance," so spoke J. Hoffman Erb in October, 1955, at St. Louis, Missouri, to the International Association of Ice Cream Manufacturers.[1] To achieve cost control the production man needs to have information about his own operation and no harm will be done if he has figures from other operations for comparison.

In the United States, in 1954, 8,424 factories produced 596,999,000 gallons of ice cream and 34,048,000 gallons of sherbet worth approximately $1,009,000,000.[10] In the same year, Michigan manufactured 29,162,000 gallons or 4.89 percent of the national total of ice cream worth approximately $46,659,000 in 448 factories, 5.32 percent of the national total. Nationally, 6,038 factories, or 71.68 percent of the total, are of eighty quarts or less capacity. In Michigan, 327 factories, 72.99 percent of the Michigan total, are of eighty quarts or less capacity. These totals do not include soft-serve parlors. In 1953, the ice cream industry employed 39,649 people with an aggregate payroll of $143,746,000.[11] Of these, 21,028 were production workers with salaries and wages of $67,216,000 for 44,647,000 man hours.

An increase of 10 percent in the average gallonage per man hour would represent a saving of approximately $650,000 per year in the United States. Because of steadily increasing labor costs, the need is imperative for the fullest utilization of labor's time by carefully planned work schedules, alternative work in event of breakdowns, short shutdowns for flavor changeovers and as prolonged flavor runs as is economically possible.

A questioning attitude is needed in viewing each person and element of each operation. Is this necessary? Is this the person to do it? Is this the time to do it? Is there a better, simpler way to do it? Will a machine do it more cheaply? These questions, and others like them, will certainly bring changes for the better unless the questioner has a perfect operation with 100 percent efficiency and zero cost.

This questioning attitude, plus the method of motion and time analysis used in the data collection for this thesis, will give an excellent basis for work simplification, methods improvement, cost reduction, invaluable information on a company's operations and improved engineering design of equipment.

There is always a better way!
Look for it!
Find it!
Use it! [9]

OBJECTIVES

The objectives of this study were:

1. To improve the efficiency of ice cream manufacturing
    a. establish freezer elapsed time ratios,
    b. establish machine use factors,
    c. establish gallons per man hour,
    d. set basic times,
    e. compare sizes of plants.
2. To provide data for plant layouts.

REVIEW OF LITERATURE

Undoubtedly efficiencies of equipment and standard times of production of ice cream packages have been taken and calculated, but they are the property of private individuals and companies, and, as such, have not been published. It was the object of this thesis to gather and report information to the industry.

Scientific management with time and motion study came into being with Frederick J. Taylor at Midvale Steel Company, Philadelphia, in 1881. Blessed with a facile, inquiring mind, Taylor proposed a "task" system, whereby each man would be given a task with written instructions for its performance carefully planned by the management. He also proposed to set a standard time of performance for each task by breaking the job into "elements" or divisions which could be timed and a total time attained by summing the elemental times.

Prior to Taylor's time, standards had been set by foremen by guess. As a consequence, they were not trusted by labor, or respected by management. But, with Taylor's beginnings, there has developed today's science of time and motion study.

The movement received a bad setback in the early Twentieth Century because of so-called "efficiency experts."

They were usually men with little or no knowledge of time study or of human relations and their standards were usually unrealistic and too difficult to attain, or if the standards were attainable or surpassable, unscrupulous managements would change the rates when the workers began to make what the management thought was too much money.

The situation became so bad that Congress, in 1913, forbade the use of any Federal money for time study. This law was not rescinded until 1949.[2] Time study is still looked upon with real or avowed suspicion by the unions in general, although many union-management contracts are written agreeing on procedures for time and motion study.

There are, in general, two methods of setting time standards.[2] One is the stopwatch method wherein a job or task is surveyed for minor method improvements, and those changes are made. The task is broken up into elements and the job cycles are timed with a time reading taken at the end of each element. Repetitions are made until a mean time is arrived at which is not significantly different from the expected value. These elemental times are summed and, with allowances added, are the standard times. This is a fairly long, tedious and fatiguing job for the time study man, and one which is complicated by the worker being studied. It is probably only too human to speed up to show off, or to slow down to try to get the standard as high as possible.

The other method is called variously: work sampling, ratio delay, or occurrence study, depending upon the particular use to which the method is put. It was first used by L. H. C. Tippet in the English textile industry in 1935 to study the efficiency of loom usage.

Nadler[5] says that work sampling is the general procedure and ratio delay and occurrence study are variations, depending on usage. Ratio delay is defined as the procedure for determining the amount of down time per day of a machine and, basically, is used for determining allowances in time study. Occurrence study is used for analysis of repetitive or non-repetitive work of humans, rather than machines.

The information[5] needed to calculate a basic time is:

1. the ratio of times that an element of a job occurs in relation to the total number of observations recorded on that job,
2. the total elapsed time of the study of that job,
3. the total units produced during that elapsed time, and
4. the performance rating of the operators on that job as rated by the observer.

This information is combined in the following formula:

$$\text{Basic time} = \frac{\text{ratio x total elapsed time x the performance rating}}{\text{total units produced}}$$

Performance rating[2] is the rating of the operators speed of performance by letting a normal performance equal one hundred and speeds more or less than normal be designated by ratings above or below one hundred. Normal performance could be compared to dealing fifty-two cards in 0.45 minutes, or walking one hundred feet in 0.35 minutes.

According to Morrow[4], two advantages of the work sampling method are: one, no objection by workers being studied to the study, because of the absence of a stopwatch, and, two, the cost of a study is cut to about one-third of that by a regular production study. At the Eagle Pencil Company, the time study department estimated that a certain study by their usual methods would take 67 hours, while an actual study by the work sampling method took eleven hours.

At J. E. Ogden Company, Bayonne, New Jersey, three jobs were surveyed by the conventional method using 22.5 hours. The ratio delay method took 7.7 hours. A third case[4], at a company not named, ten men on a materials handling job were studied with a resultant cost saving of fifty percent.

Niebel[2] says that the most extensive use of work sampling so far has been in establishing time allowances in production studies, determining machine utilization, allocation of work assignments and methods improvement.

George Knight, Chief Industrial Engineer of the Radio Tube Division of Sylvania Electric Products Corporation, said,

> We had started stop-watch studies and were obtaining reliable data but at the sacrifice of time and coverage. Through the work sampling techniques, standards were established in a small fraction of the time that

> would have been required if stop-watch studies were taken throughout, and the resulting standards have served their purpose as a management and operational control and proved valuable in highlighting areas requiring methods improvement.[2]

William Gomberg[6] said, "Application of ratio delay technique is the earliest of sound statistical thinking to time study problems."

PROCEDURE

For the purposes of study the manufacturers of Michigan were divided into six groups according to size. After consultation with Mr. F. M. Skiver of Bureau of Dairying, Michigan Department of Agriculture, it was decided to split the manufacturers as follows:

Gallons per Year	Manufacturers in Category (percent)
0- 20,000	33.9
20,001- 50,000	31.9
50,001-100,000	12.3
100,001-250,000	11.9
250,001-700,000	7.3
700,001-and up	2.7

Having decided the range of categories, Mr. Skiver supplied us with a list of manufacturers in each category. From this list a company was selected in each category and Dr. Joseph Meiser made the primary contacts to gain assent for investigation. After the contacted companies had given their consent, a time table was set up, so that the work could be accomplished during the summer months.

Bulk operations were studied with 5-, $3\frac{1}{2}$-, 3-, and $2\frac{1}{2}$-gallon cans being observed and, in consumer packages, round and square pint, quart, half-gallon and gallon operations were examined.

Each can and package filling operation was broken down into elements and, as nearly as possible, these elements were adhered to in all operations studied. To start observations, a position was selected which would afford the observer the most complete and uninterrupted view of all persons on the operation. This position was used each time the operation was observed. Then, with an observation record sheet as shown in the example, a random time sheet as shown, and a watch with a sweep hand, showing hundredths of a minute, the observations were taken of each person on the operation at the random times shown on the random time sheet as they occurred on the watch. When it was explained to the people on the operations that the watch was just to mark the time of the observation and not to measure time, there was no protest or nervousness shown by the operators, even in unionized plants. Between observations the observer's eyes were kept on the watch and, only when the time of observation was reached did the observer look at the operation. Then his eyes swept over the operation in the same direction each time, so as to observe each operator in same sequence each time. Note was made of the element that each operator was performing and a mark was placed under that element heading on the observation record sheet. This procedure was followed for all operations as nearly as was possible.

FILLING ROUND PINTS - PLANT VI

Cartons in Dispenser	Filling	Close and Put In Bag-ging Shoe	Bag and Tape	Stamp Bags	On Conveyor	Weigh	Freezer Control	Fruit Feeder	Miscel-laneous	Get Stock
卌 卌 |||	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 |	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 |	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 ||||	||	卌 |	|||	卌 卌 |||	卌 |	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 |||	||

Fig. 1. Observation record sheet.

RANDOM TIME SHEET

Minute	Random Times First Half Hour Hundredths of Minute			Random Times Second Half Hour Hundredths of Minute		
1	1	41	64	9	34	74
2	7	49	68	1	52	89
3	31	71	93	17	57	85
4	31	66	94	14	55	86
5	8	39	77	32	60	91
6	3	43	83	3	64	88
7	25	65	94	12	49	68
8	11	40	72	21	68	85
9	15	39	65	30	47	69
10	3	61	93	1	41	71
11	4	50	71	2	48	95
12	6	49	67	11	44	77
13	3	31	81	17	46	97
14	4	52	85	29	45	81
15	5	41	65	21	34	64
16	5	28	64	4	44	59
17	9	39	61	22	59	87
18	14	57	92	4	64	92
19	1	43	95	28	65	94
20	8	55	96	23	59	95
21	16	47	97	25	46	80
22	26	54	93	27	52	78
23	25	41	90	31	57	84
24	3	62	96	18	44	70
25	27	51	78	7	40	74
26	20	47	54	15	35	55
27	16	36	69	3	34	74
28	22	42	82	12	49	84
29	11	51	70	23	43	72
30	8	48	76	23	56	82

Fig. 2. Sample of random time sheet used on all operations.

