Layouts and Operating Criteria for Automation of Dairy Plants Manufacturing Butter and Dried Milk Products

Marketing Research Report No. 883

Agricultural Research Service
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Contents

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Layouts and Operating Criteria for Automation of Dairy Plants Manufacturing Butter and Dried Milk Products

By P. H. Tracy [1]

SUMMARY

Automated and highly mechanized methods of operations and an improved layout can reduce costs for dairy plants manufacturing butter and dried milk products.

Labor costs in a plant using 250,000 pounds of milk daily in its manufacturing schedule would be about $33,440 less annually in an automated plant with an improved layout compared with a nonautomated plant with a typical layout. The automated plant requires 17 workers, eight fewer than the 25 required in a nonautomated plant of the same size. Four fewer workers would be needed in the cleaning operation and one fewer worker each for receiving, for processing, for bagging products, and for maintenance. The additional equipment required to make this reduction possible would cost an estimated $92,800.

A plant layout was developed and the equipment necessary for handling 250,000 pounds of milk daily in a plant manufacturing sweet cream butter, low- and high-heat powdered skim milk, and dried instantized skim milk and buttermilk was determined. Methods of manufacturing these items by modern automated equipment are explained.

The floor area of the plant is 21,835 square feet. Scaled drawings show the location of the equipment in the plant together with the size or capacity of each item of equipment.

A flow diagram shows the movement of milk and manufactured products through the plant, indicating the various items of equipment through which each product passes.

INTRODUCTION

Butter and dried skim milk are the two most basic products manufactured by the dairy industry since they represent the outlet for much of the Nation's surplus fat and nonfat solids of milk. The concentration of solids in butter (80-percent fat) and dried nonfat skim milk (95- to 97-percent total solids) makes it possible to store these products conveniently until needed, and their relatively good keeping quality when stored under proper conditions makes it feasible to move them into channels of wide distribution in both domestic and foreign markets.

Recent changes in the food habits of people in this country have led to definite changes in the demand for both butter and dried skim milk, as shown by the following figures:

Year	*Per capita consumption of butter*	*Per capita consumption of nonfat dry milk*
	Pounds	*Pounds*
1930	17.6	1.3
1940	17.0	2.2
1950	10.7	3.7
1960	7.5	6.3

The decrease in the demand for butter since 1930 has resulted in many small creameries closing, as well as the oldtime cream centralizers where sour cream was gathered by train or truck and churned into butter. Much of this butter was not first quality. Now a large part of the butter on the market comes from creameries

[1] Dr. Tracy, formerly professor of dairy technology, Department of Food Technology, University of Illinois, conducted the research and prepared the report under a research contract with the U.S. Department of Agriculture.

where fresh whole milk is brought directly from the farm producers and separated into sweet cream, which is then churned into salted or unsalted, ripened or unripened butter of high quality. This change meant that the skim milk which, for the most part, remained on the farm under the former system now needed to be disposed of profitably by the creamery. Some plants converted the skim milk into sweetened condensed or concentrated milk and sold it to bakeries or to candy and ice cream manufacturers. More recently, however, the increased demand for nonfat solids not only for industrial use but also for household use has led many plants to convert to the manufacture of sweet cream or butter and dried skim milk or both.

This trend resulted in building plants capable of processing several hundred thousands of pounds of milk per day. Some of these plants now are merging with other plants to get the volume of milk necessary for more efficient operation.

Two types of powdered skim milk are being made—low heat and high heat. Low-heat skim milk is used primarily in food industries where a less cooked flavor is desired. In some products, however, such as bread dough, the milk proteins should be at least partly denatured by heat and the high-heat powder is used.

By raising the moisture content of a powder to about 10 percent and then redrying it, the powder particles agglomerate in such a way that they will quickly disperse, even in cold water. This process, called instantizing, led to the development of instant powder—a very popular item for household use.

The sweet cream resulting from the manufacture of dried skim milk can be used in various ways. It can be sold as a 36- to 40-percent fat product for use in ice cream manufacture; it can be sold for bottling as whipping cream, coffee cream, or half-and-half; or it can be sold for general use in the food industry. For the ice cream trade, this sweet cream can be reseparated into a 75- to 80-percent plastic cream. It can also be made into butter or butteroil. Changing market conditions may cause processors to shift from one of these products to another. For this reason, some plants are so equipped that such shifts can be readily made.

The purpose of this study is to provide the dairy industry with information that will be helpful in (a) increasing the productivity of labor in the plants through improved layouts and automated procedures, (b) improving quality of dairy products by establishing more uniform and better controlled methods of operation, (c) improving working conditions by doing away with the jobs ordinarily requiring difficult and tedious labor, and (d) estimating the benefits resulting from improved layouts, equipment, and automated procedures. Such information should be helpful in remodeling old plants, as well as in building new ones.

A plant site showing the position of the plant on an assumed location is given for a plant handling 250,000 pounds of milk per day. Layouts showing types of equipment and arrangements necessary for automated and highly mechanized operations are also shown.

The labor needed for performing the various functions necessary to operate the automated plant are described in detail to explain better how the system works and to compare the labor costs of such an operation with the estimated labor costs of a nonautomated plant of the same size.

ASSUMPTIONS REGARDING PLANT OPERATIONS

To illustrate principles of plant layout and methods of operation for a butter and dried milk products plant, it was necessary to make certain assumptions. They were as follows:

1. All the milk handled in the plant will arrive in bulk tanks from local milk producers who will cool and store their milk in farm tanks. The average test of the milk will be 3.6-percent fat and 8.7-percent milk solids-not-fat. The capacity of the plant will be sufficient to handle 250,000 pounds of milk on a peak operating day. The plant will operate 7 days per week, but workers will be limited to a 5-day workweek of 40 hours.

2. The fat (9,000 pounds daily) will be churned into sweet cream butter. Assuming no fat loss and that the butter will contain 80.2-percent fat (legal minimum 80 percent), 11,222 pounds of butter will be made daily.

3. The nonfat solids of the milk (21,317 pounds daily) will be made into dried skim milk as follows:

75 percent low-heat powder (of which 50 percent is to be made into instantized powder)

25 percent high-heat powder

4. All the buttermilk (that portion of the cream left after the fat is made into butter) will be dried. All dried products (22,423 pounds daily) will contain 97-percent total solids.

5. All the dried products will be packaged in 100-pound nonabsorbent moistureproof bags.

6. Provisions will be made to store the butter for at least 2 weeks at 40° F. The storage room will be large enough to handle 2 weeks' supply and will be maintained at ambient temperature.

7. The plant will be so designed that the capacity can be doubled without major building alteration and with a minimum of additional equipment.

SUGGESTED LAYOUT OF THE PLANT

The suggested layout of the plant is shown in figure 1. The components are arranged for efficient flow of products and containers, utilization of space, arrangement of equipment, and future expansion.

The suggested plant is shaped irregularly. The maximum dimensions are 211 feet by 143 feet, providing about 22,391 square feet of usable floorspace.

Components of the Plant

The major components of the plant are: Receiving shelter, processing room, evaporating and drying room, bagroom, powder and dry storage room, butter storage room, laboratory, cleaned-in-place (CIP) room, offices, boiler room, refrigeration room, shop and parts storage room, and loading-out area. An incinerator is located at one corner of the plant.

The layout in figure 1 shows the arrangement of each item of equipment in each component. Each item is numbered and is referred to by this number (in parentheses) in the discussion of the various components.

All the equipment is drawn to scale. The elevation of equipment was carefully noted so as to have sufficient room for ease in sanitizing and maintenance. The flow of products through the facility is shown on the flow diagram. The flow of products through the equipment in conjunction with the services required for the equipment, space requirements, and storage requirements determine the plant layout.

Receiving Shelter

The receiving shelter area contains 1,440 square feet and is 36 feet wide by 40 feet deep. A dock 12 inches high extends across the back. On the dock are located a receiving-control panel (113) and an automatic CIP unit (82) used principally in cleaning tank trucks. A monorail with a hoist holding the CIP spraying unit (117) is suspended from the ceiling so that it can be easily shifted from one truck to another. A receiving pump (2) and air exhaust fan (122) are provided in the shelter area. The floor is pitched three-fourths inch per foot toward a drain trough to facilitate draining milk and cleaning solutions from the trucks. Three positions for trucks are suggested which provide for a truck to be cleaned, one to be emptied of milk, and one in a "ready" position. An overhead garage-type door, electrically operated, is built at each position so that the area may be closed off as a precaution against unfavorable weather, dust, and insects. The milk will arrive in 3,000-gallon bulk tank trucks (1). The trucks will be emptied with a 150-gallon-per-minute (g.p.m.) receiving pump (2).

The floor is dairy tile and the walls are ceramic tile. The ceiling is constructed from moisture-proof material with an enamel finish. The height of the ceiling is 17 feet 4 inches.

Processing Room

The processing room contains 3,697 square feet. It is L-shaped to permit access to silo-type storage tanks, which are located along one wall. The main area, 40 feet wide by 80 feet long, has ceramic-tile walls and dairy-tile floors, pitched one-fourth inch per foot to drains. The ceiling is made from moisture-resistant material with an enamel finish and is 14 feet high, which gives adequate ventilation.

Located in the processing room are the following main items of equipment: Process control panels (114,115), silo-type storage tanks (6, 30, 31, 32), weighing and sampling tanks (3, 4), separators (9, 10), plate heat exchanger for preheating raw milk and cooling skim milk (8), cream-pasteurizing system (12), cream storage tanks (18, 19), churn (23), buttermilk strainer (24), transfer pump (5), plate cooler for buttermilk (26), water-cooling and storage tank (28), water pump (29), water meter (29A), skim milk pump (35), CIP hookup stations (84 and 84A), cleaned-out-of-place (COP) wash tank (87), and level control valve (116). An air-heating and ventilating unit (125) located on the roof heats or cools the processing room.

Silo-type vertical storage tanks (6, 30, 31, 32) are insulated with outer steel jackets. Each tank has an alcove which permits access from the processing room. Each alcove contains a tank manhole, an agitator, an indicating thermometer, and an air-operated sanitary-type outlet valve. The alcoves are sealed to the walls, thus permitting the storage tanks to utilize outdoor space. The 6,000-gallon tank (30), which holds buttermilk for several days before drying, is the only one with a refrigerated surface. This surface, formed by seam-welded channels welded to the outside of the inner jacket near the bottom, is 50 square feet, sufficient for holding the temperature of buttermilk below 40° F. The refrigeration is provided by circulating ammonia through the jacket channel.

The 3,000-gallon vertical weighing and sampling tanks (3, 4) are insulated with steel outer jackets. They are equipped with manhole, agitator, sampling cock, indicating thermometer, and air-operated sanitary-type outlet valve. Each tank is equipped with three electronic load cells that sense the weight of the contents. The weights are indicated on the receiving-control panel (113).

