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Distribution and Costs of Steam, Electrical Power, and Labor in Representative Idaho Creameries

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Distribution and Costs of Steam, Electrical Power, and Labor in Representative Idaho Creameries

By

J. B. RODGERS, D. R. THEOPHILUS, HOBART BERESFORD AND J. L. BARNHART*

A KNOWLEDGE of the distribution and costs of steam, electrical power, and labor in creameries is fundamental for the efficient use of these forms of energy. The information is also needed as a basis for determining costs of operating specific equipment and costs per unit of product processed, since the energy used in the processing of dairy products is an important item in the cost of manufacture. There has been considerable demand for information of this nature, and although various investigators, notably Camburn (1, 2, 3) and Farrall (4, 5), have reported on individual phases, there is no published work available in the form usually desired. Since the information is fundamental for the efficient and successful operation of a creamery, the Departments of Dairy Husbandry and Agricultural Engineering of the University of Idaho conducted, cooperatively, an investigation to determine the distribution and costs of steam, electrical power, and labor in representative Idaho creameries on the basis of equipment and unit of each product processed.

Source of Data

Arrangements were made with the managements of two creameries to conduct a detailed study of the several operations within each creamery and to obtain data from their records. The study was limited to the operation and processes going on within each creamery exclusive of the clerical work and collection of raw material. The creameries were considered as representative because of their size, location, diversity of products processed, and type of equipment used. Tables I and II list the equipment operated in Creameries A and B respectively.

The study was conducted during the months of June, July, and August; one full month was spent in each creamery. The production of the creameries during the period of the study represents average production, as it lay between the periods of maximum and minimum production. The butter production of Creamery B for the year 1934 averaged 296,589 pounds per month, and the butter produced during the month's study was 340,597 pounds, or a difference of 54,008 pounds, which difference is small since the creamery increased its 1935 production about 15 per cent over 1934. Similar small differences in comparative production data also existed for other products of both creameries.

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Distribution and Cost of Steam

A list of the boiler room equipment at Creameries A and B appears in Tables I and II. The forced draft fans at Creamery A were seldom used, as the induced draft from the stack was ample at the prevailing rate of combustion. Mechanical equipment was used at Creamery A for handling the coal and ashes except when unloading the coal cars, this was performed manually. The method of handling the coal and ashes at Creamery B was essentially manual. The coal cars were dumped and the coal gravitated into the underground storage bin, the floor of which was on a level with the boiler room floor; the coal was then shoveled into the hoppers of the four stokers. At Creamery A the water level in the boiler was controlled by a Copes automatic water regulator, while at Creamery B the water level was regulated manually by controlling the speed of the boiler feed pump. At both creameries the condensate from the driers was returned to the boilers.

The major use of steam at the two creameries was for raising the temperature of cream, milk, or water. The minor use was for actuating such equipment as boiler feed pumps, condensate return traps, a steam-driven whole milk pump at Creamery A, and a Babcock tester at Creamery B. (The creamery equipment, with the exception of the whole milk pump at Creamery A, was powered with individual electric motors.) The steam rate of some of the steam-using units was determined by condensing the steam for a known period of time and weighing the condensate. If this could not be done while the particular unit was operating on schedule, the unit would be operated at a more convenient time so as to approximate closely actual operating conditions and the steam rate determined at that time. The method of determining the steam rate of the units using large quantities of steam was to maintain a constant water level in the boilers and measure the quantity of boiler feed water necessary to maintain this level for a given period of time. This method was used in determining the steam rate of the milk driers. The total quantity of steam generated by the boilers and the cost per 1,000 pounds of steam were determined by conducting boiler tests at each creamery. The usual boiler test equipment was used: Orsat apparatus, pyrometer, thermometer, sling psychrometer, steam calorimeter, scales, and miscellaneous equipment. The boiler tests were conducted in accordance with the American Society of Mechanical Engineers' code for testing stationary steam boilers.

During the boiler tests the hourly amount of steam generated was determined by measuring the boiler feed water while the water level in the boilers was maintained constant. At Creamery A the amount of coal burned was determined by calibrating the coal hoppers on the stokers and recording the "number of hoppers" of coal burned. At Creamery B the stoker hoppers were filled from a cart, the capacity of which was known; a record was then kept of the number of carts of coal burned.

TABLE I

Equipment at Creamery A

Equipment	Type	Size	Make	Motor Size Horsepower
Can Washer No. 1	Rotary	6 cans per minute	Creamery Package	5
Can Washer No. 2	Straight-Away Type B	12 cans per minute	Creamery Package	1½, 5, 5, and 1
Can Conveyor	Live Rolls		Link Belt	1½
Sweet Cream Pump, Sour Cream Pump, and Buttermilk Pump	Viking Sanitary Gear-Driven	2-inch	Viking Pump Co.	2
Separator Nos. 1, 2, and 3	Centrifugal	No. 90, 10,000 pounds per hour	De Laval	5
Skim Milk Pump	Viking Sanitary V-Belt Driven	2-inch	Viking Pump Co.	3
Receiving Vat and Agitator	Paddle	1,000-gallon vat	Creamery Package	1
Vats Nos. 1 to 12, Inc.	Wizard	500-gallon	Creamery Package	1
Hot Water Pump Nos. 1 and 2	Circulator	No. 3	Creamery Package	7½
Churn Nos. 2, 3, and 4	Model H-15	1,500 pounds	Creamery Package	7½
Drier Nos. 1 and 2	Atmospheric Roll	42 x 90-inch	Buffalo	15 and 3
Drier Exhaust Fan	Fan		Sturtevant	3
Homogenizer	Triple Action	200 gallons per hour	Creamery Package	10
Ice Cream Mixing Vat	Wizard	300-gallon	Creamery Package	1
Ice Cream Mix Aging Vat Nos. 1 and 2	Vertical Tank	200-gallon	Creamery Package	¼
Ice Cream Freezer	Fort Atkenson Direct Expansion	50-quart	Creamery Package	5
Large Compressor	2-Cylinder Reciprocating	9 x 9-inch, 40-ton	Creamery Package	75
Small Compressor	2-Cylinder Reciprocating	6 x 6-inch, 10-ton	Creamery Package	20
Ice Lake Agitator	Propeller Type			3
Ice Cream Vat Brine Pump	Centrifugal	1½-inch	American Marsh	2
Cream Vat Brine Pump	Centrifugal	2-inch	Fairbanks, Morse and Company	2
Skimmilk Heater Pump	Centrifugal Sanitary Direct Drive	2-inch	Creamery Package	1½
Pomona Water Pump	Turbine	4-inch	Pomona	20
Centrifugal Water Pump	Centrifugal	1½-inch	Fairbanks, Morse and Company	3

TABLE I (continued)

Equipment	Type	Size	Make	Motor Size Horsepower
Ice Can Hoist	Ice Can Crane	1,000 pounds	Euclid	2
Brine Agitator (On balcony)			Homemade	2
Circulator on Water Cooler			Homemade	½
Brine Circulator on Popsicle Tank			York Agitator	2
Steam Milk Pump	Type 20-D Economy Milk Pump	20,000 pounds per hour	Creamery Package	
Whole Milk Preheater	Type B Double Tube	1½-inch	Creamery Package	
Skimmilk Preheater	Economy Barrel Type		Creamery Package	
Weigh Can and Scales	Suspension Type L			
Whole Milk	2-Compartment		Creamery Package	
Cooler for Ice Cream Mix	Alaska	7-foot	Creamery Package	
Cream Cooler			Creamery Package	
Cream Dump Vat	2-Compartment		Creamery Package	
Cream Scales			Creamery Package	
Butter Scales			Creamery Package	
Cream Can Steaming Jets			Creamery Package	

Equipment in Boiler Room

Equipment	Type	Size	Make
Boiler Nos. 1 and 2	Water Tube	310-horsepower	Stirling
Stoker Nos. 1 and 2	Chain Grate	83 inches wide	Babcock and Wilcox
Boiler Feed Pump Nos. 1 and 2	Duplex reciprocating	7½ x 4½ x 10 inches	Worthington
Automatic Water Regulator	Copes		Copes
Water Softener	Hawkeye		Hawkeye
Draft Fan Nos. 1 and 2	Cycloidal	10-horsepower drive motor	Green Fuel Economizer Company
Coal Elevator	Bucket	3-horsepower drive motor	Link Belt
Coal Conveyor	Horizontal Screw	2-horsepower drive motor	Link Belt
Ash Conveyor	Horizontal Chain	2-horsepower drive motor	Link Belt
Ash Elevator	Bucket	3-horsepower drive motor	Link Belt
Condensate Pump	Jennings Vacuum Heating Pump	1-inch	Nash Engineering Company
Excitor for Synchronous Motor	Type D, 125-volt, 32A, 4-kilowatt	Motor 220-volt, 16A, 6-horsepower	Ideal Electric and Manufacturing Company

TABLE II

Equipment at Creamery B

Equipment	Type	Size	Make	Motor Size Horsepower
Local and Truck Can Washers	Rotary	7 cans per minute	Creamery Package	5
Whole Milk Pump Nos. 1, 2, and 3	Centrifugal (Sanitary)	1½-inch	R. G. Wright and Co.	1
Skimmilk Pump Nos. 1 and 2	Viking (Sanitary) Gear-Driven	2-inch	Viking Pump Co.	3
Separator Nos. 1, 2, and 3	Centrifugal	10,000 pounds per hour	De Laval	5
Separator No. 4	Centrifugal	11,000 pounds per hour	De Laval	5
Separator No. 5	Centrifugal	12,000 pounds per hour	De Laval	5
Brine and Cream Pumps	Viking (Sanitary) Gear-Driven	1½-inch	Viking Pump Co.	1½
Vat Nos. 1 and 2	Horizontal	500-gallon	Crano	2
Vat Nos. 3 to 7, Inc.	Wizard	500-gallon	Creamery Package	2
Hot Water Circulating Pump	Centrifugal	1½-inch		1
Churn No. 1	2-Door Horizontal	1,500 pounds	Crano	7½
Churn No. 2	Model H-15	1,500 pounds	Creamery Package	7½
Brine Pump (Wash Water)	Centrifugal	¾-inch		¾
Cream Pump (To Churns) and Buttermilk Pump	Viking (Sanitary) Chain-Driven	1½-inch	Viking Pump Co.	½
Water Pump	Reciprocating	6 x 6 single cylinder	Meyers	7½
Ice Lake Agitator	Propeller Type			1
Compressor	2-Cylinder Reciprocating	15 to 20 tons	York	20
Drier Nos. 1 and 4	Atmospheric Roll	42 x 90-inch	Buffalo	15 and 2
Drier Nos. 2 and 3	Atmospheric Roll	38 x 84-inch	American	10 and 2
Whole Milk Preheater	Double Tube		Creamery Package	
2 Scales and Weigh Cans	Suspension Type		Creamery Package	
2 Milk Dump Vats	2-Compartment			
Cream Dump Vat				
Cream Can Steaming Jets				

Equipment in Boiler Room

Equipment	Type	Size	Make
Boiler A and B	Scotch Marine (dry back)	200-horsepower	The James Leffel and Co.
Boiler C	Scotch Marine (dry back)	150-horsepower	The James Leffel and Co.
Boiler D	Scotch Marine (dry back)	125-horsepower	The James Leffel and Co.
Stoker Boiler A and B	Underfeed Automatic		The James Leffel and Co.
Stoker Boiler C and D	Underfeed Automatic		The Iron Fireman
Boiler Feed Pump	Duplex Reciprocating	6 x 4 x 6-inch	Fairbanks, Morse and Co.
Condensate Return Trap	Automatic Float	No. 3	Swartwout
Water Softening Equipment	Hawkeye		

The boiler test results are reported in Tables III and IV. The boiler efficiency at Creamery A was 74.0 per cent and at Creamery B 75.6 per cent. These efficiencies are comparable with the efficiencies reported by Gebhardt* at a large central station plant. The flue gas analysis at each plant shows that an excess of air was being drawn through the boilers, as indicated by the low CO_2 reading.