At the completion of the first day's run of a package, a statistical computation was made to determine how many observations of each element were necessary to make the ratio of observations of that element to the total observations of that operation significant. The equation $\sigma_p = \sqrt{\frac{p(1-p)}{N}}$ [2]

where: p = percent occurrence of element in first run

σ_p = standard deviation of p

N = number of total observations to be made of the element.

Since approximately 95 percent of all observations of a normal distribution will fall within plus or minus $2\sigma_p$, then the equation becomes $2\sigma_p = 2\sqrt{\frac{p(1-p)}{N}}$. The use of this equation to calculate N forces this into a normal distribution. In these studies, an accuracy of plus or minus 3 percent was used, which was substituted in place of $2\sigma_p$ on the left side of the equation and N was computed. Studies of each package was continued until the requisite number of observations were obtained as computed. During the observation period, periodic performance ratings were made of the operator as described in the report of literature. The ratings were averaged at the end of the study and the average was used in calculations of the basic time.

Accurate record was kept of the time that the operation ran and the number of gallons produced during this time. These were used in the basic time computation, which was used as follows:

$$\text{Basic time of element} = \frac{\text{percent of total time the element occurs} \times \text{total time the operation ran} \times \text{performance rating}}{\text{gallons produced during the total time}}$$

Example: if an element occurred 20 percent of total time of 25 hours with a performance rating of 90 and 5,000 gallons produced, then

$$\text{Basic time} = \frac{.20 \times 25 \times 60 \times .90}{5{,}000} = .054 \text{ minutes per gallon.}$$

Standard time for an element is the basic time plus an allowance for all rest and down times during the day, such as fatigue rest periods, personal time, warm-up time for hardening room men, washing up of equipment and personnel wash-up time. For example, if two fifteen-minute rest periods were allowed per eight hour day (480 minutes), the allowance would be $\frac{30}{480 - 30}$ or .067. To compute: standard time per element = basic time (1 plus allowance). To continue the example: standard time = .054 (1 plus .067) = .058 minutes per gallon.

To calculate the elapsed time ratio (ETR) of a continuous freezer or battery of continuous freezers:

$$\text{ETR} = \frac{\text{number of gallons produced in a day}}{\text{elapsed hours from startup to shutdown} \times \text{gallons per hour capacity}}$$

For example: a battery of two freezers started at 8:00 AM and finished at 4:00 PM with one-half hour lunch time, and it produced 2,516 gallons at a rated capacity of 200 gallons per hour per freezer.

$$\text{ETR} = \frac{2516}{7.5 \times 2 \times 200} = .839$$

Calculations of machine use factor for continuous freezers is very nearly like elapsed time ratio, but with differences in the hours used in the division. For machine use factor (MUF) the hours used are those of the length of the production crew's day. For example: a battery of two 200-gallon per hour freezers produced 2,516 gallons in a day and the production crew worked eight hours per day.

$$MSU = \frac{2516}{8 \times 2 \times 200} = .786$$

Gallons per man hour would be calculated by

$$\frac{\text{gallons produced}}{\text{hours worked x number of people in the production crew}}$$

For example: three men working eight hours produced 2,516 gallons.

$$\text{Gallons per man hour} = \frac{2516}{3 \times 8} = 105$$

Calculation of elapsed time ratio and machine use factor of batch freezers was different than those calculations for continuous freezers. Since the batch freezers do not have a rated capacity per hour, another method of comparison was used.

Dr. Joseph Meiser[7], in work done for his thesis, ran a considerable number of trials on a batch freezer. These trials were run with a number of different fat sources and stabilizers and so should be quite representative. The times which he recorded were those from the moment the mix was dropped into the freezer and the suction valve was opened until the drawing began. The mean time of Dr. Meiser's recordings was 4.44 minutes or 0.074 hours and was used for Plant I and II in this study which used batch freezers.

The drawing time for each of these two plants were different because in Plant I, the packages and bulk cans were filled directly from the freezer, while in Plant II, the ice cream was drawn into cans, dumped into a filler and the packages filled from the filler. As a consequence the drawing time was much less in Plant II than in Plant I. A mean drawing time was determined for each plant and added to the 0.074 hours to give 0.152 hours and 0.096 hours allowed time per batch for Plants I and II respectively. The elapsed time ratios were calculated as follows:

$$ETR = \frac{\text{number of batches x time allowance per batch}}{\text{elapsed time}}$$

For example, if 31 batches with an allowance of 0.096 hours and elapsed time of 6.66 hours were used, then

$$ETR = \frac{31 \times 0.096}{6.66} = .447.$$

The machine use factor would be calculated by:

$$MUF = \frac{\text{number of batches x time allowance per batch}}{\text{length of operator's day}}$$

Using the figures of the above example and an eight hour day,

$$MUF = \frac{31 \times 0.096}{8} = .372.$$

Note that the gallons per man hour reported for Plant II were not broken down as to different size packages. As mentioned above, the ice cream was packed independently from the freezer, and so the cycle of freezing, whipping and drawing had nothing to do with various size packs and the time was not allotted to packages.

Description of Elements

BULK:

Stamp cans - Unmade cans were taken from shipping box and put in pile on stamping bench, stamped and repiled. This did not include getting stock or carrying to the place where cans were made.

Stamp lids - Lids were taken from shipping box and put on stamping bench, stamped and returned to box. This did not include getting stock or carrying to place where lids were put on cans.

Make cans - Cans were set up by hand or with jig and put on conveyor or on pile at arm's length. This did not include carrying or conveying from stamping bench or from making point to filling point.

Fill cans - Operator took can from conveyor or pile at arm's length, inserted under filling spout and removed full can. This did not include the bringing of empty cans from the making point.

Scrape and lid - Operator scraped excess ice cream from top of can and snapped on lid. This did not involve movement of can or bringing of lids from stamping point to the lidding point.

Weigh and convey - Operator moved lidded can from lidding point onto scale and then onto conveyor. This did not include operator standing and watching scale, but only the movement of the can.

Freezer control - Operator changed overrun control, back pressure control or checked the amount of mix remaining. This did not include startup or shutdown.

HALF GALLONS:

Cartons into Anderson magazine - Operator removed cartons from shipping box, riffled ends, aligned in magazine and replaced tension hook. This did not include movement of full shipping cases to point of magazine loading.

Align and bag filled cartons, Anderson - Operator picked up, opened and slipped bag over bagging chute, aligned two half-gallons, slid them into bag, removed bag from chute and set filled bag on table. This did not include bringing bags to point of operation.

Tape and stamp bags, Anderson - Operator took filled bag, taped with tape from dispenser, and pulled handle of dispenser to eject new strip of tape. When three bags were taped, all three were stamped.

Onto conveyor - After taping and stamping, bags were placed on conveyor.

Make up cartons - Operator picked up flat carton, folded flaps and locked outer flap on one end.

Fill cartons, manual - Operator picked up carton from pile, placed open end under filling spout, removed carton when full and set on table. This did not include getting cartons from stock and putting in pile.

Close cartons - Operator took filled carton and closed flaps. This did not include any movement of carton.

Bag and tape - Operator took closed carton, put it in sack, taped sack and ejected fresh tape from dispenser. This did not include any movement of filled bag toward destination or replenishing stock of bags at point of bagging.

Freezer control - Same as in bulk operation.

SQUARE PINTS:

Make up cartons - Same as make up cartons in half-gallon operation.

Cartons into Anderson magazine - Same as Anderson half-gallon operation.

Fill pints - Same as fill cartons, manual half-gallon operation.

Close pints - Same as close cartons, manual half-gallon operation.

Bagging and taping

All above have same meanings as half-gallon operation.

ROUND PINTS:

Fill cartons - Operator took carton from dispenser, filled at spout and put on table. This did not include putting empty cartons in dispenser.

Close and put in bag chute - Operator took cap from supply, put it on carton and put capped carton in bagging chute.

This did not include taking caps from stock and putting in supply for capper.

Bag and tape - Operator took bag from supply, opened it, slid it over the bagging chute, slid eight pints into the bag, taped the bag and pressed handle of tape dispenser to eject a fresh piece of tape. This did not include getting bags from stock to the bagger's supply or moving the taped bag toward its final destination.

Stamp bags - Operator assembled five bags of pints and stamped them. This did not include moving stamped bags toward their destination.

Onto conveyor. Operator moved the taped and stamped bags onto conveyor.

Freezer control - Same as in bulk operation.

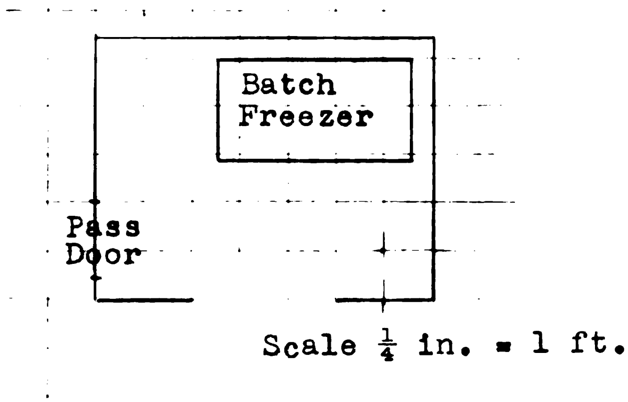

Fig. 3. Layout, Plant I.