The 6,000-gallon cream cold-wall storage tanks (18, 19) are similar to the weighing and sampling tanks (3, 4) except that each is equipped with 120 square feet of refrigerated surface for removing the latent heat of crystallization of the cream. As butterfat in cream does not solidify at once upon being cooled, the temperature of cream rises as the proportion of liquid fat to solid fat decreases. The cold-wall surface will remove this heat and maintain the cream at 40° F.

Two 40,000-pound-per-hour separators (9, 10) are suggested. Two units will provide standby service, as only one unit is required to operate the plant at a time. Unless a serviceable separator is available at all times, a plant of this type cannot continue to operate. In addition, the use of two units makes it possible to shift the flow from one to the other when the separator bowl requires cleaning. Excessive sludge in this bowl will cause a high loss of fat in the skim milk. Smaller capacity separators are available that are equipped with a desludging feature so that the sludge can be discharged without shutting down the separator. Larger units with this feature will undoubtedly be available in the future.

A plate heat exchanger (8) is suggested to heat the cold whole milk to the desired separating temperature (85° F.). The milk is forced through the unit by the positive displacement pump (7) at a rate of 40,000 pounds per hour. The warm skim milk coming from the separator (9) is used to preheat the whole milk from 40° to 72.8° F., which also cools the skim milk from 85° to 49°. Steam under vacuum is used in the final heating of whole milk to separating temperature and 34° sweet water is circulated to cool the skim milk. These heat transfers are effected by the plate and gasket arrangement which allows the product to flow between two plates while the heating or cooling medium is circulated between the adjacent plates.

Plate heat exchanger for pasteurizing cream (12) is used to treat the cream after separation and before storage. Included with this complex are a balance tank (11), 16-second holder tube (14), 3,600-pound-per-hour positive displacement timing pump (13), centrifugal pump (17), 200-gallon cream holding tank (16), flow-diversion valve (15), and vacuum steam pump (118).

The 2,025-gallon butter churn (23) is suggested for converting the 40-percent butterfat cream into butter. Associated with this operation is a 150-g.p.m. positive displacement cream pump (21) which is used to transfer cream from storage tanks (18, 19) through a tubular preheater (22) which raises the cream to churning temperature. A hot water heating and circulat-

1 BULK TANK TRUCK, 3,000 GAL.
2 RECEIVING PUMP, 150 G.P.M.
3 WEIGH TANK ON LOAD CELLS, 3,000 GAL.
4 WEIGH TANK ON LOAD CELLS, 3,000 GAL.
5 TRANSFER PUMP, 150 LB./MIN.
6 RAW MILK STORAGE TANK, 10,000 GAL.
7 POSITIVE DISPLACEMENT PUMP, 40,000 LB./HR.
8 PLATE HEAT EXCHANGER FOR PREHEATING AND SKIM MILK COOLING
9 WHOLE MILK SEPARATOR, 40,000 LB./HR.
10 WHOLE MILK SEPARATOR, 40,000 LB./HR.
11 BALANCE TANK
12 PLATE HEAT EXCHANGER FOR PASTEURIZING CREAM
13 POSITIVE DISPLACEMENT TIMING PUMP, 3,600 LB./HR.
14 16-SECOND HOLDER TUBE
15 FLOW-DIVERSION VALVE
16 20-MINUTE CREAM HOLDING TANK, 200 GAL.
17 PUMP, 3,600 LB./HR.
18 CREAM COLD-WALL STORAGE TANK ON LOAD CELLS, 6,000 GAL.
19 CREAM COLD-WALL STORAGE TANK ON LOAD CELLS, 6,000 GAL.
20 FUTURE CREAM COLD-WALL STORAGE TANK ON LOAD CELLS, 6,000 GAL.
21 POSITIVE DISPLACEMENT PUMP, 80,000 LB./HR.
22 TUBULAR PREHEATER, SUSPENDED ON SIDE OF STORAGE TANKS, 80,000 LB./HR.
22A HOT WATER HEATING AND CIRCULATING UNIT FOR TUBULAR PRE-HEATER
23 BUTTER CHURN, 2,025 GAL.
24 BUTTERMILK STRAINER
25 BUTTERMILK POSITIVE DISPLACEMENT PUMP, 150 G.P.M.
26 PLATE COOLER FOR BUTTERMILK, 150 G.P.M.
27 BUTTER BOATS (THREE), 3,500 LB.
28 WATER COOLING AND STORAGE TANK, 300 GAL.
29 WATER PUMP, 10 G.P.M.
29A WATER METER (NOT SHOWN ON FLOOR PLAN)
30 BUTTERMILK COLD-WALL STORAGE TANK, 6,000 GAL.
31 SKIM MILK STORAGE TANK, 10,000 GAL.
32 SKIM MILK STORAGE TANK, 10,000 GAL.
33 FUTURE SKIM MILK STORAGE TANK, 10,000 GAL.
34 FUTURE SKIM MILK STORAGE TANK, 10,000 GAL.
35 SKIM MILK PUMP, 26,884 LB./HR.
36 VAPOR LINE PREHEATER
37 INTERSTAGE VAPOR LINE HEATER
38 BALANCE TANK
39 EVAPORATOR PREHEATER FEED PUMP
40 EVAPORATOR PREHEATER
40A 16-SECOND HOLDER TUBE
41 FLOW-DIVERSION VALVE
42 20-MINUTE HOLDING TANK, 1,200 GAL.
43 EVAPORATOR, FIRST EFFECT
44 EVAPORATOR, SECOND EFFECT
45 EVAPORATOR DISCHARGE PUMP, 5,774 LB./HR.
46 CONDENSER
47 CONDENSING WATER DISCHARGE PUMP
48 DRYER PREHEATER
49 DRYER INFEED HIGH PRESSURE PUMP
50 SPRAY DRYER CHAMBER, 2,500 LB./HR.
51 POWDER COLLECTOR, FINAL
52 POWDER SIFTER
53 POWDER BAGGER
54 POWDER HOPPER FOR INSTANTIZER FEEDER
55 PNEUMATIC CONVEYOR
56 INFEED COLLECTOR FOR INSTANTIZER
57 POWDER AGGLOMERATING SECTION, 2,000 LB./HR.
58 WET COLLECTOR
59 AIR HEATING COIL
60 POWDER REDRYER AND AIR COOLING UNIT
61 DRY COLLECTOR
61A SECONDARY FAN FOR INSTANTIZER
62 SHAKER TABLE

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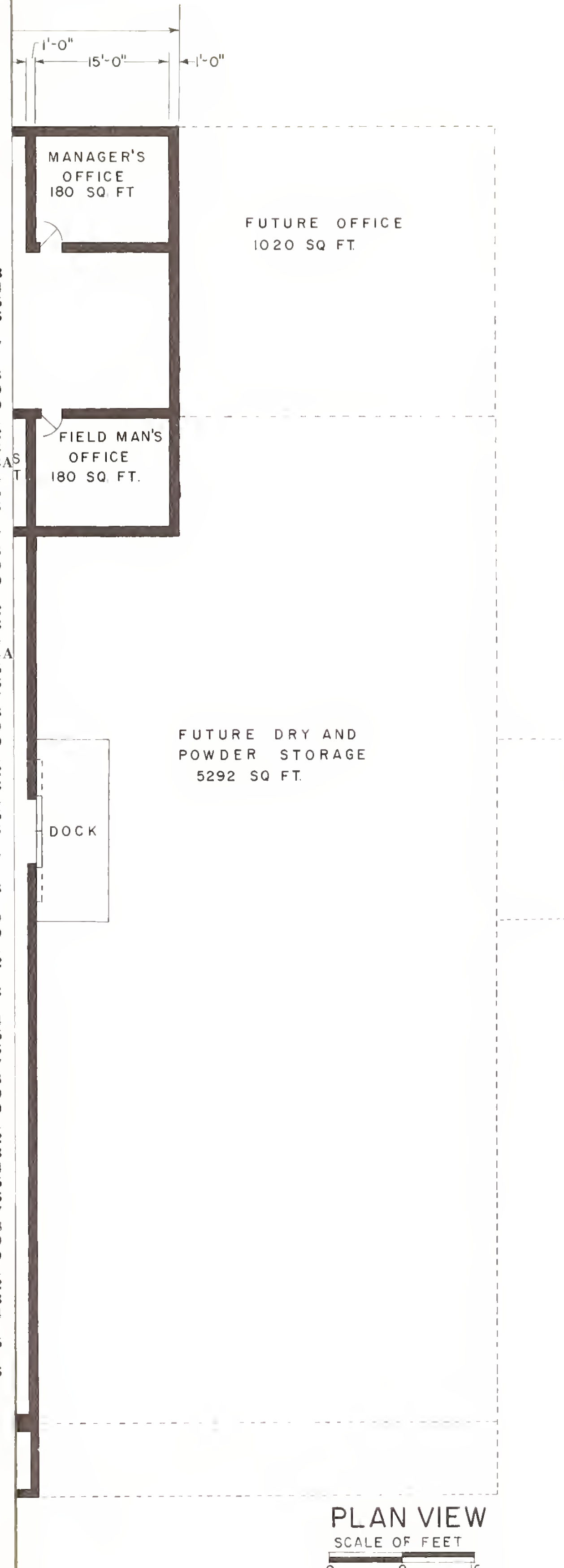