TABLE III

Results of the Boiler Test on Boilers at Creamery A

Date of test: June 18, 1935
Type of boilers: Stirling Water Tube, 310-horsepower
Kind of stokers: B. & W. Chain Grate
Average steam pressure in pounds per square inch gauge: 128.0
Average feed water temperature in degrees Fahrenheit: 196:0
Average flue gas temperature in degrees Fahrenheit: 365.0
Average relative humidity per cent (boiler room): 31.0
Average boiler room temperature in degrees Fahrenheit: 84.5
Flue gas analysis (average): $CO_2 = 5.7\%$ $0_2 = 13.9\%$ $CO = 0.0\%$
Proximate analysis of fuel (as received):

Moisture:	3.85%
Volatile matter:	41.62%
Fixed Carbon:	49.10%
Ash:	5.43%

Ultimate analysis of fuel:

Sulphur:	0.49%
Hydrogen:	5.68%
Oxygen:	15.13%
Carbon:	71.91%
Nitrogen:	1.36%

Heating value of coal B.t.u. per pound "as fired": 13,017
Water evaporated per hour in pounds average: 13,700
Horsepower developed (average): 420
Builders' rated horsepower: 620
Average per cent of builders' rated horsepower developed: 67.60
Maximum per cent of rated horsepower developed: 89
Water apparently evaporated per pound of coal fired: 9.35
Equivalent evaporation from and at 212 degrees Fahrenheit per pound of coal fired: 9:91
Efficiency of boiler, furnace, and grate: 74.00
Quality of steam in per cent: 97.69
Factor of evaporation: 1.06

TABLE III (continued)

Boiler Heat Balance

Name of Loss	B. t. u.	Per Cent
Heating value of coal in B.t.u. per pound "as fired"	13,017.0	
Heat absorbed by the boiler	9,640.0	74.00
Heat carried away in chimney gases	950.0	7.30
Evaporation of moisture from burning hydrogen	596.0	4.60
Incomplete combustion	0.0	0.00
Unconsumed carbon in ash (approximate)	130.2	1.00
Evaporation of moisture in fuel fired	45.0	0.35
Radiation and all other losses (by difference)	1,656.0	12.75
	13,017.0	100.00

* *Steam Power Plant Engineering*, 6th Edition, Gebhardt, p. 162.

Cost of coal per ton: $5.75
Fuel cost to generate 1,000 pounds of steam at 128 pounds gauge pressure: $0.307
Electrical energy consumed per 24 hours in boiler room by stokers, coal and ash conveyors, and coal and ash elevator motors: 21.880 kilowatt-hours
Cost of electrical energy per 1,000 pounds of steam: $0.00085
Labor cost per 1,000 pounds of steam (fireman @ $0.40 per hour): $0.02920
Total cost to generate 1,000 pounds of steam (Fuel, electricity, labor): $0.33700

TABLE IV
Results of the Boiler Test on Boilers at Creamery B

Date of test: July 26, 1935
Type of boilers: Scotch marine (2 200-horsepower, 1 150-horsepower, 1 125-horsepower)
Kind of stokers: Underfeed (2 Leffel underfeed stokers, 2 Iron Fireman underfeed stokers)
Average steam pressure in pounds per square inch gauge: 120.00
Average feed water temperature in degrees Fahrenheit: 185.45
Average flue gas temperature in degrees Fahrenheit:

Boiler A	433
Boiler B	413
Boiler C	390
Boiler D	382

Average relative humidity per cent (boiler room): 36.20
Average boiler room temperature in degrees Fahrenheit: 90.00
Average flue gas analysis:

	Stokers On	Stokers Off
Boiler A,	$CO_2 = 11.7$, $O_2 = 7.70$, $CO = 0$	$CO_2 = 9.35$, $O_2 = 9.5$, $CO = 0$
Boiler B,	$CO_2 = 10.5$, $O_2 = 9.00$, $CO = 0$	$CO_2 = 9.70$, $O_2 = 9.6$, $CO = 0$
Boiler C,	$CO_2 = 8.4$, $O_2 = 11.20$, $CO = 0$	$CO_2 = 4.40$, $O_2 = 15.6$, $CO = 0$
Boiler D,	$CO_2 = 5.7$, $O_2 = 14.35$, $CO = 0$	$CO_2 = 5.00$, $O_2 = 14.8$, $CO = 0$

Proximate analysis of fuel (as received):

Moisture:	7.70%	Sulphur:	1.02%
Ash:	4.69%		
Volatile:	39.08%		
Fixed Carbon:	48.53%		

Heating value of coal in B.t.u. per pound "as fired": 12,234
Water evaporated per hour in pounds, average: 18,891
Horsepower developed: 578
Builders' rated horsepower: 675
Quality of steam in per cent: 97.25
Average per cent of builders' rated horsepower developed: 85.60
Maximum per cent of rated horsepower developed: 100
Water apparently evaporated under actual conditions per pound of coal fired: 9.03
Equivalent evaporation per pound of coal fired from and at 212 degrees Fahrenheit: 9.54
Efficiency of boiler, furnace, and grate in per cent: 75.60
Factor of evaporation: 1.056

Boiler Heat Balance

Name of Loss	B. t. u.	Per Cent
Heating value of coal in B.t.u. per pound "as fired"	12,234	
Heat absorbed by the boiler	9,249	75.60
Heat carried away in flue gases	1,044	8.53
Evaporation of moisture from burning hydrogen	433	3.54
Incomplete combustion	000	0.00
Unconsumed carbon in ash (approximate)	122	1.00
Evaporation of moisture in fuel fired	86	0.70
Radiation and all other losses (by difference)	1,300	10.63
	12,234	100.00

Cost of coal per ton: $5.40
Fuel cost to generate 1,000 pounds of steam at 120 pounds gauge pressure: $0.2991
Electrical energy consumed in boiler room per 24 hours by stokers and lights in kilowatt-hours: 105
Cost of electrical energy per 1,000 pounds of steam: $0.00372
Labor cost per 1,000 pounds of steam (fireman @ $0.40 per hour): $0.0212
Total cost to generate 1,000 pounds of steam: $0.3240
(Fuel, electricity, labor)

The CO_2 content for good combustion should be 10 or 12 per cent; 12 per cent is considered excellent.* The boiler efficiencies at both creameries probably could be raised by better regulation of the draft and by stopping air leaks through the setting. Considerable difference was noted in the flue gas analysis at Creamery B when the stokers were on and off. An inspection of Tables III and IV shows little difference in either fuel cost or total cost (fuel, electricity, and labor) per 1,000 pounds of steam generated at the

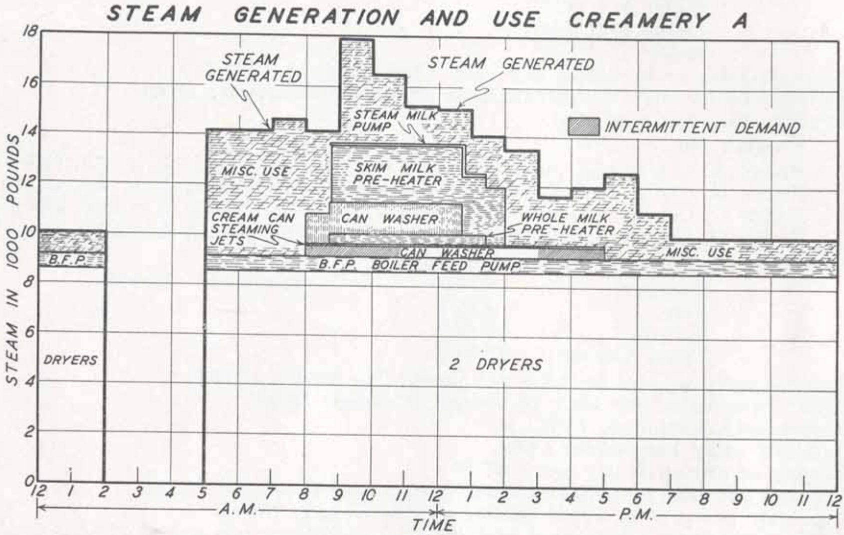

FIGURE 1

two creameries. The fuel cost was $0.307 at Creamery A, and $0.2991 at Creamery B, while the total cost (fuel, electricity, and labor) was $0.337 at Creamery A and $0.324 at Creamery B. The hourly amount of steam generated by the boilers at Creameries A and B and the average steam consumption in pounds for the principal steam using units and their hours of operation may be obtained from Figures 1 and 2. In comparing Figures 1 and 2, some points of difference are noted, the most outstanding being the amount of steam used by the milk driers at the two creameries. Sixty-five per cent of the total amount of steam generated at Creamery A was used by the two driers, while at Creamery B

* *Elementary Steam Power Engineering*, McNaughton, p. 142.