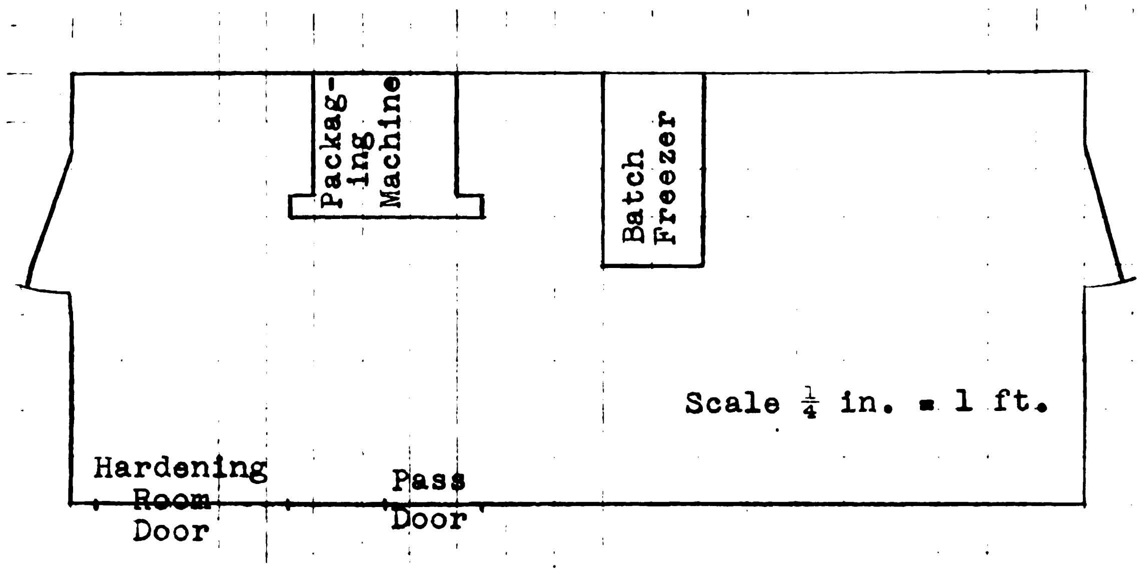

Fig. 4. Layout, Plant II.

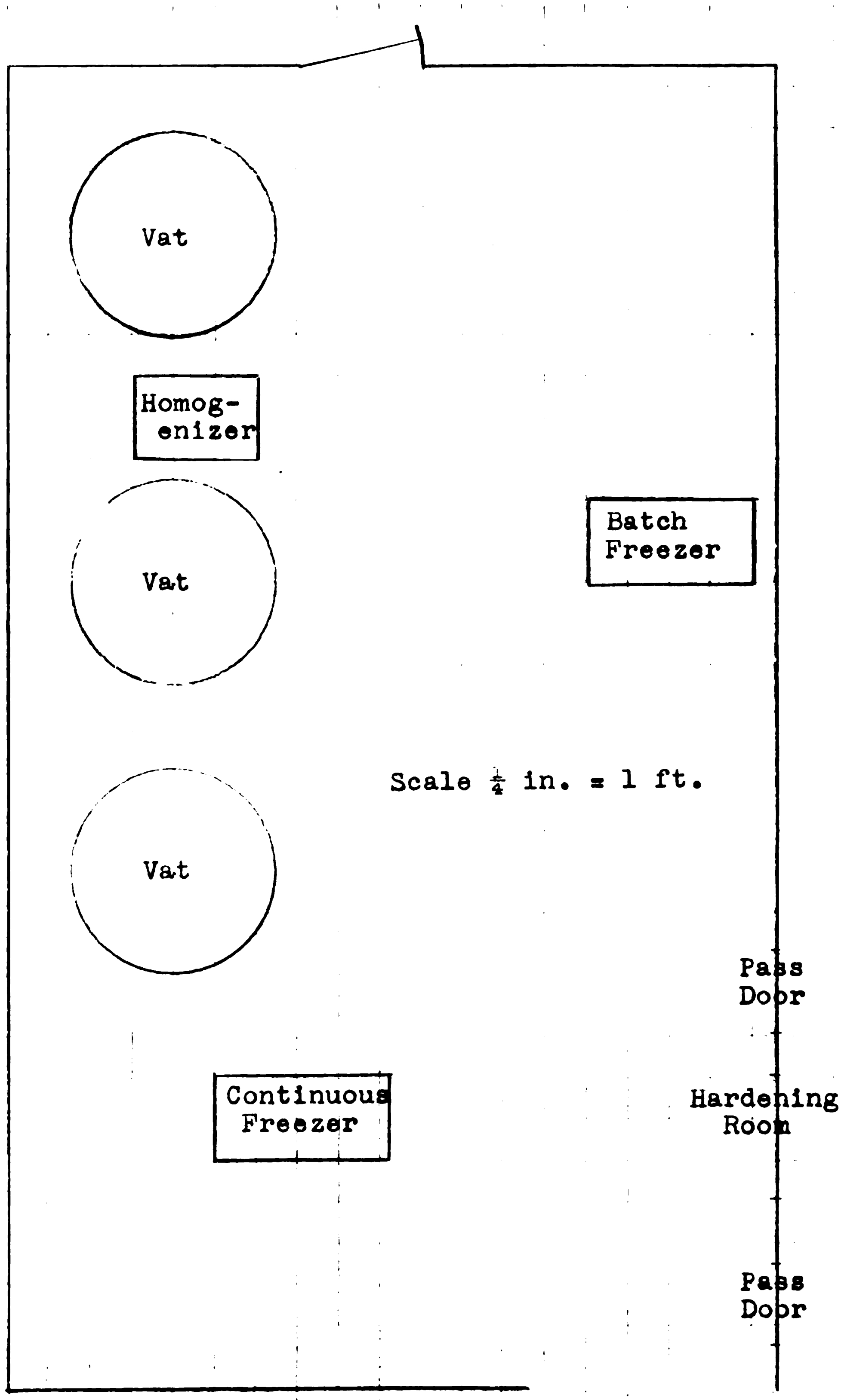

Fig. 5. Layout, Plant III.