PLAN VIEW

1 BULK TANK TRUCK, 3,000 GAL.
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55 PNEUMATIC CONVEYOR
56 INFEED COLLECTOR FOR INSTANTIZER
57 POWDER AGGLOMERATING SECTION, 2,000 LB./HR.
58 WET COLLECTOR
59 AIR HEATING COIL
60 POWDER REDRYER AND AIR COOLING UNIT
61 DRY COLLECTOR
61A SECONDARY FAN FOR INSTANTIZER
62 SHAKER TABLE
63 INSTANT POWDER BAGGER
64 STAINLESS STEEL RECIRCULATING FAN
65 INDUCTION FAN
66 AIR FILTER, FAN AND AIR COOLING UNIT, 1,000 C.F.M.
67 FREON CONDENSING UNIT FOR AIR FILTER, 10 TON
68 PRIMARY FAN
69 GAS FURNACE
70 PRIMARY COLLECTOR
71 SKIMMER COLLECTOR
72 SECONDARY FAN
73 POWDER COOLER COLLECTOR
73A COLLECTOR FAN
74 POWDER STORAGE HOPPER, 10,000-LB. CAPACITY
75 BUTTERBOX LINER
76 KETTLE FOR BOILING BUTTERBOX LINERS, 25 GAL.
77 BUTTERBOX READY RACK
78 PORTABLE GRAVITY CONVEYOR
79 SCALE
80 PALLET
81 THREE-TANK CIP UNIT
82 TWO-TANK CIP UNIT FOR BULK TANKERS
83 TWO-TANK CIP UNIT FOR DRYER
84 CIP HOOK-UP STATION
84A CIP HOOK-UP STATION
85 CIP RETURN PUMP
86 FUTURE THREE-TANK CIP UNIT FOR EVAPORATOR
87 COP WASH-UP TANK
88 BOILER, 200 HP.
89 BOILER, 200 HP.
90 FUTURE BOILER, 200 HP.
91 BOILER FEED WATER SYSTEM
92 COOLING UNIT, 7.0 TON
93 FUTURE COOLING UNIT, 7.0 TON
94 ICE BUILDER, 32,000 LB.
95 FUTURE ICE BUILDER, 32,000 LB.
96 SWEETWATER PUMP FOR SKIM MILK PLATE COOLER (8)
97 SWEETWATER PUMP FOR CREAM HTST SYSTEM (12)
98 SWEETWATER PUMP FOR BUTTERMILK PLATE COOLER (26) AND CHURN (23)
99 AMMONIA COMPRESSOR, 32 TON, 40 HP.
100 AMMONIA COMPRESSOR, 32 TON, 40 HP.
101 FUTURE AMMONIA COMPRESSOR, 64 TON, 75 HP.
102 EVAPORATIVE CONDENSER, 65 TON (ON ROOF, NOT SHOWN)
103 FUTURE EVAPORATIVE CONDENSER, 65 TON (ON ROOF, NOT SHOWN)
104 AMMONIA RECEIVER, 12 FT. BY 20 IN.
105 SUMP FOR EVAPORATIVE CONDENSER
106 EVAPORATIVE CONDENSER PUMP
107 FUTURE EVAPORATIVE CONDENSER SUMP
108 FUTURE EVAPORATIVE CONDENSER PUMP
109 INSTANTANEOUS HOT WATER HEATER, 50 G.P.M.
110 FLOOR WELL FOR MACHINERY HOIST
111 ELECTRIC DISTRIBUTION PANEL
112 MACHINERY ACCESS PANEL
113 RECEIVING CONTROL PANEL
114 PROCESSING CONTROL PANEL
115 BUTTERMAKING CONTROL PANEL
116 LEVEL CONTROL VALVE
117 CIP SPRAY ASSEMBLY ON MONORAIL
118 VACUUM STEAM PUMP
119 CHECK SCALE
120 BAG STITCHER
121 TOTE BIN SCALE
122 EXHAUST FANS
123 UNIT HEATER
124 AIR HEATING AND COOLING UNIT FOR OFFICE AND PERSONNEL AREAS, 7,000 C.F.M., ON ROOF
125 AIR HEATING AND VENTILATING UNIT FOR PROCESSING ROOMS, 30,000 C.F.M., ON ROOF
126 INCINERATOR

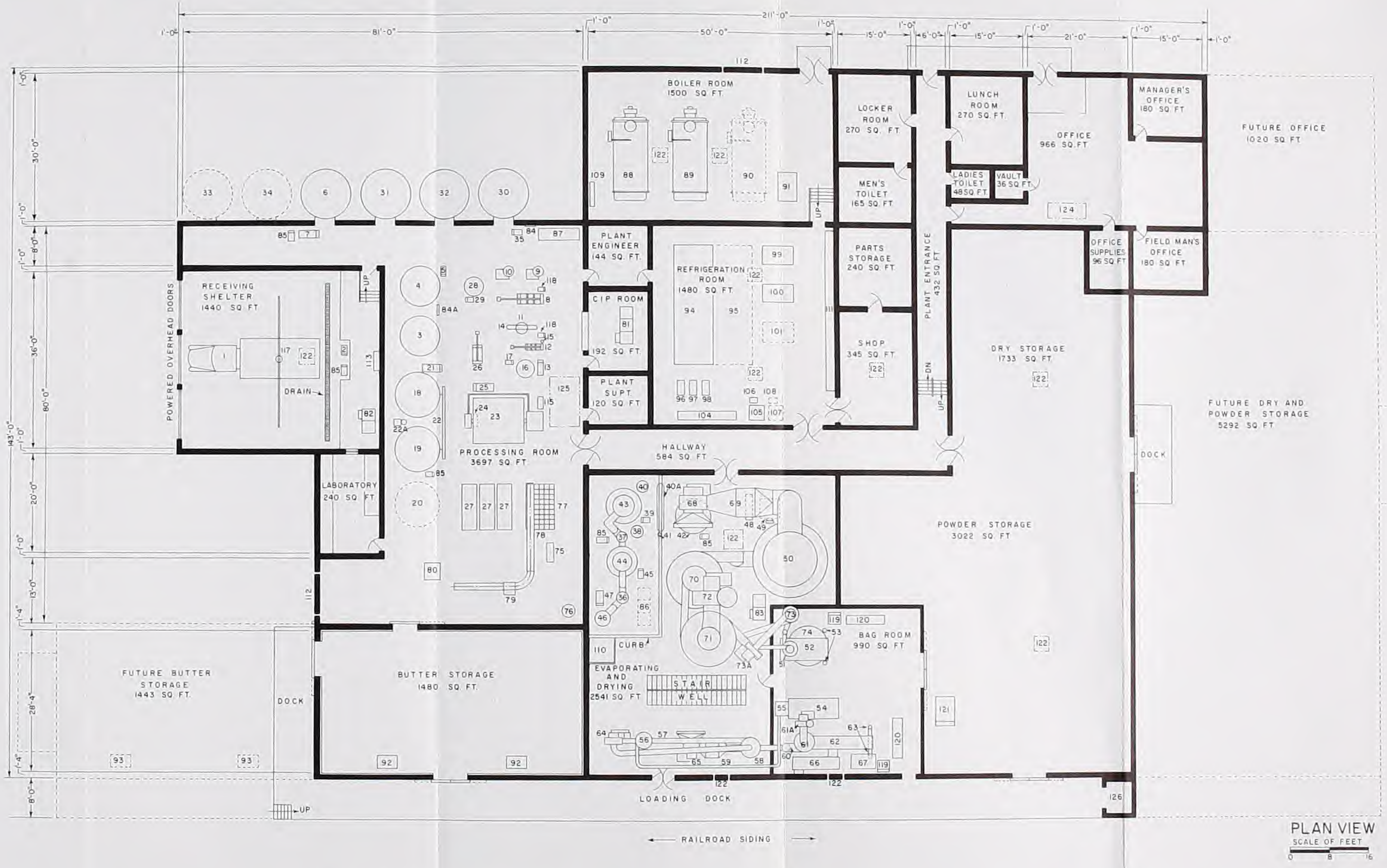

FIGURE 1.—Suggested layout of the plant.

ing unit (22A) is included with the preheater. The preheater consists of three concentric stainless steel tubes with hot water circulating between the middle and outside tube and inside the inner tube. Cream flows countercurrent to the water through the annular space between the inside tube and the middle tube. Thus, the cream is heated from two sides to a range of 48° to 52° F. The exact temperature will vary during the season of the year, usually being higher in the winter. The length of time in storage before churning, the acidity of the cream, and type of churn used will influence this temperature also.

The aluminum churn (23) is equipped with a tempering tube within it. Sweet water is circulated through this tube which controls the rise in temperature during churning. The churn has an integral system built in for controlling speed, stop-start, and positioning. It is equipped with large doors arranged so that with proper positioning practically all the butter will slide out of the churn, down the door, and into a portable aluminum butter boat (27).

The butter boats (27) are on casters so that as soon as they are loaded at the churn, they can be moved to the boxing position. Thus the churn can be unloaded rapidly and a second churning started while the butter is being boxed. The butter boats will hold 3,500 pounds of butter; they are equipped with hydraulic lifts which position the boat, making it easy to "pull" the butter for hand packing into lined fiber boxes. Three boats are suggested so that one boat will be available when needed.

The parchment liners for the butterboxes are boiled in a salt solution to prevent the later growth of yeasts and molds on the butter. A 25-gallon steam-heated kettle (26) is used for this purpose. As an aid in lining the 60-pound fiber box, a butterbox liner (75) is suggested. Parchment liners are drawn from the kettle and placed on a rack. The butterbox is positioned below this rack and held in place by a fixture so that the operator can easily drape the liner on the box and fit it inside by hand.

After the boxes are lined, they are placed on the butterbox ready rack (77) which holds the boxes within easy reach of the operator who fills them on the gravity conveyor (78). The weights are checked on a scale (79) and the boxes are placed on a pallet (80). The ready rack, gravity conveyor, and scale are portable so that on days when only one churning is made they may be arranged in front of the churn, eliminating the use of butter boats on these days.

Evaporating and Drying Room

This area contains 2,541 square feet and consists of three levels, since the overall height of the 2,500-pound-per-hour spray dryer (50) requires a 57-foot ceiling clearance. Also located in this area is a double-effect recompression evaporator, 26,884 pound per hour, and an instantizing system, 2,000 pound per hour. The second floor level is 15 feet above the first floor, and the third is 20 feet above the second.

The first and second levels have tile floors and the third has a metal grate, which permits the dust to settle to the second level. All tile floors are pitched one-fourth inch per foot to drains. The third floor grate is level. The walls are ceramic tile, and the ceiling is constructed of a moisture-resistant material with an enamel finish.

A double-effect recompression steam evaporator is recommended for this facility, equipped with a vapor-line heater, interstage vapor-line heater, and preheater. This unit has enough capacity to remove 21,110 pounds of water per hour from 26,884 pounds per hour of skim milk testing 9.02-percent solids. The unit discharges 5,774 pounds per hour of concentrate containing 42-percent solids to the drying system. The multiple-effect unit combined with recompression of part of the vapors coming from the first effect provides for good steam economy so that there will be approximately 3.03 pounds of evaporation per pound of steam consumed. Alternate selections of the evaporating equipment would include double-effect, triple-effect single pass with recompression, and indirect recompression using heat pumps. The cost of these units and the operating expense should be studied to determine the lowest total cost per pound of product made.

The 5,774 pounds per hour of 42-percent solids concentrate convert at the rate of 2,500 pounds per hour to skim milk powder testing 3-percent moisture by a vertical tower-type, gasfired spray dryer. This dryer utilizes a continuous pass principle with pneumatic collection and powder cooling.

On the third floor are components of the 2,500-pound-per-hour dryer and 2,000-pound-per-hour instantizer, including the top of the drying chamber (50), secondary fan (72), and collector fan (73A). The top part of the skimmer collector (71), cooler collector (73), and final collector (51) extend into this level. The dry collector (61), redryer (60), and secondary fan (61A) of the instantizing system also extend through to the third floor.