80 per cent of the steam generated was used by the four driers. Other than the example cited, there was no appreciable difference in the amount of steam used at the two creameries on the basis of the volume of product processed. At Creamery A the heaviest steam demand occurred between the hours of 9:00 and 10:00 a. m. (Figure 1), at which time the boilers were operating at approximately 89 per cent of their rated capacity. At Creamery B the period of maximum steam demand occurred between the hours of 11:00 a. m. and 12:00 noon (Figure 2), at which time the boilers were operating at 100 per cent of their rated capacity. In Figures 1 and 2 there is an area labeled "miscellaneous use." Under this classification all the steam used at each creamery not previously

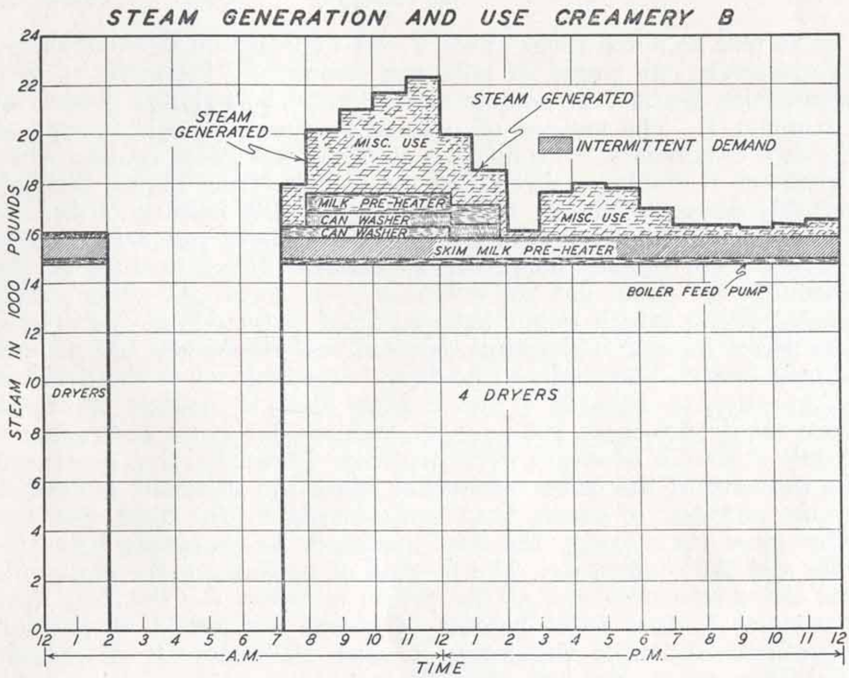

FIGURE 2

accounted for is grouped, and includes the steam used for heating water, washing, sterilizing equipment, blowing down the boilers, pasteurizing cream, etc. In other words, the "miscellaneous use" represents the difference between the gross amount of steam generated and the total amount of steam used by the various steam using units whose steam rates are known.

The boiler horsepower and the per cent capacity at which the boilers were being operated may be obtained from Figures 1 and 2. To find the boiler horsepower developed at a given time, the quantity of steam in 1,000 pounds is read from the chart and the reading divided by 32.7. Similarly, the approximate per cent capacity at which the boilers were operating may be obtained by dividing the reading by 212.

TABLE V

Drier Data - - Creameries A and B

Creamery	Number of Driers	Pounds of Milk Dried Per Hour (Average)	Method of Preheating Skimmilk	Pounds of Steam Required to Evaporate 1 Pound of Milk	Pounds of Steam Per Pound of Powder (Rolls Only)
A	2	5,899*	Barrel-Type Heater	1.44	16.84
B	4	10,521	Direct Heating (Steam)	1.41	18.65

As will be noted from Table V, the quantity of steam required to evaporate one pound of milk was practically the same at both creameries, being 1.44 pounds at Creamery A and 1.41 pounds at Creamery B. The method of preheating the skimmilk differed at the two creameries. Creamery A used a barrel-type heater, while Creamery B employed direct heating by admitting steam, through suitably designed nozzles, directly into the milk holding tanks. As far as the ultimate results are concerned, both methods of preheating were equally good, for apparently direct heating of the skimmilk by steam did not overheat it or cause any other detrimental effects which might have resulted in trouble at the driers. The direct method of heating required less steam per 100 pounds of milk heated than indirect heating. At Creamery A the detailed information in Figures 1 and 2 show that 12 pounds of steam were required to heat 100 pounds of skimmilk, while at Creamery B only 8 pounds of steam were required. Direct heating decreased the capacity of the driers somewhat, since the skimmilk is diluted by the quantity of steam that is condensed by the milk, and the drier must then supply the heat necessary to evaporate both the milk and the condensate. The method of preheating the skimmilk and the mechanical loss at the driers accounts for the fact that Creamery A used 16.84 pounds of steam per pound of powder manufactured, while Creamery B used 18.65 pounds of steam. The difference in the cost of steam, per 100 pounds of powder at the two creameries, was only $0.0224, being $0.6517 at Creamery A and $0.6293 at Creamery B (Table XVI).

With the exception of the driers and the preheaters, the largest single steam consuming unit was the straight-away can washer at Creamery A. This washer required 36.8 boiler horsepower for its operation, or about three times the boiler capacity required by the smaller rotary washers. A summary of the can washer data appears in Table VI.

* Includes skimmilk and buttermilk.

TABLE VI
Can Washers
Creameries A and B

Creamery	Type of Can Washer	Capacity in Cans Per Hour (Rated)	Capacity in Cans Per Hour (Actual)	Pounds of Steam Per Can	Boiler Horsepower To Operate	Kilowatt-Hours Per 100 Cans
A	Straight-away	720	413	2.90	36.80	1.83
A	Rotary	360	177	2.20	11.96	0.93
B	Rotary	436	297	1.62	14.79	1.31
B	Rotary	476	373	1.42	16.10	0.91

The values in Table VI compare quite favorably with those obtained by Farrall (5). Table VI shows considerable difference between the actual capacity and the rated capacity of the can washers as these washers operated at rated capacity only for relatively short periods of time. The rotary washers at Creameries A and B, which washed the cans for the "local" deliveries, operated very irregularly; oftentimes the washers would be started up with only one can on the turntable. The rotary washers which were speeded up beyond their rated capacity used less steam per can than the rotary washer at Creamery A, as shown by Table VI. No attempt was made to determine which type of washer did the most effective job of washing, as that was beyond the scope of this study. The straight-away type of washer used 2.9 pounds of steam per can, and the rotary washers used 2.2, 1.62, and 1.42 pounds of steam, respectively.

The quantity of steam used at the two creameries for pasteurizing per 100 pounds of cream was practically the same. Detailed information shows that Creamery A used 8.83 pounds of steam per 100 pounds of cream pasteurized and Creamery B used 8.85 pounds of steam at a cost of $0.00298 and $0.00286, respectively. If the total amount of steam generated (Figures 1 and 2) is charged against the milk and cream received, the steam usage for Creamery A becomes 2,037 pounds per 1,000 pounds of milk and cream received at a total steam cost of $0.685. Creamery B used 1,548 pounds of steam per 1,000 pounds of milk and cream received at a total steam cost of $0.501. Two factors contribute to this difference, the size of the physical plants and equipment which must be kept clean and the difference in volume of milk and cream received.

Distribution and Cost of Electrical Power

Before attempting to determine the power input to the various motors used in the creameries, it was necessary to study each motor's load. The motors were then grouped into two classes, constant and variable load motors. The power input to the constant load motors was determined by means of a Westinghouse Type TA Industrial Analyzer. The meter was particularly well adapted for this type of work, as it could generally be connected in and out of a motor circuit without having to stop the motor. The hours during which each motor operated were obtained by a

"Servis Recorder" clock that was fastened to the equipment being driven by the motor. The power input to the variable load motors was obtained by connecting a graphic watt-hour demand meter in each motor circuit long enough to record several cycles of opera-

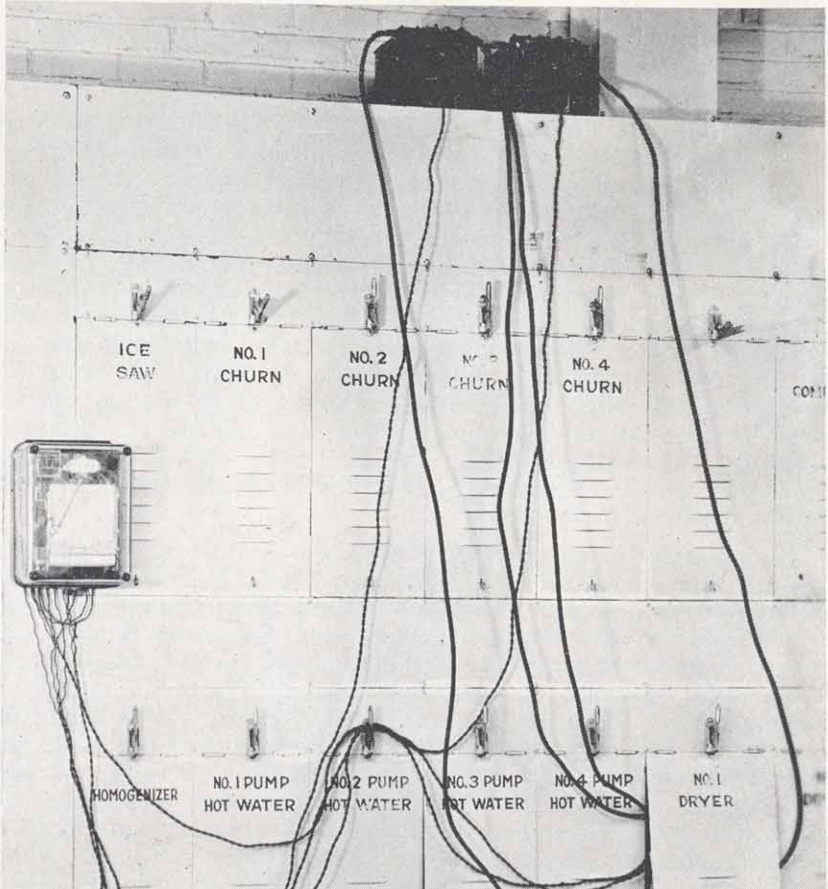

FIGURE 3
Graphic watt-hour demand meter.

tion of the driven equipment. Figure 3 shows the demand meter with the necessary current transformers connected in the roll drive motor circuit for drier No. 1, Creamery A (note the convenient, modern electrical distribution panel).

Both creameries pay for electrical power on the basis of rate schedule 4A, medium voltage power. Parts of this rate schedule are quoted to show the principal factors involved in determining the monthly power bill for the plants operating under this schedule.

SCHEDULE NO. 4-A—MEDIUM VOLTAGE POWER IDAHO POWER COMPANY

Net Rate:

$1.80 each month per contract horsepower, which charge entitles consumer to use during such month 60 kw.-hr. per contract horsepower.

.0135 per kw.-hr. for the next 50,000 kw.-hr. used per month.

.009 per kw.-hr. for all excess kw.-hr. used per month.

Gross Rate:

The net rate, increased by ten per cent up to a total of $100.00 monthly bill and two per cent on the balance thereof, constitutes the gross rate.