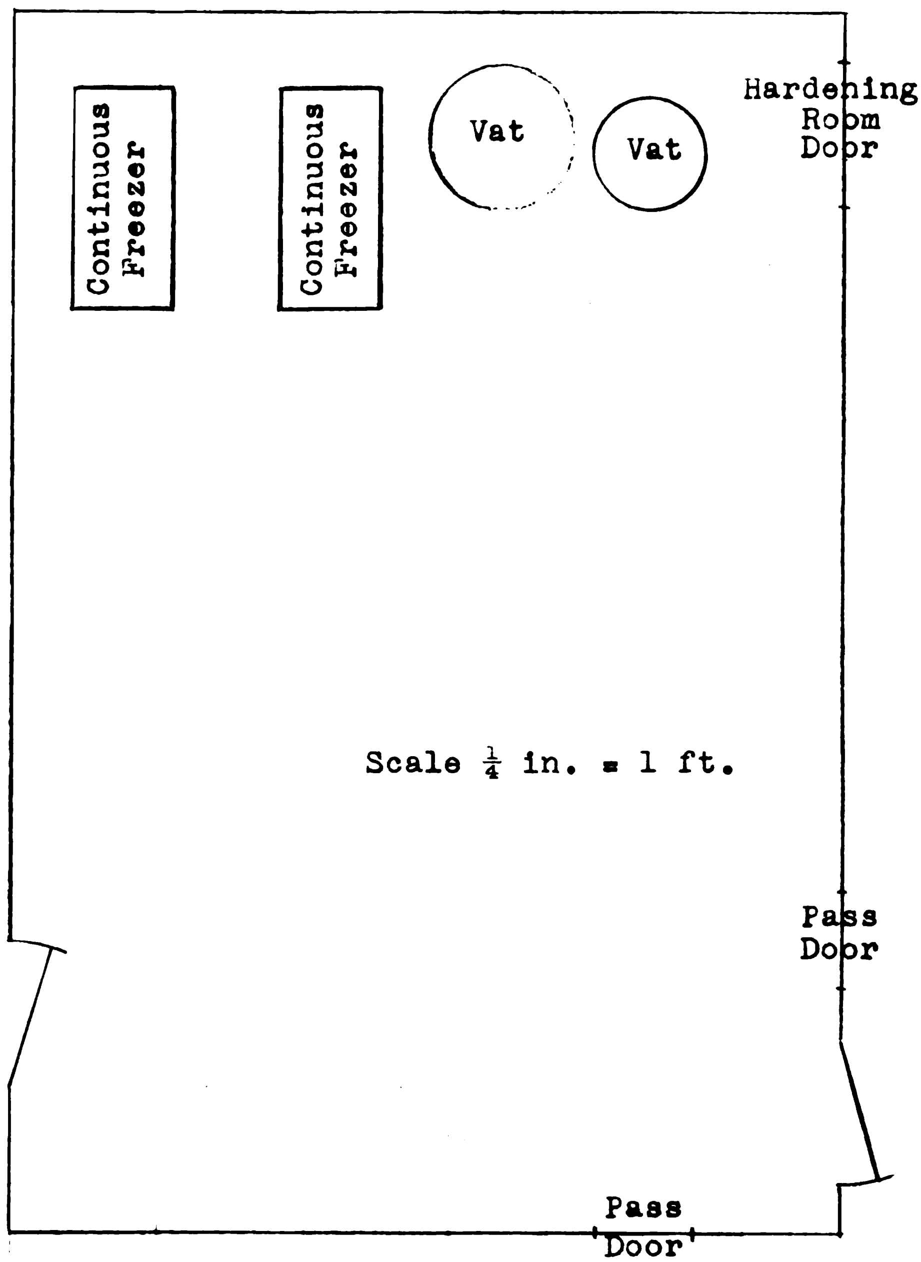

Fig. 6. Layout, Plant IV

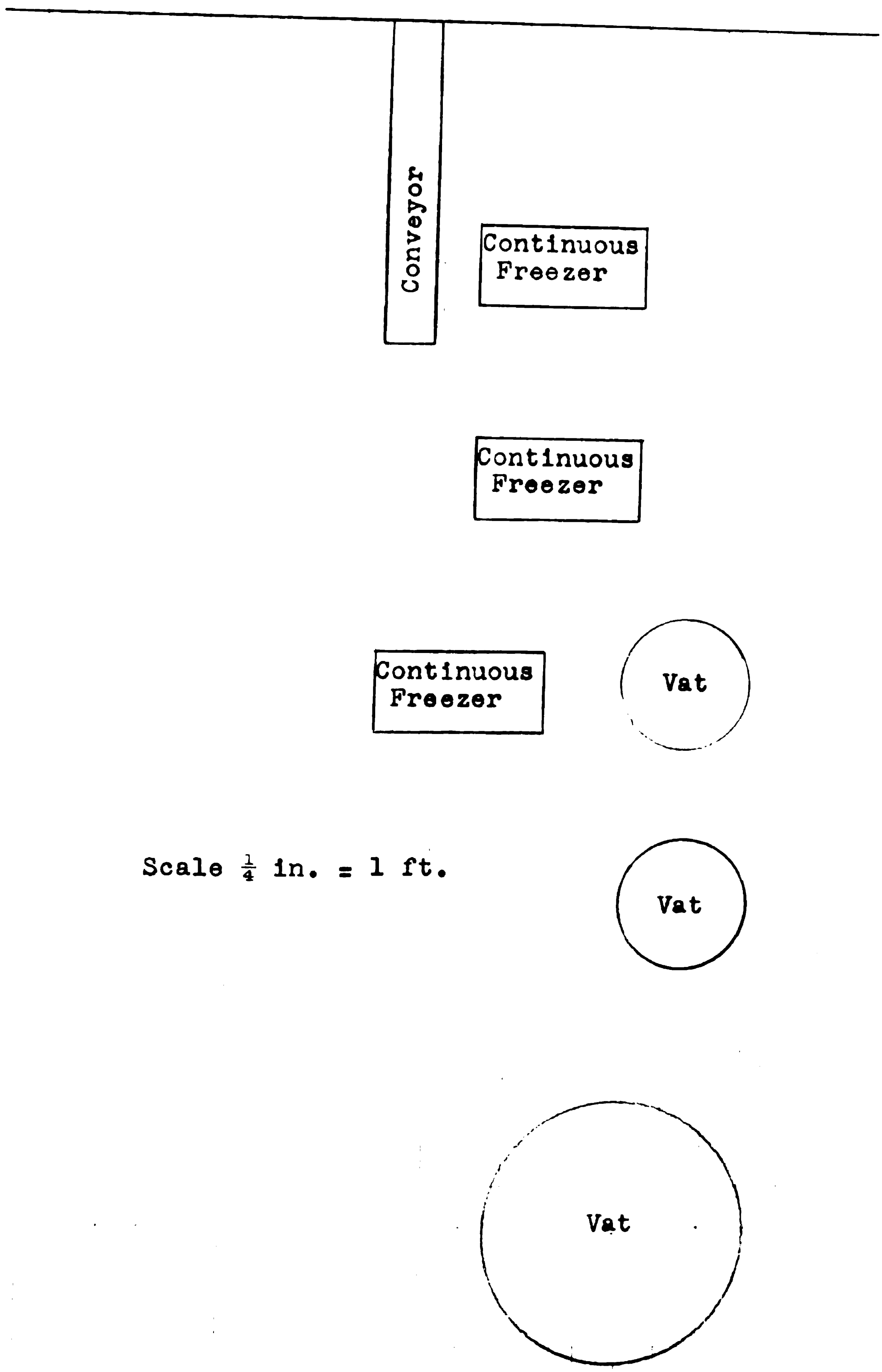

Fig. 7. Layout, Plant V

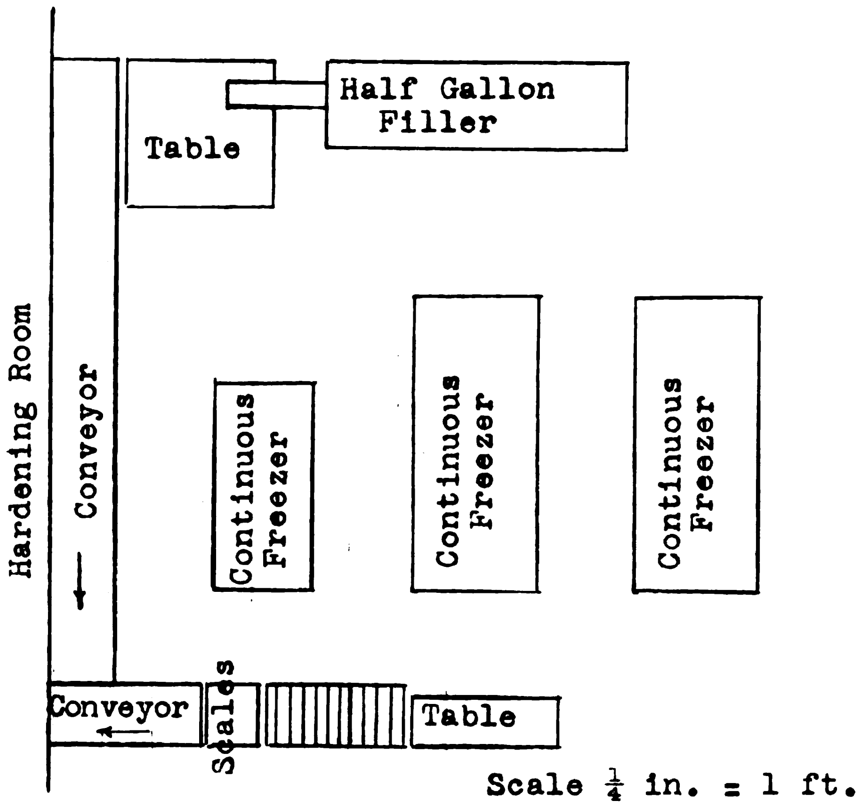

Fig. 8. Layout, Plant VI, Battery 1.

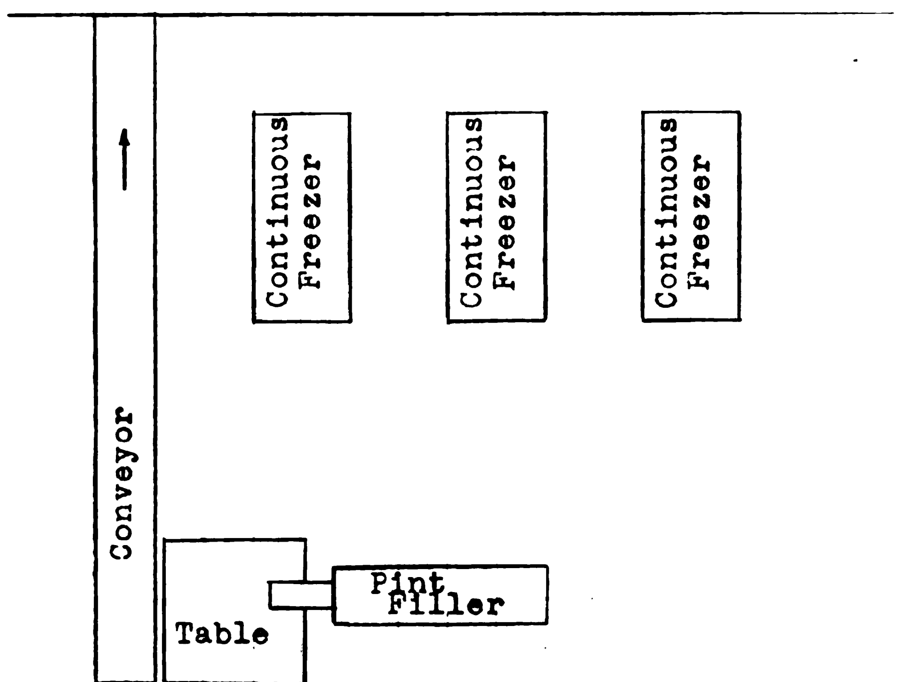

Fig. 9. Layout, Plant VI
Battery 2.

TABLE I

PLANT I
GALLONS PER MAN HOUR

Day	Pints	Quarts	Half Gallons	Gallons	Bulk 5 Gal.	Average
1st	19.5		28.6	53.4	43.5	37.9
2nd	20.0		30.2	21.7	38.0	31.6
3rd	18.8	29.4	33.3	62.5	53.7	53.7
Average	19.6	29.4	30.3	43.3	44.6	37.9

TABLE II

PLANT II
GALLONS PER MAN HOUR

Day	Total Make	Man Hours	Average
1st	221.5	5.30	41.8
2nd	284.0	6.66	42.6
3rd	255.0	5.20	49.0
Total	760.5	17.16	44.3

TABLE III

PLANT III
GALLONS PER MAN HOUR

Day	Pints	Half Gallons	2 Gal. Slabs	Bulk 3½ Gal.	Bulk 5 Gal.	Average
1st	48.8	52.5			110.2	48.8
2nd	53.4	48.5		79.5	79.4	48.8
3rd	47.8	49.3		84.2	104.8	55.5
4th	50.2	47.9		75.8	70.5	52.1
5th	53.1	56.5	78.9	84.6	88.6	57.3
6th		47.4		76.7	86.5	51.6
7th	48.3	45.0	65.0	67.8	71.9	42.3
Average	50.3	50.0	74.9	77.3	90.0	52.0

TABLE IV

PLANT IV
GALLONS PER MAN HOUR

Day	Pints	Quarts	Half Gallons	2 Gal. Slabs	3 Gal. Bulk	Average
1st	55.6	57.6	76.9	70.0	67.4	70.9
2nd	57.8		67.1		74.9	69.0
3rd	60.0		95.5		147.2	82.1
4th			86.6	60.0	59.1	70.7
5th					69.7	69.7
6th	52.0		79.4	70.1		71.2
7th	56.1		71.5		66.4	41.9
8th	62.0		94.6		72.8	77.5
9th					75.0	83.4
10th	51.7		78.2	68.1	73.2	72.3
11th	52.3		75.8	70.0	84.7	76.1
Average	54.8	57.6	80.3	68.3	73.6	69.6