On the second floor are the drying chamber (50), primary fan (68), direct-gas-fired furnace (69), primary collector (70), skimmer collector (71), powder sifter (52), and top part of a powder storage hopper, 10,000-pound capacity (74). Components of the instantizing system which extend through or are located on the second floor are: Infeed hopper (56), powder agglomerating section (57), wet collector (58), dry collector (61), shaker table (62), powder redryer and air cooling unit (60), Freon condensing unit (67), and stainless steel recirculating fan (64).

The top parts of the double-effect recompression evaporator extend through or are located on the second level. These parts include the first effect (43), second effect (44), vapor-line preheater (36), interstage vapor-line heater (37), evaporator preheater (40), and vapor condenser (46). A 4-inch curb is suggested in this area to prevent washup water from slopping over into the dryer area, as these units will be cleaned at different times.

On the first floor are the bottom of the drying chamber (50) and the bottom of the primary and skimmer collectors (70, 71). The concentrate preheater (48) and the high-pressure pump (49) are used for feeding the dryer.

Components of the instantizing system located on the first floor are induction fan (65), air heating coil (59), and powder redryer (60).

The evaporating system has the following components located on the first floor level: First-effect tube nest (43), second-effect tube nest (44), bottom portions of the vapor-line preheater, interstage vapor-line heater, and evaporator preheater (36, 37, 40), condensing water discharge pump (47), evaporator discharge pump (45), centrifugal feed pump (39), balance tank (38), 16-second holder tube (40A), flow-diversion valve (41), and 1,200-gallon 20-minute holding tank (42).

CIP return pumps (85) for the evaporator and holding tank (42) are located on this level, as well as CIP unit (83), which is used on the dryer.

An open floor well (110) placed in this area would be useful for raising and lowering heavy machinery parts, such as motors, that may have to be removed for servicing. A stairwell is located between the 2,500-pound-per-hour spray dryer and the 2,000-pound-per-hour instantizing system to provide access to the different operating levels.

Bagroom

The bagroom is 30 by 33 feet and contains 990 square feet of floorspace. The height of the ceiling is 14 feet, which means the operating level of the second floor (15 feet) provides the ceiling of this room. The 10,000-pound powder storage hopper (74) extends into this room, where it connects to a dual bagger (53). Here, the powder is put into shipping bags, or, if it is to be instantized, into 1,500-pound aluminum tote bins. Also located here are the powder hopper (54), pneumatic conveyor (55), dual instant powder bagger (63), check scales (119), bag stitcher (120), an air filter, fan, and air-cooling unit (66), tote bin scale (121), and exhaust fans (122).

The walls are ceramic tile and the floor is dairy tile pitched one-fourth inch per foot to drains. The ceiling is moisture-resistant material with an enamel finish.

Powder and Dry Storage Room

This area is located adjacent to the bagroom for convenience in handling the finished powder products. The powder storage area contains 3,022 square feet, and the dry storage area, 1,733 square feet. The dry storage area is connected to the processing room by an 8-foot hallway. This hallway also provides access to other plant areas, as shown on the layout.

The capacity of the powder storage room is 2 weeks' production. The total storage requirements will be the powder produced from 250,000 pounds per day of whole milk testing 3.6-percent butterfat (BF) and 8.7-percent solids-not-fat (SNF), plus the powder made from the buttermilk left over from churning cream. Since the whole milk is separated into 40-percent cream, the skim milk would be equal to the whole milk minus the cream.

Pounds butterfat received per day

$$= 250{,}000 \times 0.036$$
$$= 9{,}000$$

$$\text{Pounds 40-percent cream} = \frac{9{,}000}{0.40} = 22{,}500$$

$$\text{Pounds skim milk} = 250{,}000 - 22{,}500$$
$$= 227{,}500$$

The percent solids-not-fat in the skim milk is equal to:

$$\frac{\text{Percent solids-not-fat in whole milk}}{\text{100-percent butterfat in whole milk}} \times 100$$

$$= \frac{8.7}{100 - 3.6} \times 100 = 9.02.$$

The total solids-not-fat in the skim milk would be:

$$227{,}500 \times 0.0902 = 20{,}520 \text{ pounds.}$$

Approximately 50 percent of the cream will appear as buttermilk, testing approximately the same as skim milk, which would result in the following total solids in pounds:

$$22{,}500 \times 0.50 \times 0.0902 = 1{,}015$$

Since the powder is 97-percent solids and 3-percent moisture, the total pounds of powder produced would be:

$$\frac{20{,}520 + 1{,}015}{0.97} = 22{,}201.$$

Thus, for 2 weeks' storage, provision must be made to store 310,814 pounds.

The powder is stored on 40- by 40-inch pallets, with 18 bags (1,800 pounds) on each pallet. The irregular shape of the bag causes some overhang; therefore, a space 50 by 50 inches is allowed for each pallet. The number of pallets required for 2 weeks' storage would be:

$$\frac{310{,}814}{1{,}800} = 172.7.$$

The pallets are stacked two high; therefore, floorspace must be allowed for one-half of the 172.7 pallets required or 87 pallets. The square feet required per pallet would be:

$$\frac{50 \times 50}{144} = 17.36.$$

87 pallets would require $87 \times 17.36 = 1{,}510.32$ sq. ft. By allowing 30 percent of the room for aisles, the palletized-powder storage would require the following area:

$$\frac{1{,}510.32}{0.70} = 2{,}157.6 \text{ sq. ft.}$$

One-half the plant's production of low-heat powder is to be instantized, which requires a 48-hour aging period between powdering and instantizing. The instantizing is handled on the basis of 5 operating days per week. The powder is held in aluminum tote bins of 1,500-pound capacity, which are 3½ feet by 4 feet by 8 feet 3 inches high.

The amount of powder instantized per week would be:

$$20{,}520 \times 0.75 \times 7 \times 0.50 = 53{,}865 \text{ pounds.}$$

Thus, on a 5-day-week basis 10,773 pounds would be processed each day. To age the powder required for instantizing (48 hours) would require enough tote bins for 2 days' production. To allow for inventory rotation, space is provided for tote bins to handle 3 days' production. The number of bins required would be:

$$\frac{10{,}773 \times 3}{1{,}500} = 21.5.$$

Each bin is 3½ feet by 4 feet at the bottom, requiring 14 square feet of floorspace. To store 22 bins would require 308 square feet of floor area. Allowing 30 percent of the room for aisles, 440 square feet of area should be set aside for tote bins.

The total calculated floor area requirement for bag and tote bin storage is 2,597.6 square feet. The suggested facility provides 3,022 square feet, which allows space for storing empty pallets.

Adjacent to the powder storage space is the dry storage area. Dry production supplies, such as bags, boxes, bag and box liners, washing powders, and butter salt, are stored here. This area has 1,733 square feet. Since it is adjacent to the powder storage area, it could be extended into this area in an emergency.

The storage areas are serviced by two 7-foot-wide sliding doors, power-operated, which lead to a truck-loading and railcar-loading dock. A 6-foot-wide swinging door, power operated, allows a forklift truck to pass down the hallway to the processing room with butter-packaging supplies. A 7-foot-wide sliding door, power operated, permits the forklift truck easy access to the bagroom to pick up full pallets.

A ceiling height of 24 feet is suggested for the storage areas. The ceiling is moisture-resistant material with an enamel finish. All floors are concrete, pitched one-fourth inch per foot to drains.

Butter Storage Room

The suggested butter storage room is 28 feet 4 inches wide by 52 feet 4 inches long. Two ceiling-hung cooling units (92) maintain the temperature at 35° F. The room is insulated with 4 inches of corkboard or the equivalent. The walls, ceiling, and floor should be insulated. The walls and ceiling are finished with a light-colored cement plaster. The floor is concrete, pitched one-fourth inch per foot to drains.

The room is serviced by a 5-foot sliding door leading to the packaging area of the processing room and two 7-foot sliding doors leading to a loading dock for trucks and railcars.

This room will store 2 weeks' production of butter. The butter tests 80.2-percent butterfat. Assuming there is no in-plant loss, the average daily production would be:

$$\text{Pounds butterfat} = 250{,}000 \times 0.036 = 9{,}000$$

$$\text{Pounds butter} = \frac{9{,}000}{0.802} = 11{,}222$$

14 days' production = 11,222 × 14 = 157,108 pounds

The 60-pound butterboxes are 13 inches by 12 inches by 13 inches long. They are stored on a 40- by 40-inch pallet in a three-by-three pattern, two high. Thus, each pallet will hold 18 boxes, or 1,080 pounds. The number of pallets needed to provide storage for 14 days' production would be:

$$\frac{157{,}108}{1{,}080} = 145.5.$$

Allowing 4 inches between pallets for air circulation and room for positioning, a 44- by 44-inch space is required for each pallet, or a total of 13.44 square feet. To store 146 pallets two high would require a floor area of 981.12 square feet. Allowing 30 percent for aisles, an area of 1,401 square feet is needed. The area provided in the layout contains 1,480 square feet.

After the butter has been in storage for several days, it hardens and then may be palletized three high.

Laboratory

A laboratory 12 feet wide by 20 feet long, providing 240 square feet, is recommended. The height of the ceiling is 10 feet. The construction of the walls, ceiling, and floor is the same as that for the processing room. The laboratory is located adjacent to the processing room and receiving shelter, where most of the samples are taken. A pass window between the receiving shelter and laboratory would eliminate carrying samples through the processing room to the laboratory.

The laboratory is equipped to conduct tests for fat and solids content, and bacteriological examinations of raw milk, butter, and powdered products, as well as necessary tests on the powder to make certain it complies with grade requirements.

CIP Room

Adjacent to the processing room is the CIP room, which provides space for CIP unit (81) and a supply of cleaning and sanitizing chemicals. This room also provides access to the back of the process control panel (114) for servicing. The room is 12 feet by 16 feet and contains 192 square feet.

The automatic CIP unit (81) utilizes three solution tanks, one for alkali wash solution, one for acid wash solution, and one for rinse water. In the morning, the rinse tank is used to make up a sanitizing solution for most of the plant equipment. This operation is discussed further in the section entitled "How the Plant Operates."

Refrigeration Room, Shop, and Parts Storage Room

The refrigeration room is 40 feet by 37 feet. Located here are a 32,000-pound ice builder (94), two 32-ton 40-horsepower ammonia compressors (99, 100), electric distribution panel (111), 12-foot by 20-inch ammonia receiver (104), sweetwater circulating pumps (96, 97, 98), evaporative condenser pump (106), and sump tank for evaporative condenser (105). A 65-ton evaporative condenser (102) is located on the roof of the building. The refrigeration room is near the major areas requiring refrigeration.