Power Factor Correction:

Contract horsepower in any month for synchronous motor installation shall be decreased by ½ per cent for each per cent that power factor exceeds 80 per cent, and increased by ½ per cent for each per cent that power factor is less than 80 per cent. Power factor for any month shall be determined by a test at time of system maximum demand for that month and where customer wishes to install curve drawing meter at his expense the power factor may be measured continuously.

Load Factor Discount:

A load factor discount shall apply to this schedule whenever the customer's monthly load factor exceeds 50 per cent, the amount of the discount in per cent to be determined as follows:

$$\text{Discount in per cent equals } \frac{\text{L. F. in per cent} - 50}{2}$$

Minimum Charge:

$2.00 net per month per contract horsepower, and in no event less than $24.00 per year per horsepower of annual maximum demand.

Contract Horsepower:

Contract horsepower for any month shall be the maximum demand occurring during such month established in accordance with Rule 55 of the General Rules and Regulations.

In calculating the contract horsepower on installations of 50 horsepower or less the contract horsepower shall be taken as the sum of the manufacturer's ratings of motors and other electrical appliances installed as follows:

1 motor or appliance	100 per cent of total rating
2 motors and appliances	90 per cent of total rating
3 motors and appliances	80 per cent of total rating
4 or more motors and appliances	70 per cent of total rating

As will be noted, rate schedule 4A contains provisions which allow considerable latitude in the management of electrical power. For instance, a high power factor, a high load factor, and a low contract horsepower are desirable if the power bill is to be reduced to the minimum. If the power factor drops below 80 per cent, a penalty results since the contract horsepower is increased by one-half per cent for each per cent that the power factor is less than 80 per cent. If the power factor can be raised above 80 per cent, the contract horsepower is decreased by the same amount. "Power factor is the ratio of the power to the apparent power."* A load factor discount is given whenever the customer's monthly load factor exceeds 50 per cent. "The load factor is the ratio of the

* Standards of the A. I. E. E.

average power to the peak power." The contract horsepower for any month is the maximum demand occurring during that month as recorded on the chart of the master demand meter.

The two creameries differed markedly in the management of their electrical power, as is illustrated by Figure 4 and the power

STRIP FROM MASTER DEMAND METER CHART

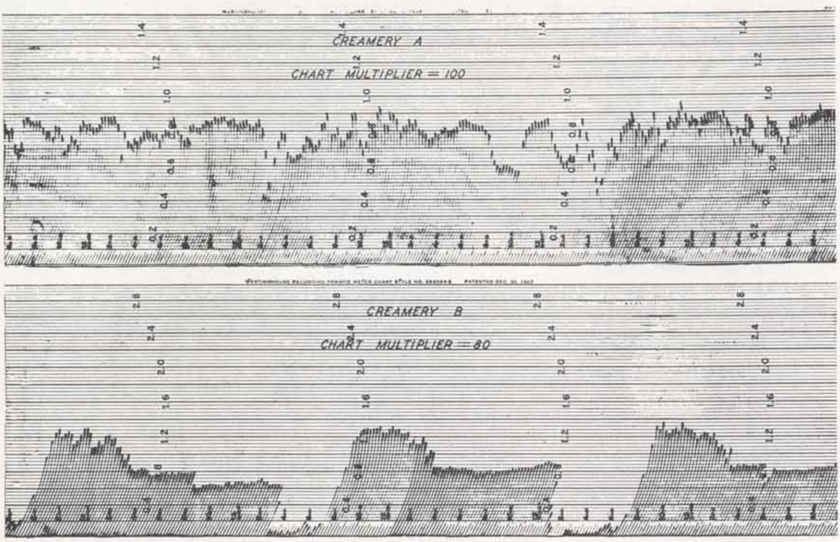

FIGURE 4

bills for July, Tables VII and VIII. The management at Creamery A has distributed the electrical power consuming operation throughout the 24 hours in order to maintain a high load factor and the lowest practical contract horsepower. The hours during which each individual piece of equipment was operated is shown in Figure 5. The numbers within the two charts refer to individual pieces of equipment, the names of which may be obtained by referring to the legend; the solid lines represent continuous operation and the broken lines intermittent operation. It is evident that the hours of operation for similar equipment at Creameries A and B differ; at Creamery A, as previously stated, the equipment was operated to effect a more nearly uniform power demand throughout the 24 hours than was the case at Creamery B.

TABLE VII
Power Bill at Creamery A

A. C. Power service rate 4-A					July 31, 1935
Meter reading 7-17-35	6420				
" " 6-17-35	5850				
	570				
" constant	100				
	57,000 Kw.-hr.				
Demand—1					
Constant—100					
100 Kw.-hr.	100 Kw.				
90% power factor					
5% power factor discount	5 Kw.				
	95 Kw.	—127 hp.			
127 hp. at $1.80			$228.60		
	57,000				
Less 60 Kw.-hr. per hp.	7,620				
	49,380 Kw.-hr. at $0.0135		666.65		
			$895.25	Gross	Net
83.3% Load factor; 16.65% load factor discount				$149.25	
Gross: 10% on $100.00, 2% on balance				746.20	$746.20
				22.90	
				$769.10	

Net amount if paid on or before August 10
Gross amount if not paid on or before August 10
Average cost per kw.-hr. = 1.31c

TABLE VIII
Power Bill at Creamery B

					July 24, 1935
Meter reading 7-16-35	0761				
" " 6-17-35	0206				
	555				
" constant	80				
	44,400 Kw.-hr.				
Plus 3½% transmission loss	1,554				
	45,954 Kw.-hr.				
Demand meter reading	1.38				
" " constant	80				
	110.4 Kw.-hr. = 148 horsepower				
148 hp. at $1.80 per hp.			$266.40		
	49,954 Kw.-hr.				
Less 60 Kw.-hr.	8,880 Kw.-hr.				
Per hp.	37,074 Kw.-hr. at 1.35		500.50	Gross	Net
			$766.90		
59.79 load factor—4.89% discount			37.50		$729.40
Gross: net plus 10% on $100.00, 2% on balance 22.70				$752.10	
Transmission rental				11.40	11.40
				$763.50	$740.80

Average cost per kw.-hr. = 1.61c

TYPICAL 24 HOUR OPERATING CHART

LABOR AND EQUIPMENT CREAMERY—A

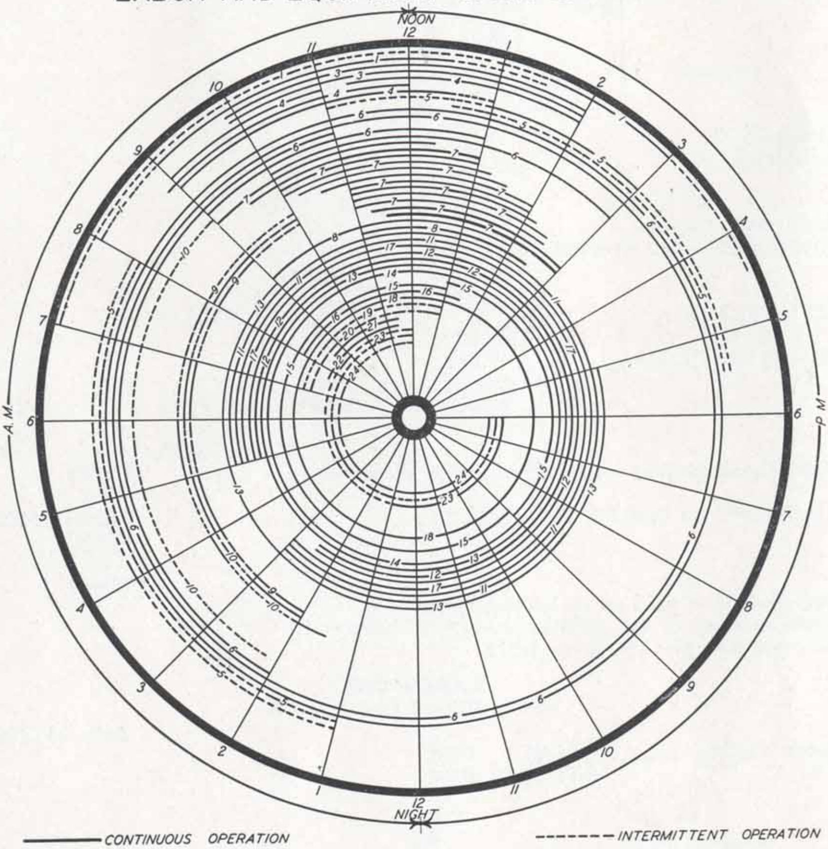

FIGURE 5A

1	Can washer	13	Compressor (ice machine)
2	Whole milk pump	14	Ice lake agitator
3	Skimmilk pump	15	Water pump
4	Separator	16	Receiving vat agitator
5	Cream pump	17	Exhaust fan for driers
6	Brine circulator	18	Coal conveyor motor
7	Pasteurizing vats	19	Ash conveyor motor
8	Hot water circulating pumps	20	Ash elevator motor
9	Churns	21	Homogenizer
10	Buttermilk pump	22	Ice cream mix vat
11	Driers	23	Ice cream aging vat
12	Stokers	24	Ice cream freezer

TYPICAL 24 HOUR OPERATING CHART
LABOR AND EQUIPMENT CREAMERY —B

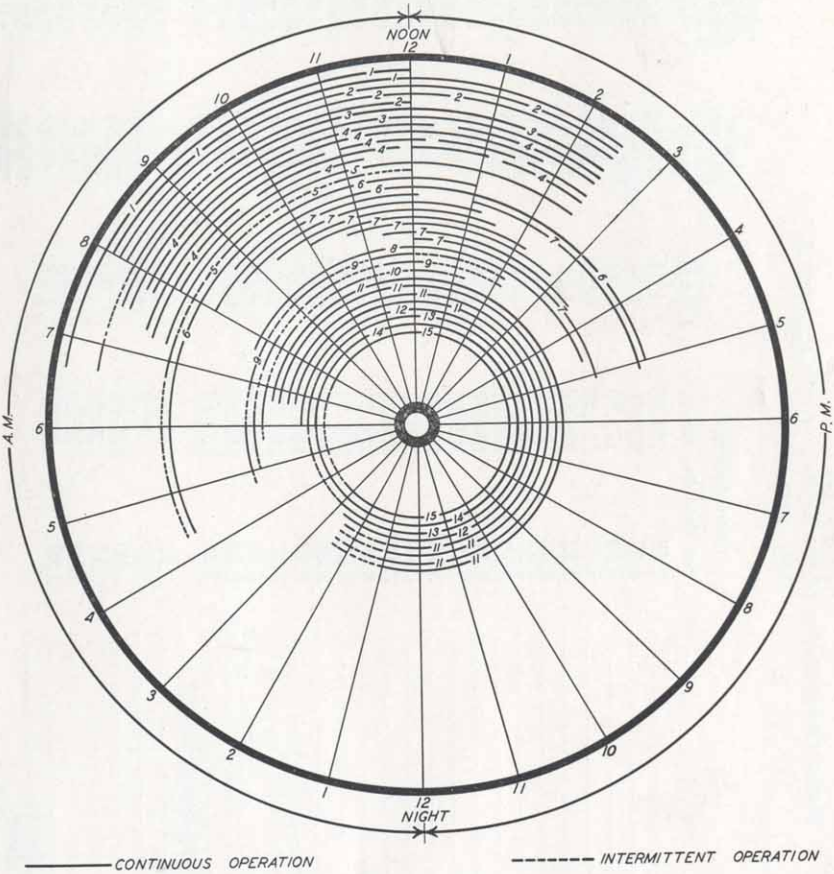

FIGURE 5B

1 Can washer
2 Whole milk pump
3 Skimmilk pump
4 Separator
5 Cream pump
6 Brine circulator
7 Pasteurizing vats
8 Hot water circulating pumps
9 Churns
10 Buttermilk pump
11 Driers
12 Stokers
13 Compressor (ice machine)
14 Ice lake agitator
15 Water pump