TABLE V

PLANT V
GALLONS PER MAN HOUR

Day	Pints	Quarts	Half Gallons	Gallons	Bulk $2\frac{1}{2}$ Gal.	Bulk 5 Gal.	Average
1st	46.3		140.8	120.0	191.8		134.5
2nd	62.0		124.3	200.0	208.3	189.8	124.8
3rd	59.6		97.6	166.7	147.1		87.3
4th	59.0		97.1	166.7	222.7	205.1	135.8
5th	61.7		128.8	166.7	176.3	184.1	138.0
6th	55.0		80.4	153.9	190.2		86.0
7th	65.1		112.7	41.7	266.7		115.1
8th	49.9			250.0	154.2		64.8
9th	40.3	67.2	138.1		104.8		96.7
Average	54.6	67.2	113.5	121.4	191.2	194.4	112.1

TABLE VI

PLANT VI

GALLONS PER MAN HOUR

Day	Round Pints	Square Pints	Quarts	Half Gallons	Bulk $2\frac{1}{2}$ Gal.	Bulk 5 Gal.	Average
1st	41.5	104.4		148.7			122.5
2nd				147.6			147.6
3rd	32.6	108.9		142.2	283.3		148.9
4th	46.1			151.8	286.5		126.6
5th	40.0		85.6	153.4	324.1		144.0
6th		109.6		131.9			115.8
7th				151.0			151.0
8th	46.6			172.0	288.6	500.0	140.7
9th		109.3		161.6	335.4		180.7
10th	43.8				267.5		107.3
11th		92.4		163.5			146.3
Average	43.6	105.6	85.6	150.0	292.0	500.0	139.2

TABLE VII

GALLONS PER MAN HOUR

Plant	Round Pints	Square Pints	Quarts	Half Gallons	Gallons	2½, 3, 3½ Gal.	5 Gal.	Average
I		19.6	29.4	30.3	43.3		44.6	37.9
II								44.3
III		50.3		50.0		73.3	90.0	52.0
IV		54.8	57.6	80.3		73.6		69.6
V		54.6	67.2	113.5	121.4	191.2	194.4	112.1
VI	43.6	105.6	85.6	150.0		292.0	500.0	139.2

TABLE VIII

ELAPSED TIME RATIOS AND MACHINE USE FACTORS

	PLANT I			PLANT II	
Day	ETR	MUF	Day	ETR	MUF
1	.555	.247	1	.436	.312
2	.392	.152	2	.447	.372
3	.555	.152	3	.517	.336
Average	.498	.184	Average	.464	.340

	PLANT III			PLANT IV	
Day	ETR	MUF	Day	ETR	MUF
1	.551	.256	1	.906	.523
2	.334	.221	2	.919	.418
3	.768	.401	3	1.012	.423
4	.602	.410	4	.891	.408
5	.732	.641	5	.865	.286
6	.507	.209	6	.891	.393
7	.426	.246	7	.557	.361
Average	.569	.340	8	.923	.416
			9	1.008	.256
			10	.934	.539
			11	.966	.568
			Average	.885	.419

TABLE VIII CONTINUED

PLANT V					
Day	**ETR**	**MUF**	**Day**	**ETR**	**MUF**
1	.895	.721	6	.563	.422
2	.810	.573	7	.652	.389
3	.510	.363	8	.332	.156
4	.722	.598	9	.643	.389
5	.792	.628	Average	.671	.472

PLANT VI					
	Battery 1			**Battery 2**	
Day	ETR	MUF	Day	ETR	MUF
1	.771	.502	1	.472	.398
2	.818	.722	2	.000	.000
3	.723	.627	3	.778	.321
4	.792	.817	4	.801	.374
5	.944	.850	5	.537	.501
6	.672	.606	6	.782	.701
7	.841	.757	7	.000	.000
8	.963	.866	8	.808	.378
9	.921	.829	9	.682	.599
10	.892	.449	10	.812	.412
11	.882	.793	11	.661	.363
Average	.848	.707	Average	.685	.450

TABLE IX

BASIC TIMES: BULK (MINUTES PER GALLON)

Element	Plant I 5 Gal.	Plant II 3½ Gal.	Plant III	Plant IV 3 Gal.	Plant V 2½ Gal.	Plant VI 2½ Gal.	Plant VI 5 Gal.
Stamp cans				.011	.011	.003	.005
Stamp lids			Too			.002	.002
Make cans		.092	few	.056	.061	.056	.038
Fill cans	.050[1]	.053[1]	to	.074[2]	.074[3]	.040[4]	.020[4]
Scrape and lid			get	.051	.028	.063	.027
Weigh and convey			times		.014	.014	.010
Freezer control				.012	.001	.001	.001

1. Filled from batch freezer.
2. Filled from continuous freezers at 300 gallons per hour.
3. Filled from continuous freezers at 385 gallons per hour.
4. Filled from continuous freezers at 900 gallons per hour.

TABLE X

BASIC TIMES: PINTS (MINUTES PER GALLON)

Element	Plant I	Plant II	Plant III	Plant IV Nested Pails	Plant V Machine Setup	Plant VI Machine Square	Plant VI Hand Round
Make up square pint cartons	.638	.444	.498				
Square pint cartons into Anderson magazine						.072	
Fill pints	.174[1]	.452[2]	.389[3]	.303[4]	.301[4]		.330[5]
Close pints	.492	.404	.261	.302	.301		.330
Bagging (no chute) and taping		.310		.271	.429		
Bagging and aligning (Anderson)						.123	
Bagging with chute and taping							.283
Freezer control			.003	.011	.021	.016	.046
On conveyor					.056	.029	.022

1. Filled from batch freezer
2. Filled by filling machine
3. Filled from continuous freezer by hand at 150 gallons per hour
4. Filled from continuous freezer by hand at 220 gallons per hour
5. Filled from continuous freezer by hand at 420 gallons per hour

TABLE XI

BASIC TIMES: HALF GALLONS (MINUTES PER GALLON)

Element	Plant I	Plant II	Plant III	Plant IV	Plant V	Plant VI
Cartons in magazine, Anderson						.015
Align and bag filled cartons, Anderson						.085
Tape and stamp bags, Anderson						.132
Make up cartons	.00[1]	.110	.00[1]	.00[1]	.177	
Fill cartons	.646[2]	.326[3]	.277[4]	.190[5]		
Close cartons	.090	.126	.070	.062	.092	
Bag and tape cartons		.235		.118	.118	
On conveyor					.020	.014
Freezer control			.004	.009	.004	.013

1. Automatic bottom
2. Directly from batch freezer
3. Filled from Bagby filler, .0465 minutes per pint shot
4. Filled directly from freezer at 160 gallons per hour
5. Filled directly from freezer at 220 gallons per hour

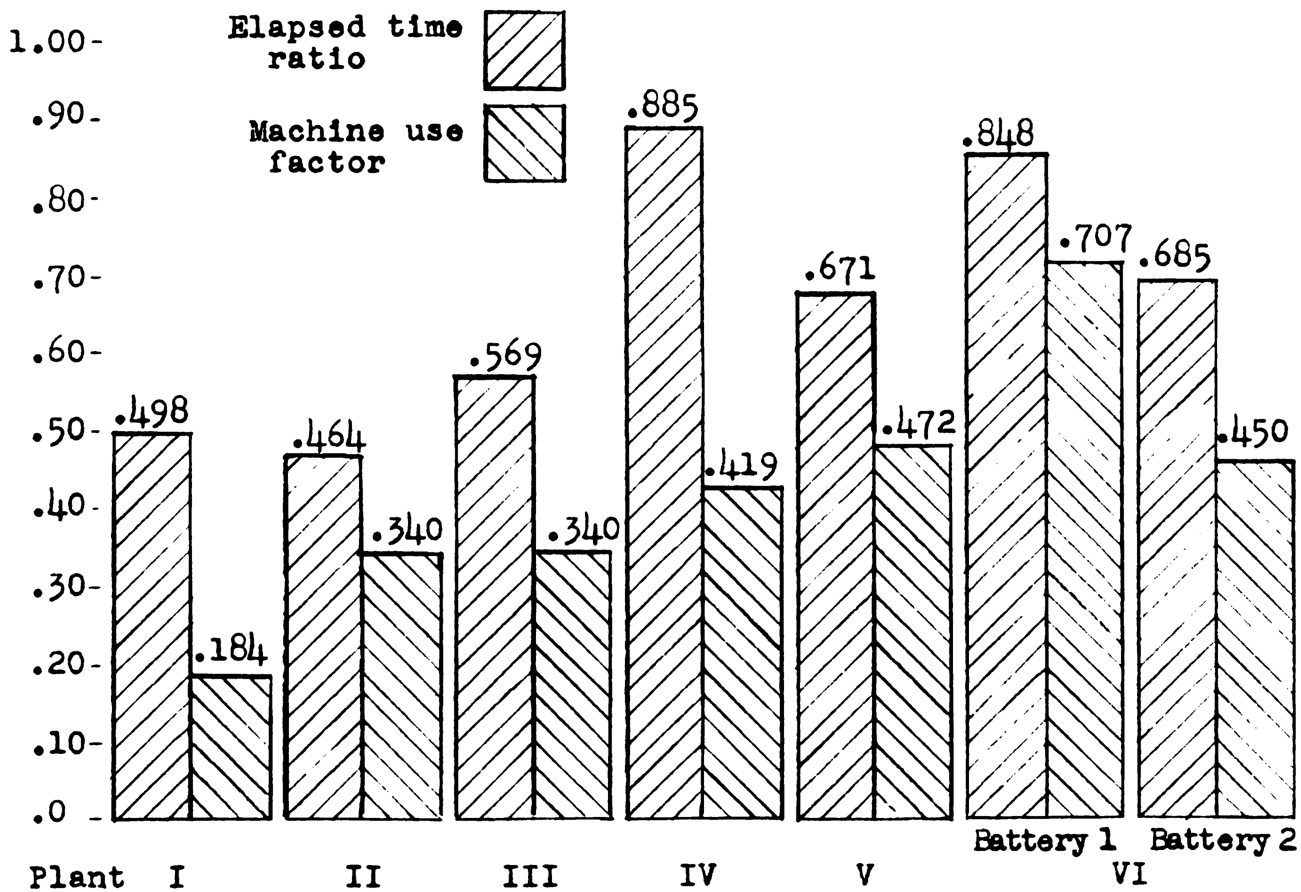

Fig. 10. Comparison of elapsed time ratios and machine use factors.