Adjacent to the refrigeration room is the shop. It is 15 feet wide by 23 feet long. A workbench and small tools for miscellaneous repair work are located here.

A 15- by 16-foot parts storage room is suggested to store parts and supplies. This room should be provided with locks.

The refrigeration room, shop, and parts storage room are constructed of cement-block walls and concrete ceiling and floor. The walls are painted; the floors are pitched one-fourth inch per foot to drains. The height of the ceiling is 14 feet.

Offices and Personnel Areas

At the front of the building are the office and personnel service areas. A 6-foot-wide entrance hallway is suggested to provide plant employees access to the locker room, men's restrooms, and lunchroom. The locker room and restrooms have ceramic-tiled walls and floors. The office area is heated or cooled by an air-heating and cooling unit (124) located on the roof.

A general office area contains 966 square feet. Two people will probably be required to keep the records pertaining to producers, production, and sales. Records will be stored in a 36-square-foot fireproof vault. A short hallway leads to the entrance of the plant and women's restroom.

At the front corner of the building is the general manager's office and across from his office is the fieldman's office. With these two offices close together, both these people are easily available to the producers, an important feature of a plant of this type.

Ceilings for the office areas are 10 feet high. Construction features would be largely determined by personal tastes.

The storage room for office supplies is 12 feet by 8 feet.

The plant superintendent's office is 12 feet by 10 feet, providing 120 square feet. Production records are kept here. The office is centrally located to the processing functions.

The plant engineer's office is 12 feet by 12 feet, or 144 square feet. It has access to both the processing and the refrigeration rooms. Records on equipment parts and maintenance are kept here.

Construction features of the superintendent's office and the engineer's office are the same as those for the processing room.

Boiler Room

The suggested boiler room is 30 feet by 50 feet and contains 1,500 square feet to house two 200 hp. boilers (88, 89), boiler-feed water system (91), 50 g.p.m. instantaneous hot-water heater (109), and a unit heater (123). Sufficient space is available in front of the boilers for retubing. A removable wall panel (112) will provide a 10- by 10-foot opening for moving boilers into or out of the room.

The ceiling is 17 feet 4 inches high. The concrete floor is 3 feet 4 inches below the main plant production and storage areas. The extra height provides for good ventilation in the summer months when a large amount of radiant heat needs to be exhausted from the room to outside.

The walls are cement block and the ceiling is concrete slab. When planning new or remodeling boiler rooms, local ordinances should be checked for construction code requirements.

Loading Docks

The plant should be located on a rail siding to permit shipment by rail to avoid cartage costs. A concrete dock for rail loading should be at car-level height and have a magnesium dockboard providing access to the railcars by the forklift trucks. The loading dock is 8 feet wide and is equipped with a canopy so that cars can be loaded during bad weather.

A loading dock for trucks is planned for both the butter storage and the dry storage and powder storage rooms. It should be constructed of concrete and equipped with a canopy. Supplies will be received by truck.

Arrangement of the Plant Components

The arrangement of the components and equipment in this plant has the following features:

1. There is no interference between the receiving and storing of the milk and the other operations in the plant.

2. The milk storage, separating, pasteurizing, and buttermaking operations are conveniently located in one compact area of the plant, and the evaporating and drying processes are located in a separate but adjacent area.

3. The cream flows a short distance from the storage tank through the preheater to the churn, resulting in a minimum gain in heat and loss in entrainment. The butterboxing equipment located between the churn and the butter storage room permits a quick and convenient transfer of the butter to the coldroom.

4. The evaporators are located in a separate room close to the supply of skim milk and adjacent to the dryers, making possible minimum direct flow of the milk both before and after condensing. This arrangement also makes it possible to have the high-head space required adjacent to that needed for the dryers, simplifying building construction.

5. The drying operations proceed by steps with the machinery located on three levels of floors, one above the other. Having all the operations together in one room minimizes travel for the powder, confines the powder dust to one area of the plant, and finishes the powder on the first floor in the bagroom, which is adjacent to the powder storage room.

6. All storage rooms are on the outside of the building convenient to the loading docks.

7. The dry storage room is easily reached through a hallway that serves the four main areas of the plant—the office, the boiler and the refrigeration rooms, the processing and buttermaking area, and the evaporating and drying area.

8. The boiler and the refrigeration rooms are centrally located, yet have an outside wall. This arrangement permits the use of short-power and refrigeration lines to the various points required and helps to keep objectionable fumes out of the processing area.

9. The location of the locker room and restrooms near the plant entrance makes it unnecessary for the workers to enter the working areas of the plant in their street clothes.

10. The lunchroom is located away from the processing areas and is convenient for both the office and the plant employees.

11. The office is located away from the noise of the plant, yet it is easily accessible to the various processing and storage areas through the connecting hallways.

12. Extending the storage tanks through the wall of the plant to the outside not only reduces the amount of inside floorspace needed, but places them close to the intake room and adjacent to the processing room.

13. Visitors can reach the main office and the superintendent's office without passing through the processing areas.

14. Additions can be made to the building without changing any of the existing operating or storage areas and without major changes in the present structure.

15. The laboratory is located close to the incoming milk and the processing room so that samples for testing can be conveniently obtained.

16. The superintendent's office is located practically in the center of the plant, simplifying his supervisory duties.

Provisions for Future Expansion

The plant as planned has a capacity of 250,000 pounds of milk per day, operating on one shift. This capacity can be doubled by operating two shifts and still allow ample time for necessary cleanup or minor repairs before the next day's operations begin.

When the volume of the production is doubled, additional butter, powder, and supply storage rooms will be needed. An addition to the office may be advisable. Provisions for these additions, as well as the additional equipment that will be needed, are shown on the layout. The additional equipment that will be needed are as follows:

Two 10,000-gallon skim milk storage tanks (33, 34)
One 6,000-gallon cream storage tank (20)
One 200-hp. boiler (90)
One 64-ton, 75-hp. ammonia compressor (101)
One 3-tank CIP unit for evaporator (86)
Two 7-ton cooling units (93)
One 32,000-pound ice builder (95)
One 65-ton evaporative condenser (103)

One evaporative condenser sump (107)

One evaporative condenser pump (108)

The building will need an additional 7,755 square feet of space which includes 1,020 square feet for the office, 5,292 square feet for dry and powder storage, and 1,443 square feet for the butter storage room. This means that to double plant capacity overall floorspace will need to be increased 36 percent.

Plant Site

A suitable location for a plant making dried nonfat milk products and butter is near a small town in a rural community where there is an ample supply of milk. An ample supply of cold, safe water is imperative, and if city sewers are not available, the soil and drainage must be suitable for installing a waste disposal system.

The building site should be large enough to provide sufficient parking space for employees and visitors and adequate driveways for trucks and cars.

The plant site shown in figure 2 is 445 feet wide and 280 feet deep. The site is adjacent to a railroad so that large deliveries of fuel oil and certain supplies are possible. This location also permits use of the railroad to ship butter and powder if desired. The plant should be located on an improved side road or on a main highway.

The plant site (fig. 2) shows the area to be used for parking and the location of the service driveways and walks.

The incinerator (126) for disposing of combustible waste material should be built adjacent to the building and near the dock that services the dry and powder storage rooms.

Landscaping in front of the building will improve the appearance of the plant.

HOW THE PLANT OPERATES

Surplus milk processing plants that manufacture milk powder and butter operate differently from city market milk plants. Occasionally, because of seasonal changes in milk production or temporary market conditions, such as the closing of schools, the volume of milk needed for bottling by the city plants is reduced. Usually these plants dispose of their surplus by transferring it to processing plants that convert the surplus into products that can be stored for future use. Such processing plants must be prepared to handle widely fluctuating volumes of milk. The operating procedures which follow provide for processing 250,000 pounds of milk in approximately 9 hours. If necessary, the plant can be operated on a three-shift basis, which would make possible the processing of 500,000 pounds of milk in 18 hours, allowing 6 hours for cleanup.

The flow of products through the plant is shown in figure 3.

Receiving and Processing Milk

Receiving Milk

The raw milk is delivered to the plant in 3,000-gallon tank trucks, which back into the receiving shelter for unloading. A transparent receiving hose is connected to the truck's outlet valve and the manhole on top the tank is opened. The receiving man notes the odor of the milk to ascertain whether the quality is acceptable. If the milk is satisfactory, it is transferred into one of the 3,000-gallon weighing and sampling tanks (3, 4) by a 150-g.p.m. receiving pump (2) by turning on the "Fill" switch located on the receiving-control panel (113) (fig. 4). The operator actuates pushbutton 2 by pulling it out from the panel approximately a fourth of an inch to aline the air-operated sanitary valve so that the milk will pass to the weighing and sampling tank selected.

The pushbuttons that operate the equipment, shown in the control panels, are pulled out to actuate and pushed in to stop. A pilot light located within the transparent button lights up when a circuit is closed. With a glance the operator knows what machine is operating. When the weighing and sampling tanks are being filled, the agitator is turned on by activating the agitator-control buttons 3 and 4 in control panel (113) (fig. 4).

When the truck tank is empty, as noted from the transparent receiving hose, the pump is stopped by pushing button 2. A blast of filtered air is then automatically released into the receiving line, pushing any milk remaining in the pipeline into the weighing and sampling tank. After a predetermined time, the air blast stops