TABLE IX

Power Consumption of the Equipment at Creamery A
July 1935

Equipment	Hours Operated Per Day	Hours Operated Per Month	Power Kilowatts	Energy Kilowatt-Hours Per Month	Per Cent of Total Kilowatt-Hours for Plant	Operating Cost For Electrical Power Per Month
Can Washer No. 1	3.48	107.88	1.64	176.92	0.31	$ 2.32
Can Washer No. 2 (Complete)	4.35	134.85	7.55	1,018.12	1.79	13.33
Can Conveyor (Washer No. 2)	5.50	170.50	0.44	75.02	0.13	0.98
Receiving Vat Agitator	5.50	170.50	0.32	54.56	0.10	0.72
Separator No. 1	4.22	130.82	1.78	232.86	0.41	3.05
Separator No. 2	3.32	102.92	1.78	183.20	0.32	2.40
Separator No. 3	3.23	100.13	1.78	178.23	0.31	2.33
Skimmilk Pump	5.17	160.27	1.56	250.02	0.44	3.27
Skimmilk Heater Pump	5.17	160.27	1.08	173.09	0.30	2.27
Vat No. 1	3.23	100.13	0.49	49.06	0.09	0.64
Vat No. 2	3.23	100.13	0.49	49.06	0.09	0.64
Vat No. 3	3.23	100.13	0.49	49.06	0.09	0.64
Vat No. 4	3.23	100.13	0.49	49.06	0.09	0.64
Vat No. 5	3.23	100.13	0.49	49.06	0.09	0.64
Vat No. 6	3.23	100.13	0.49	49.06	0.09	0.64
Vat No. 7	3.23	100.13	0.49	49.06	0.09	0.64
Vat No. 8	3.23	100.13	0.58	58.07	0.10	0.76
Vat No. 9	3.23	100.13	0.49	49.06	0.09	0.64
Vat No. 10	3.23	100.13	0.49	49.06	0.09	0.64
Vat No. 11	3.23	100.13	0.40	40.05	0.07	0.53
Vat No. 12	3.23	100.13	0.49	49.06	0.09	0.64
Vats Nos. 13 to 16, Inc. (Not in use at present time)						
Sweet Cream Pump	1.20	37.20	1.20	44.64	0.08	0.58
Sour Cream Pump	0.27	8.37	1.24	10.38	0.02	0.14
Hot Water Pump No. 1	5.00	155.00	4.10	635.50	1.11	8.32
Hot Water Pump No. 2	3.17	98.27	4.10	402.91	0.71	5.27
Cream Pump No. 1 (to churn)	1.20	37.20	1.24	46.13	0.08	0.60
Cream Pump No. 2 (to churn)	1.20	37.20	1.24	46.13	0.08	0.60
Churn No. 2 (from demand meter chart)				805.69	1.41	10.55
Churn No. 3 (from demand meter chart)				805.69	1.41	10.55
Churn No. 4 (from demand meter chart)				805.69	1.41	10.55
Buttermilk Pump	2.17	67.27	1.08	72.65	0.13	0.95

TABLE IX (continued)

Equipment	Hours Operated Per Day	Hours Operated Per Month	Power Kilowatts	Energy Kilowatt-Hours Per Month	Per Cent Of Total Kilowatt-Hours For Plant	Operating Cost For Electrical Power Per Month
Drier No. 1 (Roll Drive)	(from demand meter chart)			5,245.20	9.20	$ 68.67
Drier No. 2 (Roll Drive)	(from demand meter chart)			5,245.20	9.20	68.67
Flaker and Elevator (Drier No. 1)	21.50	666.50	0.60	399.90	0.70	5.24
Flaker and Elevator (Drier No. 2)	21.50	666.50	0.60	399.90	0.70	5.24
Exhaust Fan (for driers)	21.50	666.50	1.60	1,066.40	1.87	13.96
Large Compressor	(from demand meter chart)			20,132.00	35.31	263.54
Small Compressor	(from demand meter chart)			5,115.00	8.97	66.96
Ice Cream Freezer	(from demand meter chart)			235.00	0.41	3.08
Ice Cream Mix Vat		25.33	1.00	25.33	0.04	0.33
Homogenizer		24.00	6.00	144.00	0.25	1.88
Ice Cream Aging Vat No. 1	6.50	201.50	0.15	30.22	0.05	0.40
Ice Cream Aging Vat No. 2	6.50	201.50	0.15	30.22	0.05	0.40
Brine Pump (Ice Cream)	4.00	124.00	2.40	297.60	0.52	3.90
Cream Vat Brine Pump	5.00	155.00	2.20	341.00	0.60	4.46
Ice Lake Agitator	24.00	744.00	0.96	714.24	1.25	9.35
Pomona Water Pump	8.00	248.00	10.00	2,480.00	4.35	32.47
Centrifugal Pump	16.00	496.00	2.70	1,339.00	2.35	17.52
Ice Can Hoist	1.00	31.00	1.08	33.28	0.06	0.44
Brine Circulator	24.00	744.00	1.24	922.56	1.62	12.08
Brine Circulator (on popsicle tank)	24.00	744.00	1.08	803.52	1.41	10.52
Circulator on Water Cooler	8.00	248.00	0.15	37.20	0.07	0.49
Boiler Room Power	(from boiler test)			658.44	1.16	8.62
Transformer Loss	(calculated)			1,002.66	1.76	13.12
Plant Lights (calculated from globe size and hours used)				1,282.41	2.25	16.80
Excitor for Synchronous Motor	24.00	744.00	3.00	2,216.00	3.89	29.00
Miscellaneous, Power, Lights, Office Equipment				197.67	0.34	2.59
Total				57,000.00	100.00	$746.20

TABLE X
Power Consumption of the Equipment at Creamery B
July 1935

Equipment	Hours Operated Per Day	Hours Operated Per Month	Power Kilowatts	Energy Kilowatt-Hours Per Month	Per Cent Of Total Kilowatt-Hours For Plant	Operating Cost For Electrical Power Per Month
Local Can Washer	4.510	139.81	3.90	545.26	1.20	$ 8.80
Truck Can Washer	5.820	180.42	3.40	613.43	1.32	9.89
Separator No. 1 (Capacity 11,000 lbs.)	5.750	178.25	3.00	534.75	1.16	8.60
Separator No. 2 (Capacity 10,000 lbs.)	5.170	160.27	2.70	313.93	0.68	5.06
Separator No. 3 (Capacity 11,000 lbs.)	7.000	217.00	2.65	575.05	1.25	9.25
Separator No. 4 (Capacity 11,000 lbs.)	7.000	217.00	2.74	594.58	1.30	9.55
Separator No. 5 (Capacity 12,000 lbs.)	3.250	100.75	1.60	161.20	0.35	2.60
Skimmilk Pump No. 1	6.500	201.50	0.94	189.41	0.42	3.05
Skimmilk Pump No. 2	6.500	201.50	0.94	189.41	0.42	3.05
Cream Pump	7.170	222.27	0.56	124.47	0.28	2.00
Hot Water Circulating Pump	9.000	279.00	0.44	122.76	0.26	1.96
Brine Pump (Cream Cooling)	8.250	255.75	0.64	163.68	0.35	2.63
Local Milk Pump	3.250	100.75	0.88	88.66	0.19	1.43
Truck Can Milk Pump No. 1	6.500	201.50	0.70	141.05	0.30	2.27
Truck Can Milk Pump No. 2	6.500	201.50	0.70	141.05	0.30	2.27
Ice Lake Agitator	24.000	744.00	0.40	297.60	0.65	4.80
Brine Pump (Churn wash water cooler)	8.500	263.50	0.50	131.75	0.29	2.18
Buttermilk Pump	2.000	62.00	0.73	45.26	0.09	0.73
Pasteurizing Vat No. 1	8.200	254.20	0.43	109.31	0.23	1.76
Pasteurizing Vat No. 2	4.100	127.10	0.43	54.65	0.11	0.88
Pasteurizing Vat No. 3	4.100	127.10	0.43	54.65	0.11	0.88
Pasteurizing Vat No. 4	4.100	127.10	0.60	76.26	0.16	1.23
Pasteurizing Vat No. 5	1.100	127.10	0.36	45.75	0.09	0.74
Pasteurizing Vat No. 6	4.110	127.41	0.40	49.56	0.10	0.80
Pasteurizing Vat No. 7	4.100	127.10	0.36	45.75	0.09	0.74
Compressor Motor	19.630	608.53	13.00	7,905.89	17.22	127.58
Water Pump	18.034	559.05	1.87	1,045.42	2.30	16.85
Drier No. 1 (Complete)	19.000	389.00	13.60	8,010.40	17.45	129.13
Drier No. 2 (Complete)	19.000	589.00	6.94	4,087.66	8.90	65.89
Drier No. 3 (Complete)	19.000	589.00	6.94	4,087.66	8.90	65.89
Drier No. 4 (Complete)	19.000	589.00	13.88	8,170.32	17.80	131.75
Churn No. 1	(from demand meter chart)			436.48	0.95	7.04
Churn No. 2	(from demand meter chart)			525.48	1.15	8.47
Stokers	(from demand meter chart)			3.247.56	7.06	52.35
Transformer Loss	(from power bill)			1,554.00	3.38	25.00
Lights and Miscellaneous Power	(by difference)			1,473.90	3.20	
Total				45,954.00	100.00	$740.80