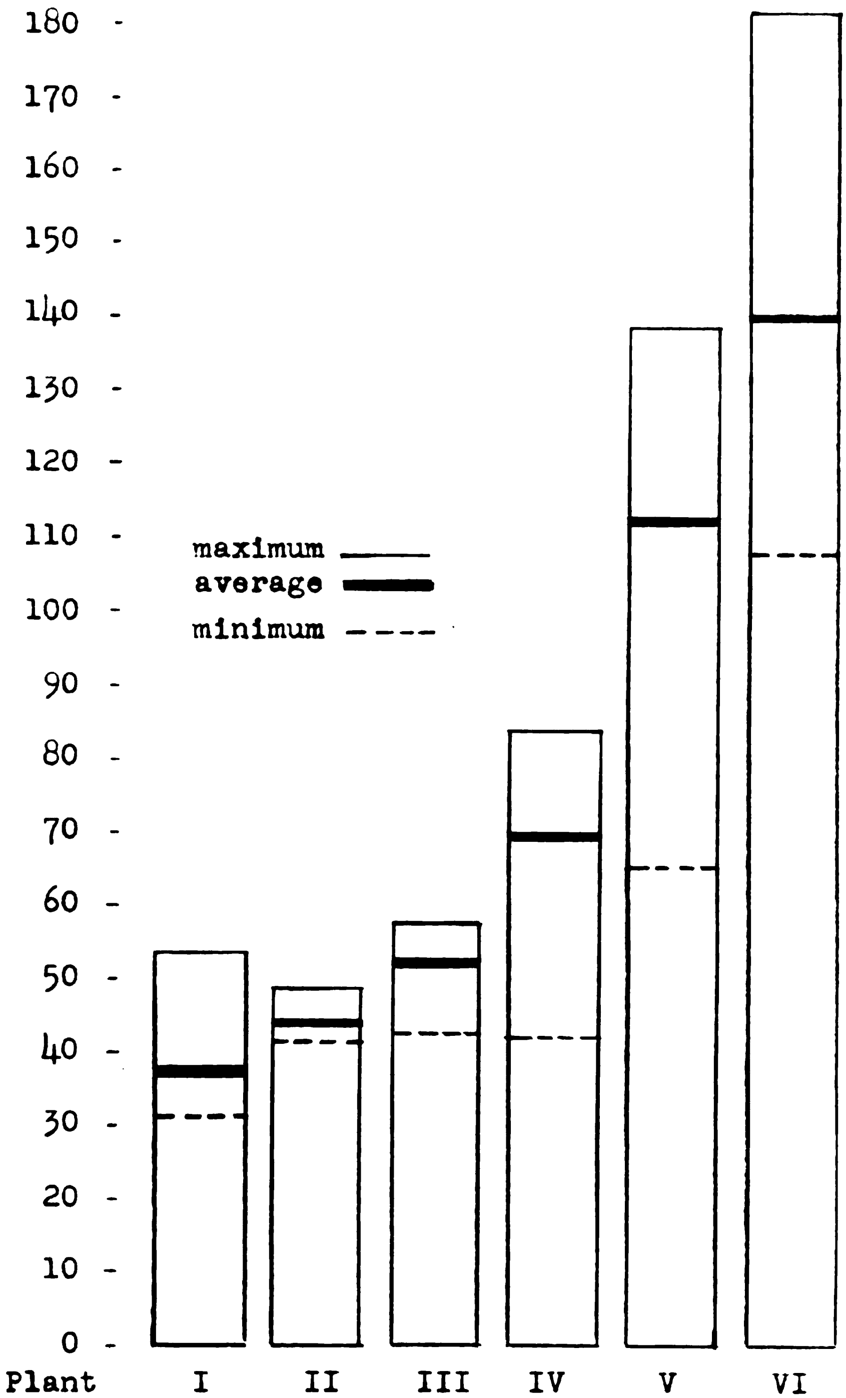

Fig. 11. Comparison of gallons per man hour.

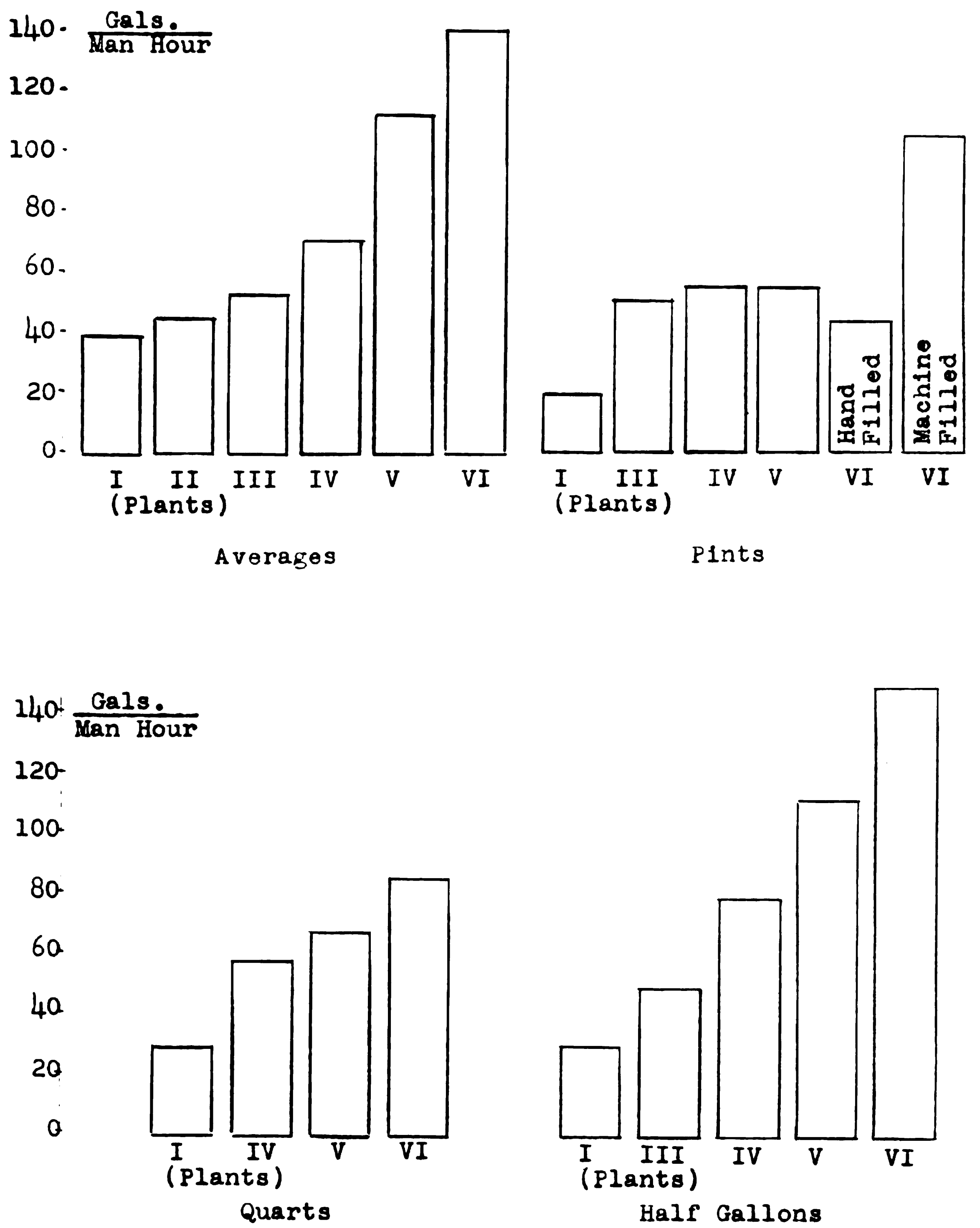

Fig. 12. Gallons per man hour for consumer sized packages.