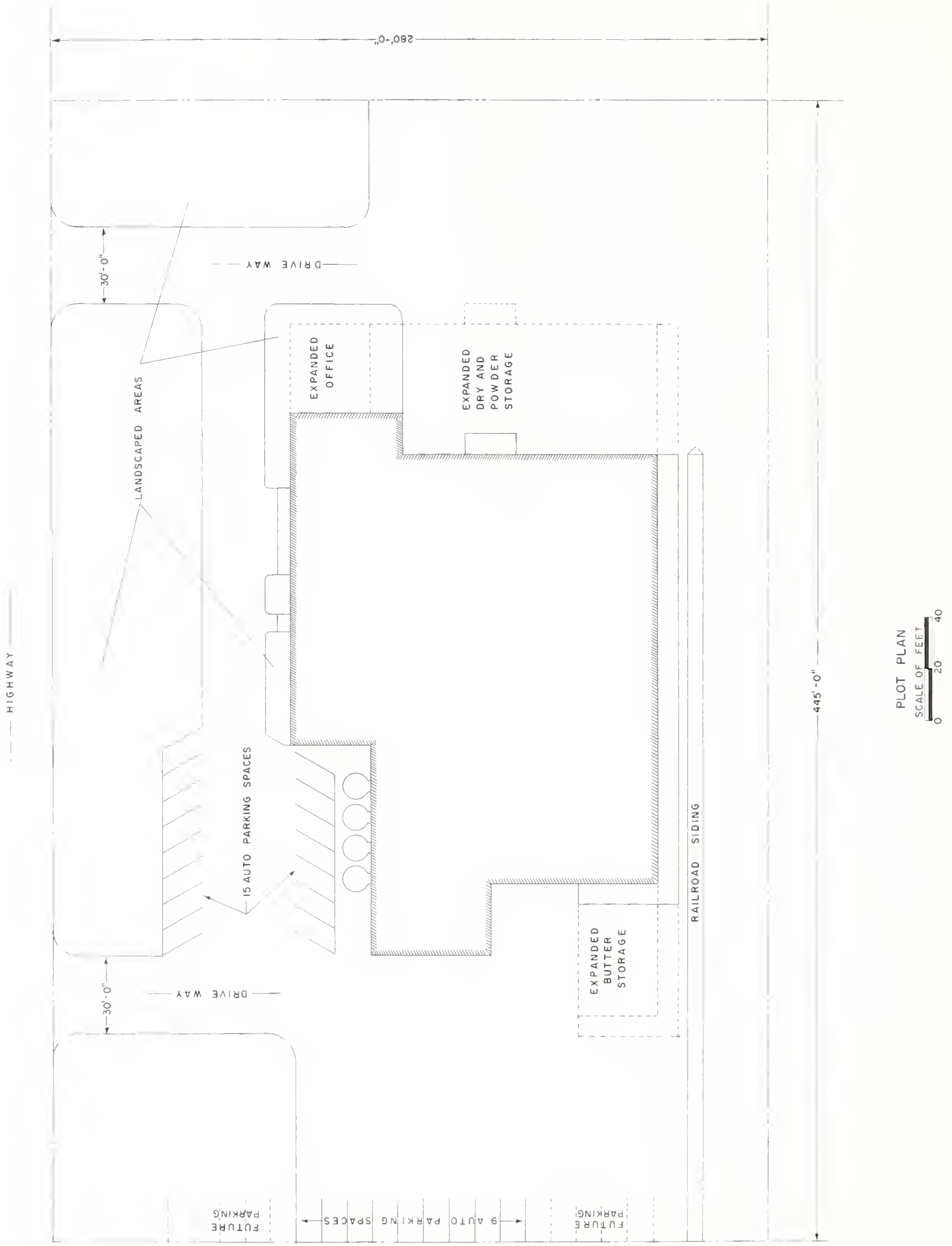

FIGURE 2. — A suggested layout for the site of an automated butter and dried products plant handling 250,000 pounds of milk daily.

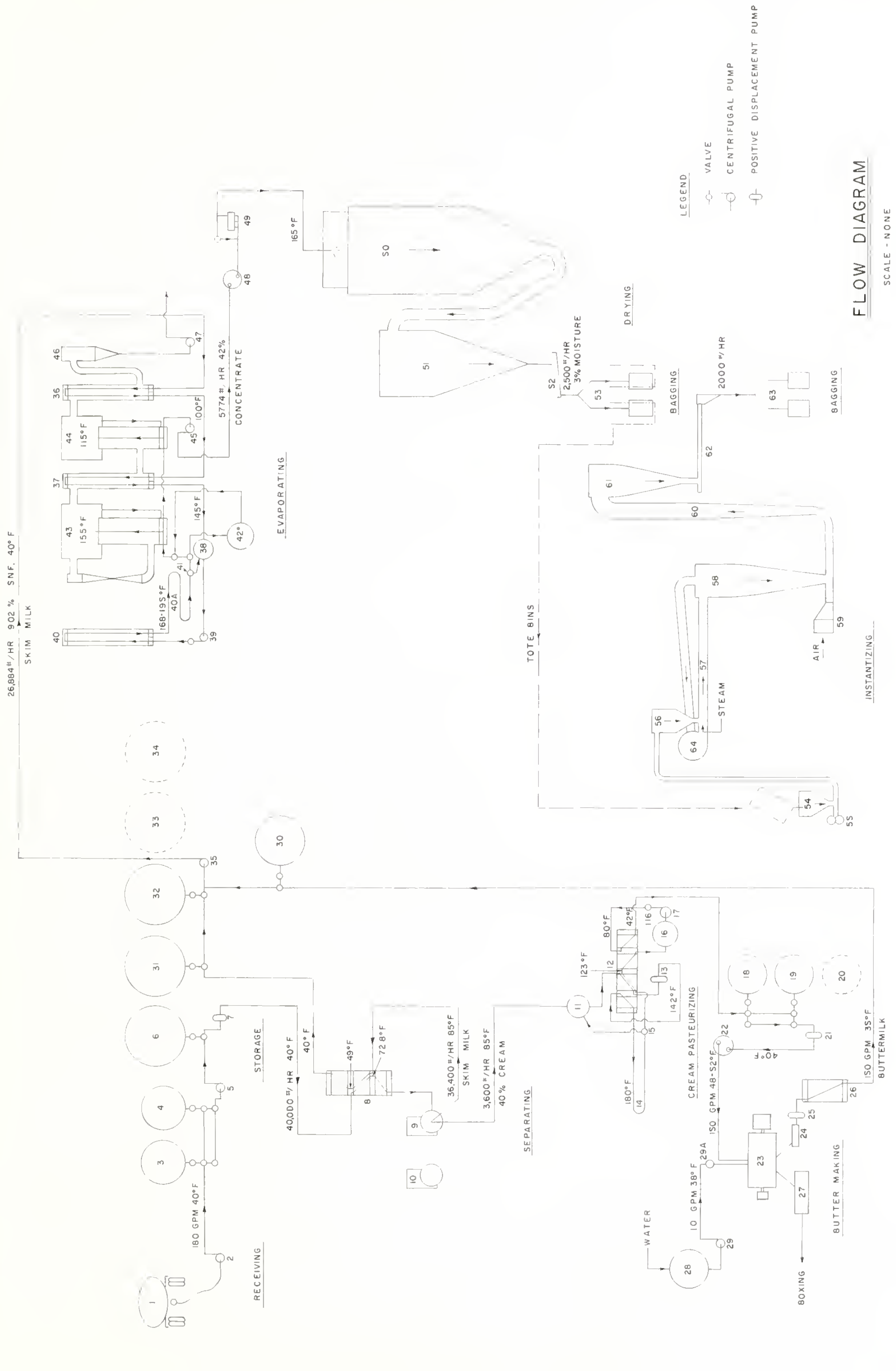

FIGURE 3.—Flow of milk and milk products through the receiving, processing, and packaging operations in an automated butter and dried milk products plant handling 250,000 pounds of milk daily.

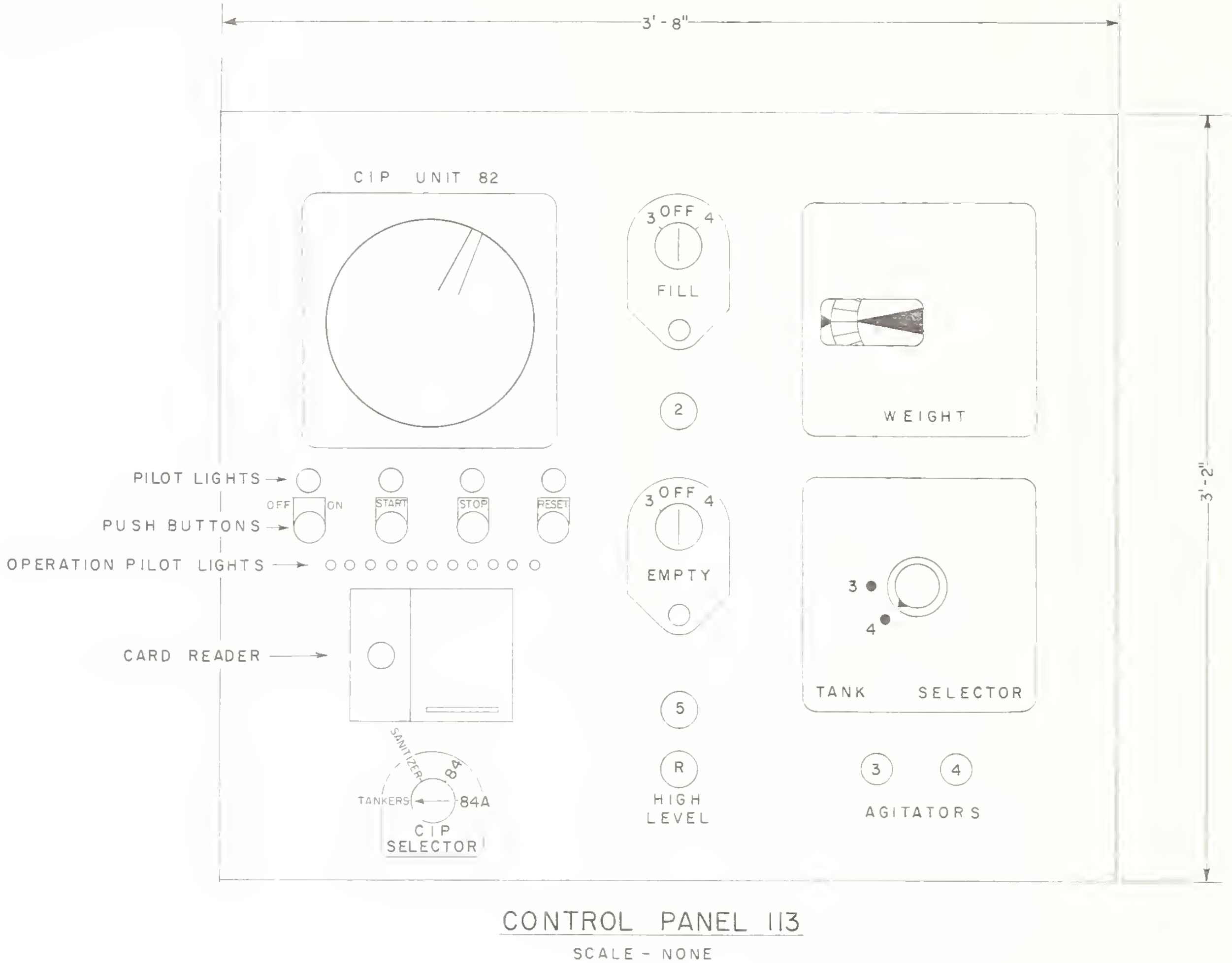

FIGURE 4. – A suggested control panel for use in the receiving operation in an automated butter and dried milk products plant handling 250,000 pounds of milk daily.

and the air-operated sanitary valve closes automatically.

The "Tank Selector" switch is then set on the weighing and sampling tank that has just been filled. This switch connects the load cells of the full tank to the weight indicator, and the weight of the milk in the tank is recorded. A sample of the milk is drawn from the sample cock in the tank manhole for laboratory analysis.