The power demand at Creamery A (Figure 4) varies but little during the 24 hours, while at Creamery B the power demand varies from zero to 148 horsepower. At Creamery A the load factor for July was 83.3 per cent, resulting in a discount of 16.65 per cent or a saving of $149.25. The load factor at Creamery B during the same period was 59.79 per cent, resulting in a discount of only 4.89 per cent or a saving of $37.50. The contract horsepower at Creamery A was 127 after five per cent had been deducted for power factor correction, while at Creamery B the contract horsepower was 148. By raising the load factor the contract horsepower is decreased, thus resulting in a double saving. (All the motors at Creamery B were induction-type motors.) The largest single power load at Creamery A was a 40-ton compressor which was driven by a 75-horsepower synchronous motor. All other motors

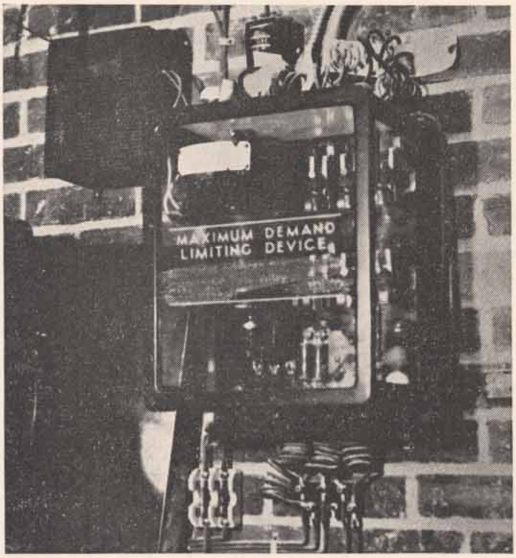

FIGURE 6
Maximum demand limiting device.

at Creamery A were induction-type motors. By operating the synchronous motor at Creamery A with the maximum possible degree of field excitation for continuous operation, the plant power factor was raised to 90 per cent, thus effecting a five per cent reduction in the contract horsepower or a saving of $12.06 for the month.

Creamery A had a very ingenuous piece of electrical apparatus known as a maximum demand limiting device.* This apparatus shown in Figure 6 was connected in the main circuit near the master meter and was so constructed as to sound an alarm in the

* The maximum demand limiting device was designed and built by Mr. J. F. Emery of the Idaho Power Company.

boiler room when the demand exceeded a predetermined value. When the alarm sounded the fireman on duty reduced the plant load by shutting off some non-essential motor until the peak demand had dropped below the set value; the idle motor could then be turned on again. A short time interval elapsed after the alarm sounded to allow time for reducing the plant load; if the warning was not heeded, relays operated and shut off the large compressor motor. This device made it possible to keep the demand from going above a predetermined value which resulted in lower power bills. By this means Creamery A has practically eliminated the power peaks, as will be noted in Figure 4. Such was not the case at Creamery B.

TABLE XI
Motor Operation and Rating Table
Creamery A

Equipment Operated by Motor	Manufactured Rating of Motor in Horsepower	Per Cent of Manufactured Rating While Operating
Can Washer	5	94.0
Can Washer	5	82.0
Separator (After it has come up to speed	5	38.6
Separator (After it has come up to speed)	5	65.0
Skimmilk Pump	3	37.8
Cream Pump	½	135.0
Water Circulating Pump	1	53.0
Brine Pump	1½	51.5
Milk Pump	1	106.0
Pasteurizer	2	24.0
Pasteurizer	2	21.7
Pasteurizer	2	21.7
Pasteurizer	2	36.0
Water Pump	7½	30.0
Drier (Roll Drive)	10	70.0
Drier (Flaker Drive)	2	33.2
Drier (Roll Drive)	15	96.0
Receiving Vat Agitator	1	39.0
Pasteurizer	1	70.0
Homogenizer	10	72.0
Vat Brine Pump	2	130.0
Ice Pond Agitator	3	38.5
Ice Cream Mix Pasteurizing Vat	1	119.0

The electrical power data secured by means of the various instruments made it possible to charge to each unit its percentage of the total electrical power used by the plant. Table IX is a list of the equipment at Creamery A using electrical power showing the hours of operation, the energy consumed in kilowatt-hours per month, the percentage of the total plant power consumed by each unit, and the electrical power cost for the month on the basis of the average cost per kilowatt-hour. The largest single load of any of the individual units was the large compressor, which used 35.32 per cent of the total power for the entire plant. The next largest load was the driers, each drier accounting for 9.2 per cent of the total energy consumed. Table X, similar to Table IX, is included for Creamery B. The largest loads at Creamery B were the number 1 and 4 driers, requiring 17.43 and 17.8 per cent, respectively, of the total kilowatt-hours for the creamery. The next largest load was the compressor, requiring 17.21 per cent of the total plant power. The equipment at Creamery B operated more hours per month than the equipment at Creamery A as will be noted in Tables IX and X. As a result of the analyzer readings, many units were found to be over-motored, (Table XI) particularly the pasteurizers equipped with 2-horsepower motors. Motors on four pasteurizers of this type were operating at only 24.0, 21.7, 21.7, and 36.0 per cent of their rated capacity. An ice cream mix pasteurizing vat equipped with a 1-horsepower motor was found to be operating at 119 per cent of its rated capacity. It will be noted from Table VI that the straight-away type washer used more power per 100 cans washed than did the rotary washers. This machine has four individual motors or a total connected load of 12½-horsepower, as compared with a single 5-horsepower motor for the rotary washers.

Two makes and sizes of motors were found on the 1500-pound churns at the two creameries, one a 220-volt, 60-cycle, 3-phase, 10-horsepower, 1200 r.p.m. motor, and the other a 7½-horsepower, 720 r.p.m. motor of the same voltage and phase. Apparently there was very little difference in the operation or power consumption of these motors. Both motors handled the job adequately, the larger motor having more reserve capacity to meet the peak loads; for this reason it ran somewhat cooler than the smaller motor. Figure 7 is a demand meter record of a representative day's churning (four churnings) of three individual churns all driven by 7½-horsepower, 720 r.p.m. motors. During the churning cycle the motor driving the churn operated under various degrees of load, ranging from a medium load when the churn was first started to a maximum of approximately 135 per cent rated capacity as the churning neared completion; then followed a period of violent power surges and current reversals.

In Figure 7 the churnings progress from left to right. As indicated in the legend, (1) is a demand meter record for one churning; (2) is the record for working the butter churned during (1); (3) is the record of the power consumed in washing the churn at the end of the day's churning; and (4) is a record of the power required to churn one churning of cream fresh that day. As will be noted by reference to Figure 7, the power required to drive the churns increased as the churning progressed. As the viscosity of the cream increased, more power was required to operate the churn, the power peak coming just as the butter was breaking and shortly after it broke. The long lines on Figure 7 clearly illustrate this condition. It should be remembered that the demand meter records graphically the average or integrated power drawn from the line during the 15-minute interval. For example, if the meter is connected in a motor circuit and the motor is not started until after five minutes of the interval has elapsed, the line on the chart will not be as long as the next succeeding line, provided the motor is still operating under constant load, owing to the fact that during the first five minutes the power demand was zero. This accounts for the small variation in length of some of the lines

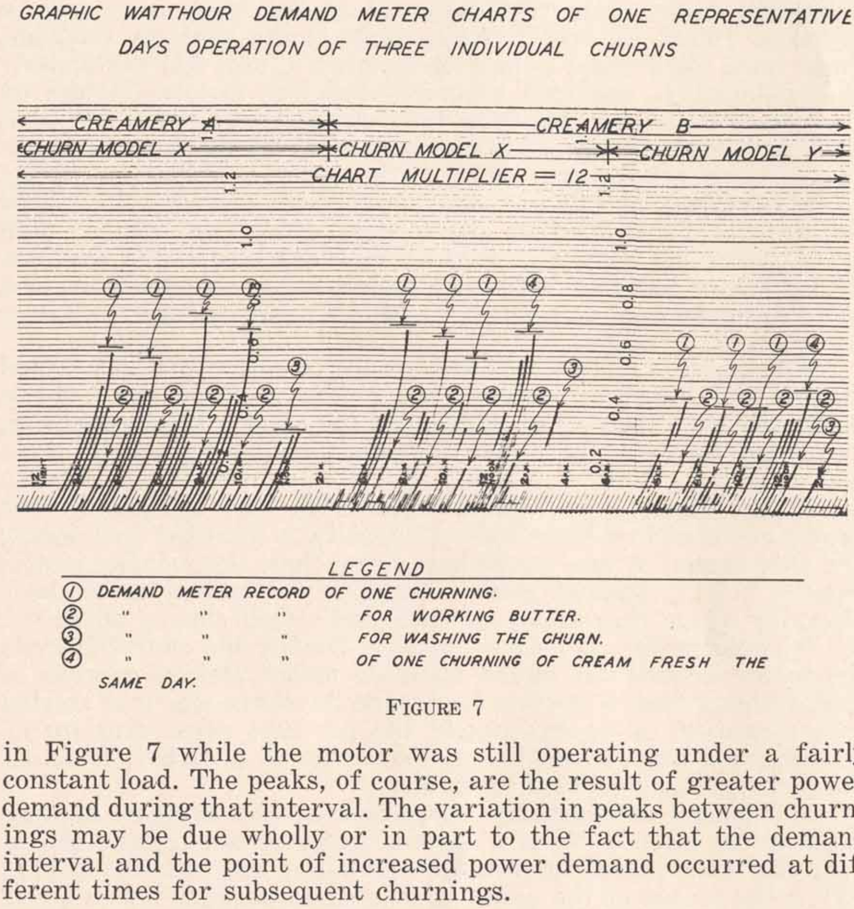

FIGURE 7

in Figure 7 while the motor was still operating under a fairly constant load. The peaks, of course, are the result of greater power demand during that interval. The variation in peaks between churnings may be due wholly or in part to the fact that the demand interval and the point of increased power demand occurred at different times for subsequent churnings.

The demand meter did not record a true picture of the power demand during the part of the churning cycle in which the butter broke. The actual power demand during this period was noted by carefully observing the meter disk. As the churning progressed, the individual granules of butter collected into a large mass of butter weighing between 1300 and 1500 pounds. During each revolution of the churn this mass of butter, lodging on the shelf in the churn, would be lifted a height equal to the diameter of the churn, the greatest surge of power coming just as the butter was lifted to a height corresponding to the horizontal axis of the churn. At this point, the effective lever arm of the butter mass reached its maximum. When the butter reached the peak of the lift and started on the down stroke, its weight caused the churn to rotate faster than it was being driven by the motor; this in turn speeded up the motor, actually driving it above synchronous speed for a brief interval of time causing it to act as an induction generator. On the uplift of the shelf the meter disk was observed to spin rapidly, then slow down, stop, and reverse its direction of rotation as the shelf in the churn was on the down stroke. This interesting observation was noted with the model X churns (large diameter, short barrel type) at both creameries, but was not the case with the model Y churn, a model of the same capacity but having a smaller barrel diameter and greater overall length.