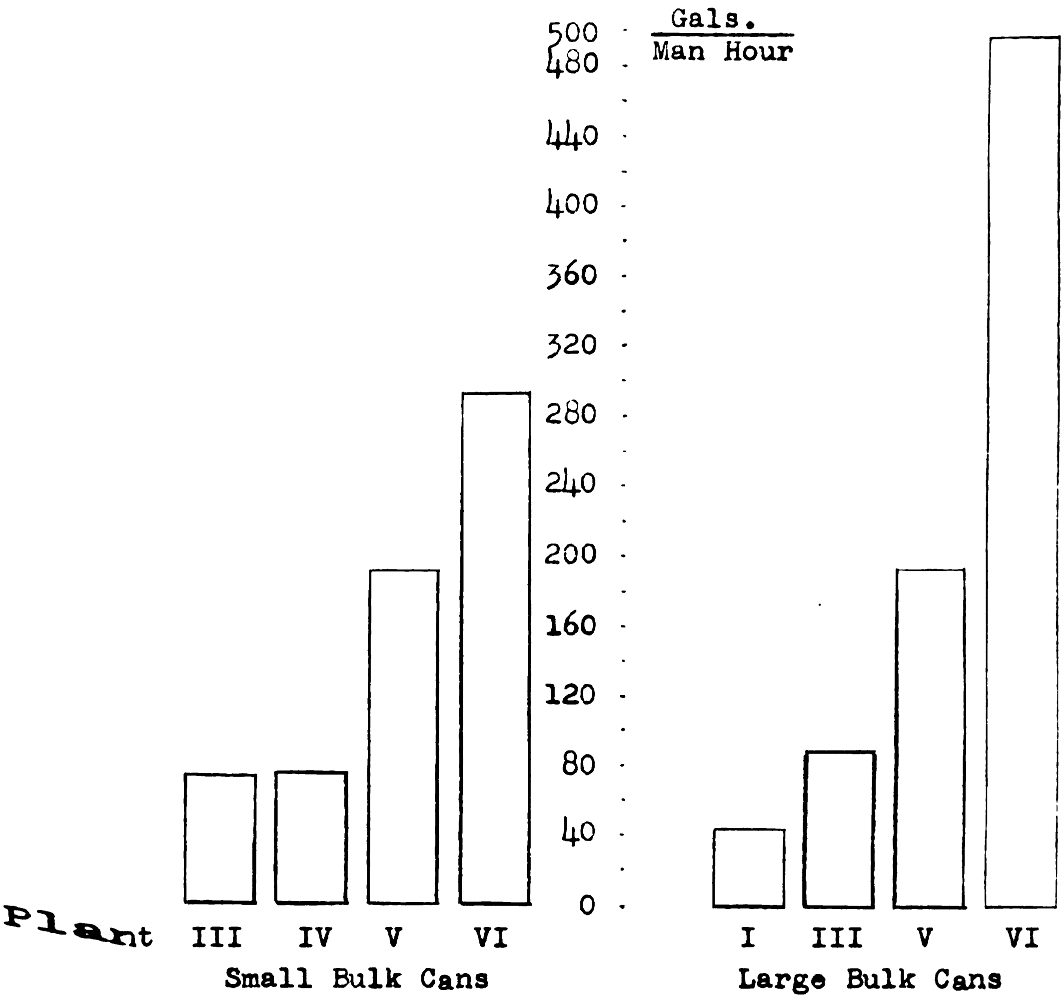

Fig. 13. Gallons per man hour for small and large bulk cans.

RESULTS

Plant IV had the best and most consistent elapsed time ratio, mainly because the freezers were rarely shut down from the time they were started until the end of the freezing time. The operators set up the piping for the next operation and with the turn of a valve or two the next operation continued without loss of time. When possible, flavors were run from mild flavors and light colors to strong flavors and darker color to minimize shut downs for washups.

Plants III, V and VI had lower elapsed time ratios, mainly because of shutdowns to make new setups which could have been made before the previous operation was finished. The elapsed time ratios of Plants I and II were low because length of time needed for freezing and whipping were high as compared with the standard set. The freezing and whipping time of 4.44 minutes was based on the only published figures found[7]. Farrall[8] states that the freezing and whipping time should be five to seven minutes. This would still make an elapsed time ratio of a little less than sixty percent if the seven minute figure was used which, while not a high elapsed time ratio, would be better than those figures recorded.

Plant VI's first battery of freezers was utilized to 70.7 percent of its potential and Plant IV's machine use

factor was 62.8 percent, but the other plants were below fifty percent, showing that their potential was two to five times the amount produced. Part of the reason for this loss of potential was due to cool summer weather. The ice cream was not needed for sales and so could not be made.

In Plant I, the freezer was operated by the owner. During the third day of the study, it was discovered that the ice cream was being frozen down to 22.5 degrees or 23 degrees Fahrenheit before the refrigeration was shut off. This lengthened the whipping time considerably because the frozen mix had to warm up to 24 degrees Fahrenheit, or higher, before it would whip. From freezing and whipping times of 8.42 minutes, 10.20 minutes and 10.76 minutes, he was able to reduce his time to 6.87 minutes, 6.55 minutes and 6.47 minutes on the next three batches. Had he been able to affect this time saving earlier, the elapsed time ratio would have been much better and the freezer and refrigeration compressor motor would have run a much shorter time, saving power costs.

In Plant II, the freezer operator was doing a good job in keeping the freezer running. There was no delay time recorded between the end of the drawoff of a batch and the dropping of the mix for the next batch, the suction valve being opened before the drawoff was completed. The blades were sharp, but there was no gage on the compressor which only served the freezer, so that backpressure could not be noted; there was no method of liquid level indication to show how much refrigerant was in the system; nor did the observer see the oil drained from the system at any time. Any of these last three items could have slowed the freezing.

In Plant III, the owner was plagued by inexperienced help, too much help and insufficient time for supervision, due to the time needed for the other phases of his business. There was adequate refrigerant, the backpressure was sufficiently low, the blades were sharp and the oil was drained, so the freezer could give adequate production. The loss in time was due to delays between flavors and short runs. On the first day, when there was an elapsed time ratio of 55.1 percent, there were delays and freezer starting times totaling 1.24 hours out of an elapsed time of 3.71 hours. On the second day with an elapsed time ratio of 33.4 percent, there were delays and freezer start-up times of 3.24 hours out of an elapsed time of 5.30 hours. There was only one flavor tank, so a flavor batch had to be finished before a new batch could be flavored. Also, the piping for a different setup was done during the shutdown, rather than having the setup made during the freezer run. This plant was supplying several small distributors in their packages, so variety of flavors, sizes of packages and brands were too much for the size of the hardening room. Duplication of packages, flavors and brands were run in small amounts on consecutive days, contributing to the lack of efficiency.

Plant IV had the best elapsed time ratio of the six plants studied. Work was planned and executed so that there were practically no shutdowns or delays. On the third and nineth days the freezers ran wide open from starting time to finishing time without shutting down or reducing the speed, so there was produced a little over the rated capacity, which accounted for elapsed time ratios of more than 1.0. On the seventh day, when an elapsed time ratio of .55 was reported, cups were run and only part capacity of one freezer was used for 1.83 hours with 71 gallons produced. After the cups were finished, the elapsed time ratio for the remainder of the day was .846. Beyond a very few one-, two- or three-minute delays, the only loss of efficiency in this plant was slowing down to 75 percent capacity to run hand-filled pints.

At Plant V, the main decrease in elapsed time ratio was caused by delays between flavors and/or packages. These delays, which ranged from 14 to 43 percent, appear as the chief reason for loss of efficiencies. The 43 percent delay time occurred on the eighth day, when the elapsed time ratio of the day was .332. This was lowered further by running sherbet, which was run at 49 percent of capacity.

The delays were in the main of two categories: those used to change piping, and those used to flavor batches of mix. In almost all cases they could have been eliminated by proper planning and making the pipe setups and mix flavorings while the preceding batch was running.

At Plant VI, Battery 1, which froze the ice cream for half-gallon and bulk can operations, had the best elapsed time ratio and the second best overall elapsed time ratio of the plants studied. The main reason for decrease of elapsed time ratio in this battery was shutdowns to set up piping. On the sixth day studied, the battery was shut 74 minutes for the piping setup for neapolitan half gallons. This could have been done during the preceding operation with an increase in elapsed time ratio of 11 percent for the day. In the main, the delays noted for Battery 1 were usually not long and were due to piping.

Battery 2 at Plant VI was used for machine-filled square pints and hand-filled round pints. The filling rate for square pints was 56 pints per minute or 420 gallons per hour. The machine was new to them and they had not learned to adjust the sources of trouble, so there was production lost due to jam-ups during the runs. The hand-filled round pints were run at 28 pints per minute or 210 gallons per hour. There was rarely time lost during the operating time, but the low rate reduced the elapsed time ratio. Efficiency was reduced by using the people operating this battery for other operations, such as cups, drumsticks, etc. When this occurred during the elapsed time between freezer startup to final shutdown, it lowered the elapsed time ratio of the battery. Of course, if pints were not needed and the other items were, then the best utilization of labor should take precedence over the machine efficiency, but this practice did reduce the elapsed time ratio figures for this battery.

Everything said so far about elapsed time ratio is also true for machine use factor, since the elapsed time of the ratio calculations is in the length of time used in the machine use factor. At each plant there were different reasons for not running their freezers all day.

Plant I was freezing for its own store and one other stop and so did not have enough demand to keep the freezer busy. The hardening room was not large enough to permit running the freezer all day when the operator did freeze, therefore, the machine use factor was low for each day that it was used.

At Plant II, the operator placed the filled packages in trays for hardening and so the packages had to be bagged for distribution before freezing could begin in the morning. Two mornings had time losses of 105 minutes and 123 minutes, respectively. The operator did not have delays between batches, but was handicapped by the slow freezing time.

At Plant III, the demand for ice cream was insufficient to keep the freezers going all day. They usually made mix in the morning and froze it after the batch was all homogenized and standardized. Part of the possible freezing day was lost in this and in the cleanup, which also was done during the possible freezing day.

Plant IV was unable to gain the first place position in machine use factor which it held in elapsed time ratio. This drop was due to lack of demand for ice cream because of cool weather, which would exploit the plant's full freezing potential, and to the fact that the operating crew used about two to two-and-one-half hours at the beginning of each day to load out drivers, restack hardened ice cream and clean the hardening rooms. After freezing, the crew finished its time in stenciling brick slices, cutting cake rolls, etc., and cleaning work. During the course of the study, the elapsed time of freezer operation varied from 25 percent to 65 percent of the work day and/or a total of 47.4 percent of the potential freezing time; the 47.4 percent is not far from the plant's overall machine use factor of 41.9 percent.

The machine use factor of Plant V reflects, along with a fairly low elapsed time ratio, a lower demand, due to cool weather, than the freezing potential could satisfy. The remainder of the crew's day after freezing was spent on cleanup and fancy orders.

In Plant VI, during this study, the elapsed running time of Battery 1 was 92.3 percent of its potential running time, so the machine use factor of Battery 1 reflects only this small loss of potential time and loss in elapsed time ratio.

Battery 2 of Plant VI had a much lower machine use factor than Battery 1, due to less demand for products produced on these freezers than the potential of those freezers and, of course, to the fairly low elapsed time ratio.

It was interesting to note that as the plant size increased, the average gallons per man hour increased from 37.9 gallons per man hour for Plant I to 139.2 gallons per man hour for Plant VI. With few exceptions this increase also showed up in the average gallons per man hour for the different package sizes.