To empty the weighing and sampling tank, the "Empty" switch is set on the tank to be emptied and button 5 actuated. This button automatically alines the air-operated sanitary valves so that the 150-g.p.m. transfer pump (5) will force the milk into the 10,000-gallon raw milk storage tank (6).

The receiving operation can be practically continuous with two weighing and sampling tanks because they can be alternated between trucks. Ten 3,000-gallon bulk delivery trucks are required to deliver 250,000 pounds of milk. These trucks can be handled in 6 hours 40 minutes, or at the rate of one every 40 minutes. Twelve minutes are needed to empty the truck, 12 minutes for CIP, and 16 minutes for connecting the receiving hose and CIP unit and washing the pump compartment. The rate of flow through the separator is 40,000 pounds per hour, which means 6¼ hours will be needed to handle 250,000 pounds of milk. Thus, the time requirements for receiving and separating are well balanced.

The receiving-control panel (113) is equipped with a high-level red alarm light, which comes on when the volume of milk in the 10,000-gallon raw milk storage tank (6) reaches 8,000 gallons. This light is actuated by the tank manometer gage in control panel (114) and indicates to the receiving man that an overflow might occur.

The CIP unit (82) operation is discussed later in this report in the section on cleaning equipment.

Separating Milk

The milk is pumped from the 10,000-gallon storage tank (6) by a 40,000-pound-per-hour positive displacement pump (7). This pump forces the milk through a plate heat exchanger, which preheats the whole milk before separation and cools the skim milk after separation.

To start the separating process, pushbutton 9 on the process-control panel (114) is actuated (fig. 5). After the separating bowl is up to speed, pushbuttons S and 118 under the recorder-controller are actuated. This admits steam to the heating section of the plate heat exchanger and starts the vacuum-condensate pump, which removes the condensed steam from the heat exchanger. The "Separator Feed" switch is turned to tank (31), and the buttons under both switches actuated to open the tank inlet-outlet valves. Actuating buttons 96 and 7 starts the sweetwater-circulating pump to cool the skim milk and the positive displacement feed pump, (40,000 pounds per hour). The operator checks the recorder-controller (8) to make certain it is set on 85° F. This instrument automatically controls the steam to achieve the desired temperature. In addition, the instrument records this temperature and the time of day.

The system soon reaches equilibrium, which results in the (40,000 pounds per hour) whole milk being heated from 40° to 72.8° F. by cooling the (36,400 pounds per hour) skim milk from 85° to 49°. The steam-heating section finishes preheating the raw milk to 85°, and the sweetwater-cooling section finishes cooling the skim milk to 40°.

The separator is adjusted to deliver 40-percent cream, which flows to the balance tank (11), a part of the cream high-temperature, short-time (HTST) pasteurizing system. As soon as 3,000 gallons of skim milk are in tank (31), the evaporator starts. Since the skim milk flows to tank (31) faster than the evaporator utilizes it (36,400 pounds per hour versus 26,884 pounds per hour), some of the skim milk eventually must be switched to tank (32). This switching is done by stopping pump 7, turning the selector switch to 32, and actuating the button beneath the selector switch to restart pump 7.

Pasteurizing Cream

The 6,000-gallon cold-wall tank into which the cream is to be directed is selected on the "Cream Discharge" switch on control panel (114). The cream-pasteurizing system is started by actuating button 13, which starts the positive displacement timing pump. The pump draws the cream by vacuum through the raw side of the regenerative section in the plate heat exchanger (12) and pumps it through the heating section holder tube (14), flow-diversion valve (15), pasteurized side of the regenerative section, and finally into the initial cooling section, where it is discharged into a 200-gallon, 20-minute holding tank (16). The flow-diversion valve will divert any cream below 161.5° F., the legal pasteurizing temperature, back to the balance tank. The flow-diversion valve is controlled by the HTST recorder-controller in the control panel (114).

Immediately after starting pump 7, the vacuum steam pump (118), steam inlet solenoid valve S, 3,600-pound-per-hour pump (17), level control (116), and sweetwater pump (97) are started. This brings the product up to pasteurizing temperature quickly and thus into forward flow.

The system is controlled by the HTST recorder-controller. The operator sets the desired pasteurizing temperature (180° F.) on the instrument. The cream is heated from 85° to 142° F. by regeneration while cooling the pasteurized cream from 180° to 123°.

The speed of the timing pump is controlled over a narrow range by a float in the balance tank, which modulates a pneumatic signal to the air-operated speed-control mechanism on the pump. The purpose of this float is to make any adjustments in capacity that may be needed as variations in the output of the separator are encountered. The pump, however, is sealed so

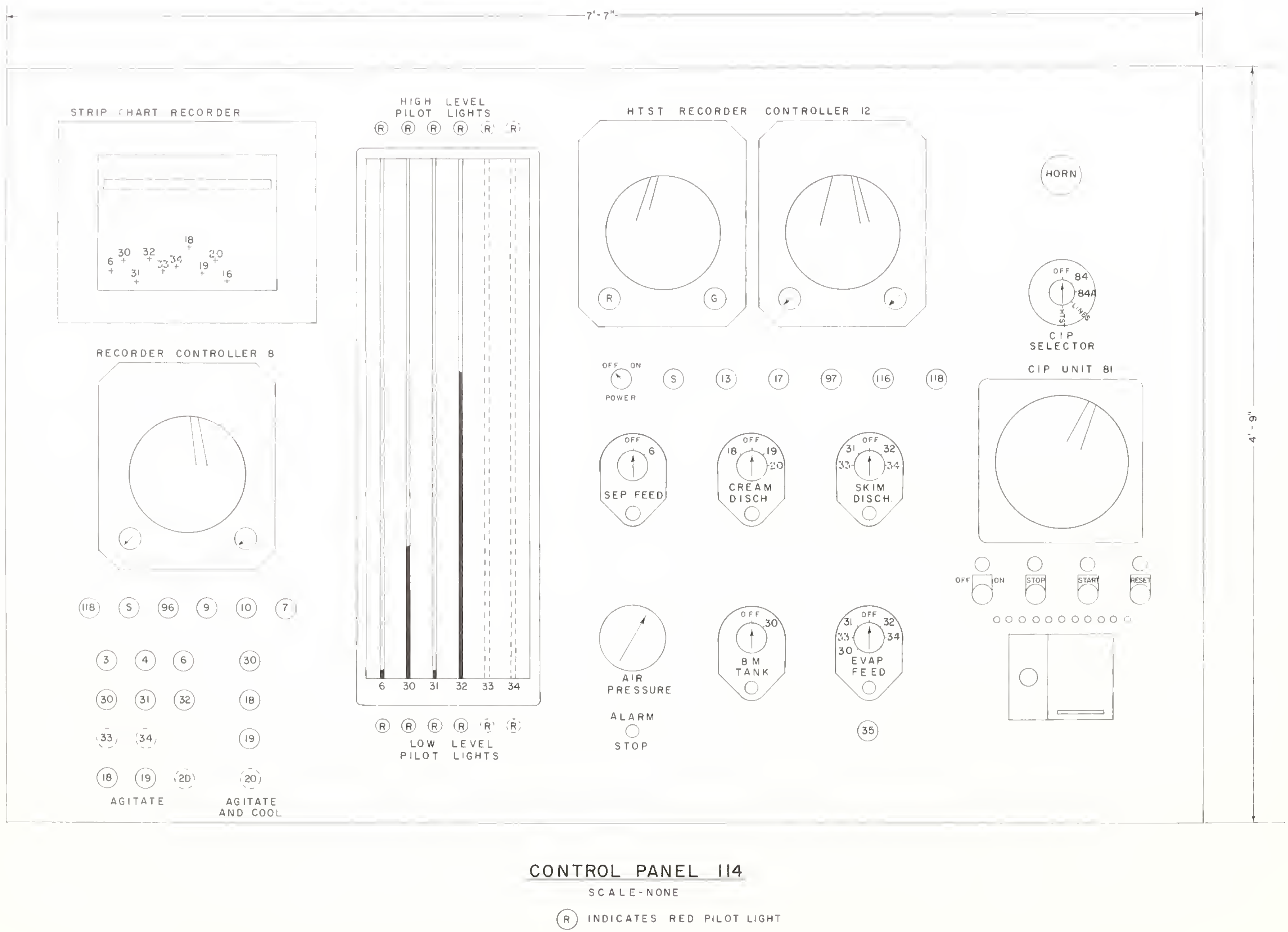

FIGURE 5.—A suggested control panel for processing operations in an automated butter and dried milk products plant handling 250,000 pounds of milk daily.

that the pasteurizing holding time is never less than 16 seconds.

An air-operated sanitary valve (116) throttles the discharge of pump 17 so that cream in holding tank 16 is held approximately 20 minutes at 80° F. The throttling valve is controlled by a float that maintains a level of approximately 144 gallons in the tank. From pump (17) the cream is forced through the final cooling section, where it is cooled to 42° on its way to storage.

Holding the cream at 80° F. for approximately 20 minutes after pasteurization improves the body and texture of butter. The holding tank and twin cooling sections in the plate heat exchanger provide for this. The temperature is controlled by admitting a constant amount of 34° sweet water to the section. The sweet water in the cooling section of the plate heat exchanger will hold the temperature of the cream at the time of discharge into the holding tank within close limits, since the entering temperature and rate of flow are nearly constant.

The cream is further cooled to 40° F. in the 6,000-gallon cold-wall storage tanks (18, 19). Agitating and cooling operations for these tanks as well as other storage vessels in the processing room are controlled from process control panel (114). Control buttons are provided for "Agitate," which operates the agitators only, or "Agitate and Cool," which operates the agitator and admits ammonia refrigerant to the cold-wall sections.

Control panel (114) is equipped with gages that indicate the level of product in the 10,000-gallon tank (6), the 6,000-gallon buttermilk tank (30), and the 10,000-gallon skim milk storage tanks (31, 32). The gages operate high- and low-level red pilot lights located above and below the gages. The low-level indicators come on at 500 gallons. The high-level indicators come on when 90 percent of the tank volume is reached, except for the 10,000-gallon whole milk receiving tank (6) which is set for 80 percent or 8,000 gallons. Whenever an alarm light comes on, a horn sounds to alert the operator. The horn is stopped by pressing the alarm-stop button.

A strip chart recorder records the temperatures of all storage tanks and the 20-minute cream holding tank (16). Thermocouples are attached to the outside of the inner jackets to transmit an electric signal to the instrument. These records permit routine checking by the plant manager and are helpful in determining causes for production problems.