Figure 7 shows that the power required to work the butter was less than that required during the first 15 minutes of the churning cycle, owing to the fact that while the workers were in gear the mechanical advantage of the motor was increased by the change in gear ratio. Figure 7 also shows that it takes more power to churn fresh cream than it does to churn cream held over from the previous day. This was noted for both churn models at Creamery B. Table XII shows that it took 21.8 per cent more power for churn X to churn fresh cream than day-old cream and 24.5 per cent more power for churn Y. Table XII shows that the model X churn required 40 per cent more power for fresh cream, and 43.2 per cent more power for day-old cream per 100 pounds of butter churned than did the model Y churn at Creamery B, both churns being managed by the same butter maker. Figure 7, intended primarily to illustrate the power requirements during churning, also brings out a difference in the management of the churns at the two creameries. At Creamery A the washing period was long; Table XII shows that the washing operation required 3.16 kilowatt-hours for churn X, while the same model churn at Creamery B was washed in a shorter period of time and required only 0.855 kilowatt-hours. The model X churns at the two creameries required different amounts of power per 100 pounds of butter churned. It required 14.8 per cent more power to operate churn X at Creamery A, than it did to operate churn X at Creamery B. This difference may be accounted for, in part, by the difference in the management of the two churns. The model X churn at Creamery A was operated at 88 per cent capacity, while at Creamery B the same model churn was operated at 93.5 per cent capacity.

A demand meter was connected in the main drive motor circuit at Creamery A to obtain the power required to operate the driers. The milk powder at the two plants was produced by the atmospheric roller process. The rolls of the two driers at Creamery A measured 42 inches in diameter and 90 inches in length, and each drier was driven by a 15-horsepower, 1200 r.p.m. induction motor through a set of Maag reduction gears having a gear ratio of 13.973 to 1. Two of the driers at Creamery B were of the same make and size as the driers at Creamery A, and the other two were of different makes, being older belt-driven type machines with smaller rolls (38-inch diameter and 84 inches long) driven by 10-horsepower motors. Figure 8 is a typical one-day power record for drier number 1 in Creamery A. It shows the hours

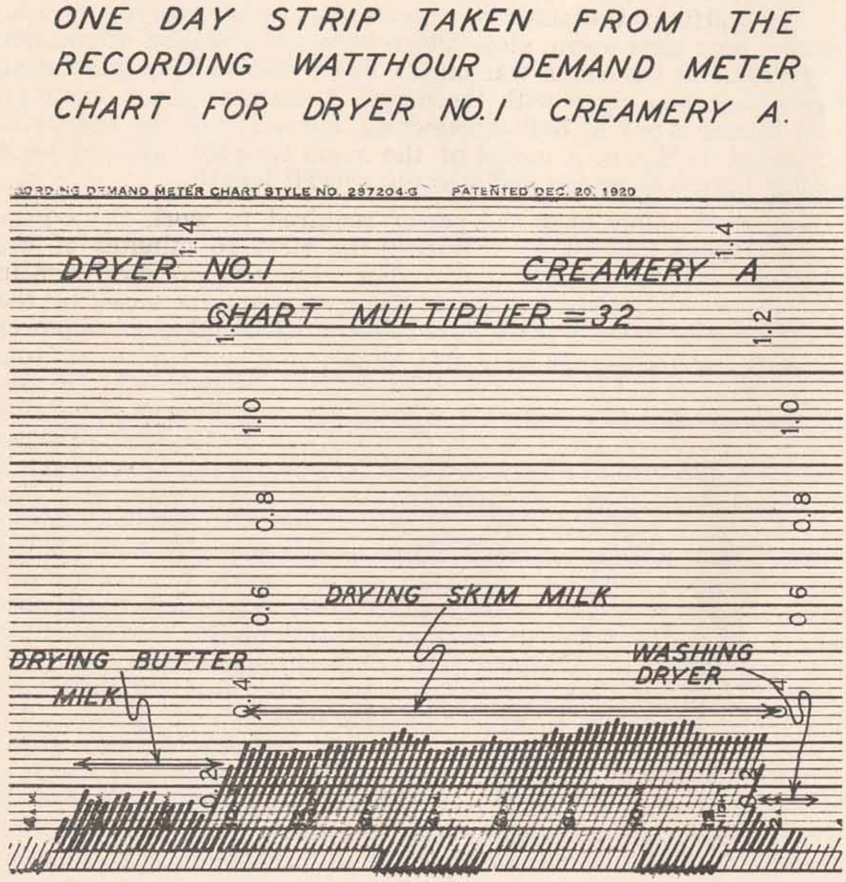

FIGURE 8

during which buttermilk and skimmilk powder were being dried, also the period at the end of the day when the drier was being washed and cleaned. During the washing period the rolls were operated until the driers were clean. The power required to turn the rolls during this period was low, as the blades were raised and the rolls separated. The power required to operate a drier was fairly uniform, fluctuating but little over a given period of time. The maximum power demand for skimmilk recorded in Figure 8 in terms of horsepower is 14, while the average is 12, which means that on the average the 15-horsepower drive motor was operating at approximately 80 per cent of its rated capacity. It must be remembered that this represents the operating conditions

TABLE XII

Churn Operating Data Creameries A and B

Creamery	Churn Model	Number of Churnings: Day Old Cream	Number of Churnings: Cream Fresh Day Churned	Total Butter Churned Pounds	Churn Capacity Pounds	Capacity at Which Churn Was Operated Per Cent	Kilowatt-Hours Per 100 Pounds of Butter Churned Average*	Kilowatt-Hours to Operate Churn While Washing
A	X	19		25,136	1,500	88.00	0.442	3.160
B	X	12		16,765	1,500	93.14	0.385	
B	X		2	2,884	1,500	96.13	0.469	0.855
B	Y	15		22,307	1,500	99.14	0.269	
B	Y		5	7,349	1,500	97.99	0.335	0.672

* Does not include power to operate churn while it is being washed at the end of the day's churning.
Average churning temperature of day old cream = 50-55 degrees Fahrenheit.
Average churning temperature of fresh cream = 40-44 degrees Fahrenheit.

for one individual drier at the time the tests were made, and the foregoing figures could easily be changed if the blade pressure on the rolls were increased or decreased, or the pressure of the end boards on the rolls altered. At Creamery B the drive motor on the same make of drier at the time the test was made was operating at approximately rated capacity, but the drive motor on one of the smaller driers was operating at only 72.5 per cent of its rated capacity.

Blades were replaced every four days at Creamery A and on July 17 a sharp set of blades replaced the dull blades on drier number 1. The meter record during the next four days did not show any power increase which could be attributed to the blades becoming dull. Apparently the degree of dullness occurring within a four-day period would not warrant changing the blades that often from the standpoint of the additional power consumed. As a matter of fact, during the day in which the blades were changed, slightly more power was required to drive the rolls than during the next three days. This may be due in part to the fact that it requires some time to effect a blade adjustment that will give satisfactory operating conditions. The difference in power required to drive the rolls when drying skimmilk and buttermilk is shown in Figure 8. It took approximately 100 per cent more power to operate the rolls when drying skimmilk than buttermilk. No doubt there are several factors contributing to this difference. Two factors thought to be mainly responsible are: first, greater adhesive power of skimmilk, and second, driers operated in such a manner that there was a heavier layer of skimmilk than buttermilk on the rolls.

During a comparable period the electrical rate in kilowatt-hours per 1,000 pounds of milk and cream received is quite different at the two creameries. If the electrical energy used during a given period (see Tables VII and VIII) is charged against the milk and cream received, Creamery A has an electrical rate of 14 kilowatt-hours and Creamery B an electrical rate of 6.76 kilowatt-hours per 1,000 pounds of milk and cream received. In terms of dollars and cents this represents an electrical power cost of $0.1835 and $0.109 for Creameries A and B, respectively. This difference, while quite marked, is not as significant as the figures would indicate. Creamery A manufactures, in addition to butter and milk powder, ice cream and popsicles as well, and maintains two community refrigeration produce storage rooms, where patrons can store meat, vegetables, etc. During a comparable 31-day period Creamery B received 3,401,021 pounds more milk than Creamery A, and Creamery A received 654,396 pounds more cream than Creamery B.

Distribution and Cost of Labor

In studying the distribution of labor at the creameries, the labor operations were segregated into groups, such as receiving, butter manufacture, milk powder manufacture, etc. A work chart was then prepared for each group. The study was confined to plant labor and excluded clerical labor, truck drivers, delivery men, and managers. No difficulty was experienced in allocating the time of the regular men to a specific group. There were two men whose time was not so easily assigned, namely, the plant foreman and the plant mechanic. Their time was distributed as shown in Table XIII, based upon the approximate time given to each group. Table XIV shows the number and per cent of the total man hours allocated each group. Considerable difference was noted at the two creameries in the number of man hours and the per cent of the total man hours required for receiving milk and cream, and for testing. These differences are due to the larger quantity of milk received at Creamery B which required more labor for receiving. Creamery A receives larger cream shipments which must be tested daily, requiring more labor for testing. The boiler room at Creamery A is more completely mechanized than the one at Creamery B; hence less labor is required in the former.

TABLE XIII

Distribution of Foreman's and Mechanic's Time

	Creamery A		Creamery B	
Labor Groups	**Foreman**	**Mechanic**	**Foreman**	**Mechanic**
Receiving	25.0%	25.0%		25.0%
Butter Manufacture	25.0%	25.0%		25.0%
Ice Cream Manufacture	12.5%	12.5%		
Milk Powder Manufacture	25.0%	25.0%		25.0%
Testing				
Boiler Room	12.5%	12.5%		25.0%

TABLE XIV

Distribution of Labor in Man Hours Per Day

	Creamery A		Creamery B	
Labor Groups	**Number of Man Hours**	**Per Cent of Total**	**Number of Man Hours**	**Per Cent of Total**
Receiving	31.5	16.3	54.0	32.9
Butter Manufacture	44.0	22.7	38.0	23.2
Ice Cream Manufacture	34.0	17.6		
Milk Powder Manufacture	30.0	15.6	30.0	18.3
Testing	32.0	16.5	16.0	9.8
Boiler Room	22.0	11.3	26.0	15.8
Total	193.5	100.0	164.0	100.0

Table XV shows the cost and per cent of total cost for receiving, testing, etc. Tables XIV and XV are similar, the main difference being that the former lists the man hours per day and the latter the labor cost per day for the various groups. In Tables XIV and XV the per cent of total is approximately the same; the difference is due largely to the difference in the rate of pay received by individuals in similar groups.