In pints, Plant III did not bag at the time of freezing, but at odd times after hardening, so its gallons per man hour is higher than it would be if the bagging were also done. Plants IV and V had almost identical figures. Their average production was 219.1 and 218.3 gallons per hour for Plants IV and V, respectively, and they each used four people on the operation, filling, closing, bagging, and sending to the hardening room. Plant V will probably have a higher figure when the idiosyncrasies of the pint filling machine are overcome with a potential of 140 gallons per man hour.

Quarts were a minor item as far as production went in all of the plants studied. Plants II and III did not fill any and the others filled only one time each during the study.

Plant III had a lower gallons per man hour for quarts than pints, with the same potential production for each. They were filled in two different brands of machines, which possibly made the difference. The production was so brief that quarts were not studied.

In half-gallons, the gallons per man hour averages climbed from a low of 30.3 gallons to 150.0 gallons per man hour from Plant I to Plant VI. Plant III had one man too many on the operation, that is, there were three men for 150 gallons per hour production whereas two men could have done the job and the gallons per man hour would have been 75 rather than 50. Plant IV had four men on a 300 gallons per hour production where three could have done the job with a resulting 107.1 gallons per man hour, rather than the reported 80.3. Plant V was producing at its freezer potential using three people. Plant VI had a potential of 900 gallons per freezing capacity hour with a half-gallon filling machine with five people on the operation, which gave 180 gallons per man hour potential. Here again there was one extra person on the operation, with only four needed. There could have been an 187.5 gallons per man hour reported with four people, rather than 150.0 which was reported with 225 gallon per man hour potential.

Plant III packed too few small cans of bulk to study. Plant I filled no small cans and Plant II packed $3\frac{1}{2}$-gallon square containers, but there are no gallons per man hour figures for Plant II. Plant IV would have had a figure double its 73.6 gallons per man hour if two men had been used rather than four. Plant V used two people on its bulk operation, averaging 191.2 gallons per man hour. Plant VI used three people to average 292.0 gallons per man hour with a possible potential of 300 gallons per man hour.

Plant II made no five gallon bulk and Plant IV made so few five gallon bulk that this filling operation was not studied because of insufficient time to gather data. At Plant III, two men were on the five-gallon bulk operation when one could have handled the flow from the freezer, so the 90 gallons per man hour could have been doubled. Plant V used two people on their operation as did Plant VI with the former having 194.4 and the latter 500.0 gallons per man hour.

The basic time given in the tables are times from the operations where the elements followed the descriptions as given previously. If an element in an operation did not fit the description, a basic time was not reported.

To compute the total basic allowance for an operation using the reported basic times, break the operation down into elements and select from the table the basic times which fit those elements. Add the elemental times together to get operation time. For example, compute the amount of time to make, fill, scrape, lid, weigh and convey a bulk can. Basic times from different plants:

Stamp can .011 minutes per gallon x 2½ gallons (Plants IV and V)	.0275 minutes per can
Make can .056 minutes per gallon x 2½ gallons (Plants IV and VI)	.1400 minutes per can
Scrape and lid .051 minutes per gallon x 2½ gallons (Plant IV)	.1275 minutes per can
Weigh and convey .014 minutes per gallon x 2½ gallons (Plants V and VI)	.0350 minutes per can
Total	.3300 minutes per can

With the freezers delivering 300 gallons per hour, a 2.5 gallon can is filled each 0.5 minutes. Therefore, during the filling time of 0.5 minute there would be time to complete the above four elements totaling 0.3300 minutes, so it would be feasible to have one person making, filling, lidding and conveying 2.5 gallon bulk cans. Of course, the operation would need to be surveyed to improve the method and the setup so that the times can be achieved or improved.

Check List for Ice Cream Plants

1. Keep supplies, cartons, wrappers, cans, etc., protected from dirt and moisture and off of floor. Unused supplies from production room should be put back into stock and protected as before.
2. In production room place supplies as near operations as possible to eliminate walking.
3. If possible, put supplies at point of use by drop chute from storage floor above to save hauling.
4. Do not permit operator to run out of supplies.
5. Do not have too many people on operation. This is an obvious statement, but it does occur.
6. For packages, use bagging shoes loaded by carton closer.
7. Use conveyors to save walking and carrying.
8. Drain oil from freezers before each freezing day and frequently from hardening room coils, cabinet or surface cooler coils and holding tank coils.
9. Keep freezer blades properly sharpened.
10. Maintain sufficient ammonia in system for adequate refrigeration.
11. Maintain low enough back pressure to permit capacity operation at all times.
12. Keep an operator on a machine so that he may learn its foibles and how to cope with them. He can learn causes and effects which are not always apparent on rapidly moving machines.

13. Give operators the best training available and check for faithfulness to established operating procedures.

14. Encourage an operator's trying to better an operation, but insist on being informed before change in method is tried.

15. Reduce mix temperature to as much under 40 degree Fahrenheit as possible to facilitate heat removal in the freezer.

16. Go from light to dark colors of ice cream to avoid shutdown for flavor changeover. For example, from vanilla to strawberry to chocolate.

17. Relieve personnel on operations for rest periods rather than shut down the operation.

18. Have the freezer operator go to lunch ten to fifteen minutes before the remainder of the crew and return that much earlier. He can start up the freezers and be ready to freeze immediately when the crew returns to work after lunch.

19. Avoid shutdowns by having piping in place for next operation, so that a valve turn may change ice cream flow to the next operation.

20. Stack packages on spot in hardening room where they will remain until loadout to conserve labor.

21. Fill three gallon bulk containers rather than $2\frac{1}{2}$ gallon containers. The difference in size and cost of the two sizes is negligible, but there would be quite a saving in the number of cans used and the handling involved.

22. Check the temperature of freezing mix in the batch freezer. Mix whips slowly below 24 degrees Fahrenheit.

23. To maximize the length of flavor runs, have hardening room large enough to hold seven to fourteen day's supply of ice cream.

24. Remember that subordinates are human beings and that a supervisor's record of accomplishment depends on their good will and desire to work properly.

SUMMARY

Six ice cream plants in Michigan were studied, each a representative of one of the six categories of plant sizes. The categories were 0-20,000 gallons per year; 20,001 to 50,000; 50,001-100,000; 100,001-250,000; 250,001-700,000; and 700,001-up; represented by Plants I through VI, respectively.

Basic times were established for elements of pint, quart, half-gallon, gallon and bulk filling operations; elapsed time ratios and machine use factors, and gallons per man hour averages for each plant also were established.

The "occurrence study" variant of work sampling was used. In this technique each operation was divided into elements and the elements were observed. At random times, observations were taken of each person on the operation and a mark was made under the heading describing the element performed. At the end of the first day's observations, the data for each observation were analyzed statistically to determine how many observations were needed for each element. At the end of the study, the observations on each element were summed and the sums were totaled. The ratio of the observations of each element to the total observations of the operation was the fraction of the total time of the operation that the element occurred. This fraction multiplied by the total time in

minutes that the operation ran and divided by the number of gallons produced during those minutes yielded a basic time in minutes per gallon.

The total gallons produced on an operation divided by the number of people on the operation and the number of hours in which the gallonage was produced gave gallons per man hour.

The ETR, elapsed time ratio, was calculated by dividing the gallons produced in a day by the number of elapsed hours from the initial startup to the final shutdown and the capacity of the freezer or freezers. The MUF, machine use factor, was calculated by dividing the gallons produced in a day by the length of the work day and the capacity of the freezer.

The elapsed time ratios ranged from a low of 0.464 to a high of 0.885, while the machine use factors ranged between 0.184 to 0.707.

The highest gallons per man hour, Plant VI, was more than three times as great as the lowest figure, Plant I.

The most important time and labor saving procedures are:

1. Avoid shutdowns due to flavor changeover by changing from light to dark colors and from mild to heavy flavors.
2. Have piping for next operation in place before preceding operation is finished, so that production can proceed without loss of time.
3. Use conveyors to move finished products into the hardening room to save walking and carrying.
4. Have sufficient supplies at the point of use to prevent running out and subsequent shutdown.

CONCLUSIONS

1. The elapsed time ratios established by this study ranged from a low of 0.464 for Plant II to a high of 0.885 for Plant IV. The low 0.464 was due to batch freezer running times which were two to three times as great as the standard. The 0.885 of Plant IV was accomplished by good planning of the management.
2. The machine use factors ran from 0.184 for Plant I to 0.707 for Plant VI. The 0.184 was due to insufficient business and too small a hardening room, along with slow freezing and whipping. Plant VI could have had a higher machine use factor if the demand for the product had been great enough to keep the freezers running.
3. The basic times for defined elements of machine-filled pints at Plant VI were: 0.072 minutes per gallon to place cartons in the magazine of the filling machine, 0.123 minutes per gallon to align the filled pints in the bagging shoe and bag them, 0.016 minutes per gallon for controlling the freezer and 0.029 minutes per gallon for placing the bagged pints on the conveyor. Basic times were set in all the plants on all elements which conformed to the definitions.
4. Gallons per man hour ranged from 37.9 for Plant I to 139.2 for Plant VI. Plant I could double its 37.9 gallons per

man hour by shutting off the refrigeration when the semi-frozen mix reaches 24 to 25 degrees Fahrenheit, rather than letting the temperature go down to 22 to 23 degrees Fahrenheit. While Plant VI had a gallons per man hour of three to four times that of Plant I, the figure could be increased by reducing the number of persons on all the operations to only those needed.

FUTURE WORK IN ICE CREAM PLANTS

1. Fill out basic time charts.
2. Survey cup-filling operations for basic times, dozens per man hour and elapsed time ratio.
3. Survey mix operations for basic times and gallons per man hour.
4. Survey bar tank operations for basic times and dozens per man hour.
5. Survey drumstick operations for basic times and dozens per man hour.
6. Survey maintenance to set standards.
7. Energy requirements of ice cream plants.
8. Floor space requirements for manufacturing, maintenance and power and refrigeration departments.
9. Hardening room floor space requirements.

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