There is practically a direct relationship between the operation of equipment and the use of labor, as can be noted in Figure 5, which shows a typical 24-hour operating period. It is true that some

TABLE XV
Distribution of Labor Cost Per Day

	Creamery A		Creamery B	
Section	**Cost in Dollars**	**Per Cent of Total**	**Cost in Dollars**	**Per Cent of Total**
Receiving	13.43	16.00	21.90	30.05
Butter Manufacture	20.08	23.85	19.60	26.85
Ice Cream Manufacture	16.35	19.45		
Milk Powder Manufacture	12.05	14.30	13.81	18.95
Testing	14.00	16.65	5.80	7.95
Boiler Room	8.20	9.75	11.81	16.20
Total	84.11	100.00	72.92	100.00

few pieces of equipment, such as ice lake agitators, water pumps, etc., which operate continuously, have no direct relationship with labor, but in general all other equipment needs labor for its operation. Creamery A distributes its labor more uniformly throughout the day than Creamery B, as shown by Figure 5.

Cost of Steam, Electricity, and Labor Per Unit of Product

A comparison of steam, electrical, and labor costs per unit of manufactured product is given in Table XVI. In arriving at the cost data for milk powder, it was considered as a by-product, butter being the main product at both creameries. On this basis only the steam, electrical, and man power costs, which could be attributed directly to the powder, were charged against its manufacture. Ice cream and popsicles were considered on the same basis.

A striking fact is noted by an inspection of Table XVI, namely, the low cost of steam, electricity, and plant labor per unit of product manufactured. The total cost of steam, electrical, and plant labor per 100 pounds of butter was $0.5537 at Creamery A and $0.5654 at Creamery B, and for 100 pounds of milk powder $0.8272 at Creamery A and $0.8033 at Creamery B. The difference in the manufacturing costs of butter and milk powder can be attributed principally to the difference in the volume of product manufactured at each creamery. Creamery A produced 3,113 pounds more butter per day during the test period than Creamery B, and the steam, electrical, and labor costs averaged $0.0117 less per 100 pounds of butter. Creamery B, on the other hand, produced on an average of 4,396 pounds more milk powder per day than Creamery A at a cost of $0.0239 less per 100 pounds than Creamery A. An analysis of the data in Table XVI shows that the steam cost per 100 pounds of butter at Creamery A was higher than at Creamery B due largely to two factors: a slightly greater steam cost and more extensive equipment at Creamery A that had to be washed and sterilized. The cost for electrical power per 100 pounds of butter was less at Creamery A, due largely to the difference in the management of the electrical power as previously explained. The labor cost also per 100 pounds of butter was $0.0195 less at Creamery A than Creamery B.

TABLE XVI

Steam, Electrical, and Plant Labor Costs Per Unit of Product

Energy	Creamery A								Creamery B			
	Butter		Powder		Ice Cream		Popsicles		Butter		Powder	
	Per 100 Pounds in Dollars	Per Cent of Total	Per 100 Pounds in Dollars	Per Cent of Total	Per Gallon in Dollars	Per Cent of Total	Per Dozen in Dollars	Per Cent of Total	Per 100 Pounds in Dollars	Per Cent of Total	Per 100 Pounds in Dollars	Per Cent of Total
Steam	0.1651	29.8	0.6517	78.8	0.0004	0.3	0.00002	0.06	0.1521	26.9	0.6293	78.3
Electricity	0.0727	13.2	0.0562	6.8	0.0367	28.8	0.01000	31.10	0.0779	13.7	0.0921	11.5
Labor	0.3159	57.0	0.1193	14.4	0.0901	70.9	0.02216	68.84	0.3354	59.4	0.0819	10.2
Total	0.5537	100.0	0.8272	100.0	0.1272	100.0	0.03218	100.00	0.5654	100.0	0.8033	100.0

The electrical power cost per 100 pounds of milk powder was higher at Creamery B, due largely to the difference in the average cost per kilowatt-hour, which was $0.0161 at Creamery B and $0.0131 at Creamery A. The method of operating the driers differed somewhat as the driers at Creamery B required more power for their operation than did the ones at Creamery A (Tables IX and X). The steam cost per 100 pounds of powder was slightly less at Creamery B, as the cost to generate 1,000 pounds of steam at Creamery B was less than at Creamery A (Tables III and IV). The largest item of difference in cost per 100 pounds of milk powder was the labor, which cost $0.0374 less at Creamery B. At Creamery B one drier man per shift and a part-time helper handled the four driers, while at Creamery A the services of one man were required for two driers. However, it will be noted that the total power cost per 100 pounds of milk powder for the two creameries was approximately the same; Creamery B produced powder at a cost of $0.8033 per 100 pounds, and Creamery A for $0.8272 per 100 pounds.

The power costs per gallon of ice cream and per dozen popsicles for Creamery A are also included in Table XVI. Creamery B manufactured only butter and milk powder. The labor cost for the manufacture of ice cream represents the greatest item of cost, being $0.0901 per gallon or 70.9 per cent of the total power cost. Very little steam and electricity were needed for the manufacture of the ice cream. The same was true of popsicles, the labor cost being $0.02216 per dozen or 68.84 per cent of the total power cost.

No attempt has been made in this bulletin to evaluate such items as interest, depreciation, overhead, maintenance, etc. It is realized that these factors may be of equal or greater importance than the power costs in the ultimate cost of the finished product, especially in view of the fact that the power costs are low; however, it was beyond the scope of this study to include these factors.

Summary

1. The boiler capacity at Creameries A and B was 620 and 675 boiler horsepower, respectively, and the boiler efficiency averaged 74.8 per cent.
2. The cost of generating steam averaged $0.33 per 1,000 pounds of steam where an average of 294,659 pounds was generated per day.
3. The average steam consumption of the driers was 1.42 pounds per pound of milk evaporated.
4. Steam consumption of the straight-away can washer was 2.9 pounds per can as compared with 2.2, 1.62, and 1.42 for the rotary washers.
5. The boiler horsepower required for the operation of the 720-can capacity straight-away can washer was 36.8 as compared with 11.96, 14.79, and 16.10 boiler horsepower for the 360-can capacity rotary can washers.

6. The average quantity of steam required to pasteurize 100 pounds of cream was 8.84 pounds.
7. The driers used 65 and 80 per cent of the total steam generated at Creameries A and B, respectively.
8. The direct method of preheating milk for the driers required less steam than indirect heating. The direct method decreased the capacity of driers as the milk was diluted by the amount of steam condensed.
9. Average steam used per 1,000 pounds of milk and cream received was 1,792.5 pounds, or a cost of $0.591.
10. Electrical power peaks can be eliminated by staggering power operations.
11. A synchronous motor correctly operated will raise the plant power factor and lower power costs.
12. A maximum demand limiting device aids in lowering power costs.
13. Some pasteurizing vats were found to be over motored.
14. Churn motors operate under various degrees of load during a churning cycle, ranging from negative loads to overloads.
15. Churns operated at rated capacity require less power per 100 pounds of butter churned than when operated below rated capacity.
16. The long barrel, small diameter churn used less power per 100 pounds of butter than the short barrel, large diameter type of churn.
17. The electrical energy required to churn fresh cream was 23.1 per cent greater than was required to churn aged cream.
18. Only one-half as much power was required to drive the drier rolls for buttermilk as was required for skimmilk.
19. The straight-away can washer used 1.83 kilowatt-hours per 100 cans as compared with 0.93, 1.31, and 0.91 kilowatt-hours for the rotary washers.
20. The average energy consumption per 1,000 pounds of milk and cream received was 10.38 kilowatt-hours when the average daily quantity of milk and cream received was 174,900 pounds.
21. The average energy cost per kilowatt-hour was $0.0146 when an average of 51,477 kilowatt-hours per month was used.
22. The labor operations were distributed more uniformly throughout the day at Creamery A than at Creamery B.
23. Creamery B received an average of 110,000 pounds more milk per day than Creamery A, and as a result 32.9 per cent of the total man-hours of labor per day was charged to "receiving" as compared with 16.3 per cent at Creamery A.
24. Creamery A received an average of 21,100 pounds more cream per day than Creamery B, resulting in 16.5 per cent of the total man-hours per day being charged to "testing" as compared with 9.8 per cent for testing at Creamery B.

25. More extensive boiler room equipment was in operation at Creamery A resulting in fewer man-hours for "boiler room" operation.
26. Steam, electricity, and labor averaged respectively 28.35, 13.45, and 58.20 per cent of the total energy cost of manufacturing butter.
27. Steam, electricity, and labor averaged respectively 78.55, 9.15, and 12.30 per cent of the total energy cost of manufacturing milk powder.
28. Labor represented 70.9 per cent of the total energy cost of manufacturing ice cream.
29. Labor represented 68.84 per cent of the total energy cost of manufacturing popsicles.
30. The cost of electrical energy for manufacturing ice cream and popsicles averaged 29.95 per cent of the total cost.
31. The average total cost of steam, electricity, and labor used in manufacturing butter was $0.5595 per 100 pounds of butter.
32. The average total cost for steam, electricity, and labor used in manufacturing milk powder was $0.8152 per 100 pounds of powder.
33. The steam, electricity, and labor cost for manufacturing one gallon of ice cream was $0.1272.
34. The steam, electricity, and labor cost for manufacturing one dozen popsicles was $0.03218.

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REFERENCES

(1) **Camburn, O. M.**
1931 Cooperative Creamery Operation in Vermont. University of Vermont and State Agricultural College, Vermont Agricultural Experiment Station, Burlington, Vermont. Bulletin 335.

(2) **Camburn, O. M.**
1932 Steam Usage in Vermont Cooperative Creameries. University of Vermont and State Agricultural College, Vermont Agricultural Experiment Station, Burlington, Vermont. Bulletin 339.

(3) **Camburn, O. M.**
1935 Electrical Power Usage in Vermont Cooperative Creameries. University of Vermont and State Agricultural College, Vermont Agricultural Experiment Station, Burlington, Vermont. Bulletin 388.

(4) **Farrall, A. W.**
1927 Power Requirements of Electrically Driven Dairy Manufacturing Equipment. University of California, College of Agriculture, Agricultural Experiment Station, Berkeley, California. Bulletin 433.

(5) **Farrall, A. W.**
1929 The Continuous Can Washer for Dairy Plants. University of California, College of Agriculture, Agricultural Experiment Station, Berkeley, California. Bulletin 466.

(6) **Hills, J. L.**
1934 Forty-Seventh Annual Report. University of Vermont and State Agricultural College, Vermont Agricultural Experiment Station, Burlington, Vermont. Bulletin 380.

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