A selector switch, "Buttermilk Tank" controls the inlet-outlet air-operated valve on the 6,000-gallon buttermilk tank (30). A similar switch, "Evaporator Feed," controls the inlet-outlet valves on 10,000-gallon skim milk storage tanks (31, 32), as well as the sanitary line manifold in front of these tanks, which feeds skim milk to the evaporator.

An air-pressure gage in the panel shows the pressure of the air supply used for activating the sanitary valves in the processing system.

Controls for CIP unit (81) are located on the right side of the control panel. These controls are discussed elsewhere in the report.

Making Butter

Butter will be churned 5 days per week (Monday, Tuesday, Thursday, Friday, Saturday). Two days' accumulation of cream (45,000 pounds) with three churnings of 15,000 pounds each will be made on Monday and Thursday. On the other days, two churnings of 11,250 pounds each will be made.

In some sections of the country the milk production falls off as much as 50 percent in late summer months. During these periods only two churnings will be necessary on Monday and Thursday, and one on the other days.

A typical time schedule for churning is as follows:

	Minutes
Fill churn	10
Churning process	30
Drain buttermilk	10
Add salt	3
First working	20
Make moisture test	12
Add water and second working	20
Make and break pipe connections	10
Fill boats	5
Total	120

The operator starts the buttermaking process by first selecting the tank from which the cream is to be churned on the "Cream Discharge" switch in control panel (115) (fig. 6). The button is actuated to aline the sanitary inlet-outlet tank valves with the manifold so that the cream will

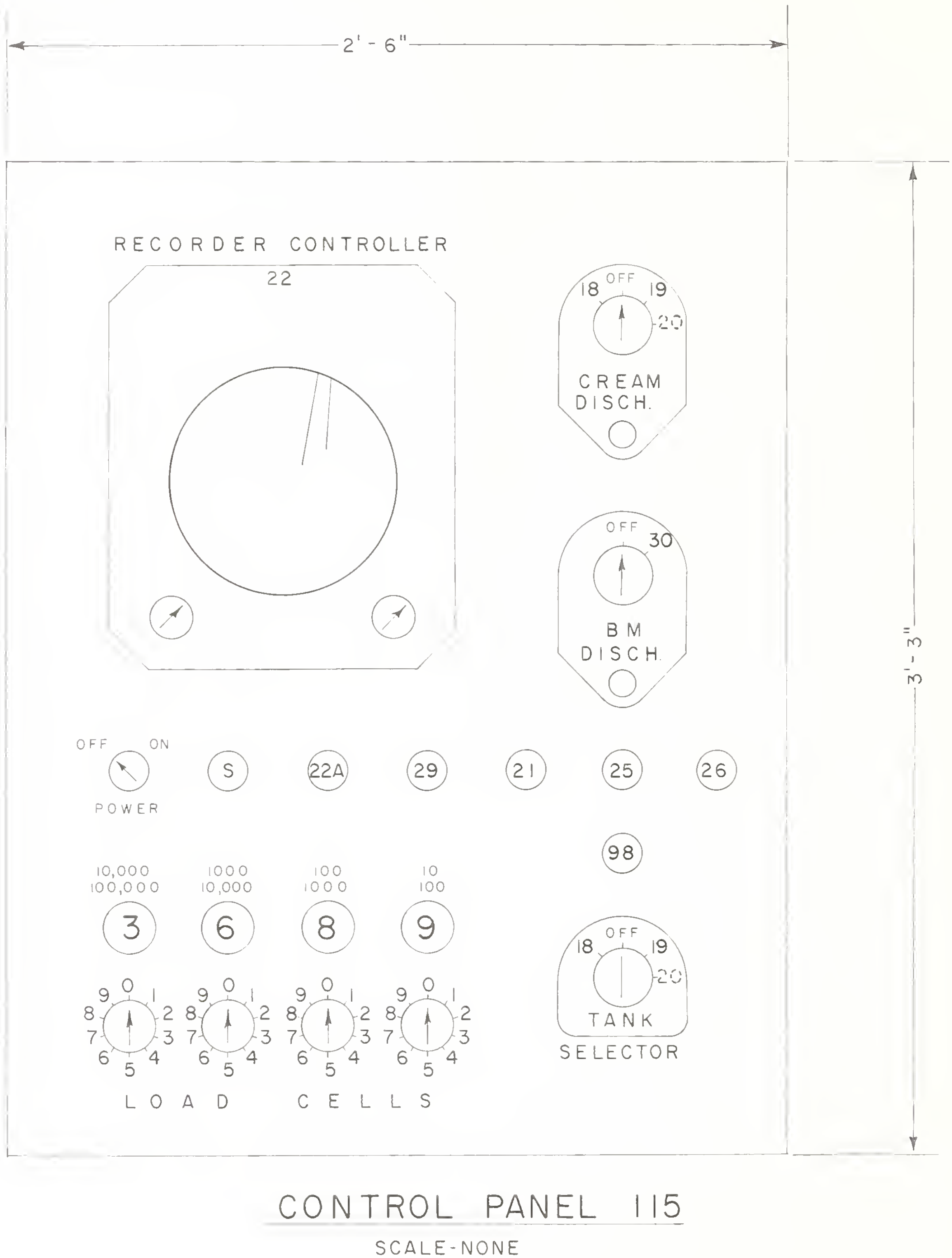

FIGURE 6. – A suggested control panel for use in the buttermaking operation in an automated butter and dried milk products plant handling 250,000 pounds of milk daily.

flow to the 80,000-pound-per-hour positive displacement pump (21). The proper churning temperature (48° to 52° F.) is set on the recorder-controller. The hot water circulating unit, which recirculates hot water through the 80,000-pound-per-hour tubular preheater, is started by actuating button 22A. The steam to the hot water circulating unit (22A) is turned on by actuating pushbutton S.

The 6,000-gallon-cold-wall cream storage tanks are mounted on load cells. The amount of cream in the tanks can be read in the digital readout by turning the "Tank Selector" switch to the proper storage tank. On the drawing of control panel (115), this amount is shown as 36,890 pounds. If a churning of 15,000 pounds of cream is to be made, 15,000 is subtracted from weight in the tank and the resultant set on the four digital dials, indicating the contents of the cream tank after 15,000 pounds are removed.

Pump (21) is then started by actuating button 21. When 15,000 pounds have been removed from the cream storage tank, pump 21 shuts off, the tank inlet-outlet valve closes, and a blast of filtered compressed air pushes the cream remaining in the piping and tubular preheater (22) into the churn (23). The hot water circulating pump (22A) and steam supply (S) are turned off by depressing the proper buttons. Sweetwater pump (98) is started to circulate sweet water through the tempering tube in churn (23) and the churning process begins.

After the butter granules form, the buttermilk is ready to drain. The churn is stopped so that the drain valve is at the bottom. The buttermilk strainer (24) is placed in position and connected to the 150-g.p.m. positive displacement buttermilk pump. The selector switch "Buttermilk Discharge" is set on tank (30) to aline the sanitary valves so that the buttermilk will flow through the 150-g.p.m. buttermilk plate cooler (26). Sweetwater pump (98) is started by actuating button 98, which circulates the cold sweet water through the buttermilk plate heat exchanger (26). The buttermilk pump (25) is started by pressing button 25, and the valve on the churn is opened. The buttermilk flows by gravity into the strainer (24) and is then picked up by pump (25) and passed through plate cooler (26) on its way to the 6,000-gallon storage tank (30).

The 300-gallon water cooling and storage tank (28) is equipped with a refrigerated cold-wall section and thermostat. It is filled with fresh water, slightly chlorinated, at the end of each day and held at 38° F.

After the first working of the butter, a moisture test is made and the amount of water required to raise the moisture content of the butter calculated. This amount of water is set on the water meter (29A), and the 10-g.p.m. water pump (29) is started. After the meter passes the required amount of water into the churn, the pump shuts off automatically.

The second working of the butter follows. After the butter has fully incorporated the desired amount of water and reached the proper body and texture, churning is complete.

On days when more than one churning is required, the churn is emptied into the butter boats (27), and the second churning then follows.

The butter is boxed as described in the section under "Components of the Facility."

Preparing Dried Milk Products

Milk Evaporating System

Before starting the evaporator, manholes on the vapor separators (43, 44) and cover plates on the vapor-line heater (36), the interstage heater (37), and the preheater (40) are closed. The water in the condenser (46) is turned on and the condensing water discharge pump (47) is started. The steam is then turned on the air ejector which pulls a vacuum in the evaporator.

The evaporator preheater feed pump (39) is throttled down to 50 percent of its normal operating speed by a valve on the pump discharge. This speed will restrict the milk flow to one-half of normal capacity through the preheater (40) during startup. The tank containing the skim milk is selected on the "Evaporator Feed" selector switch in control panel (114). The steam supply is turned on to the preheater, and the recorded-controller is set for 168° F. if low-heat powder is to be made, or 195° if high-heat powder is to be made. For low-heat powder, the milk is directed from the flow-diversion valve (41) direct to the evaporator milk level control valve. If high-heat powder is to be manufactured, the milk is directed to the 1,200-gallon, 20-minute holding tank (42).

The 26,884-pound-per-hour skim milk pump (35) is started by pushbutton 35 in the control panel (114). The skim milk passes through the vapor-line heater (36) and interstage vapor-line heater (37) to the balance tank (38), where a float-control valve maintains a constant level. Since no evaporation is taking place at this time, the skim milk remains at 40° F. For this reason the capacity of the evaporator preheater feed pump is restricted on startup, as the heating capacity of the preheater will not raise the normal full flow of milk from 40° to 168° (or 195° for high-heat powder). By throttling the flow back, the skim milk is raised to the proper temperature so that the flow-diversion valve (41) directs the flow to the evaporator rather than back to the balance tank (38) for rerun through the preheater.

When the level of skim milk in the evaporator reaches the correct operating level, the steam is turned on to the thermal recompressor jet on the evaporator. Steam is now admitted to the first-effect tube nest, causing the milk to circulate through the tubes. Evaporation now takes place. All condensate pumps are started. A part of the vapor coming from the milk in the first-effect vapor separator (43) is picked up by the thermal recompressor and used for heating the first effect; the rest of the vapor travels through the interstage vapor-line heater (37) to the second-effect tube nest (44). This vapor preheats the incoming skim milk as well as causing skim milk circulation and evaporation in the second effect. Vapor from the second-effect vapor separator (44) travels through the vapor-line heater (36) on its way to the condenser (46) where it is liquified by cold water. Part of the vapor is condensed in the vapor-line heater, which further preheats the incoming skim milk.

With evaporation underway, the discharge from the pre-heater feed pump (39) is gradually adjusted to the full-open position. Proper level is maintained in the evaporator by the level-control valves. The system soon reaches equilibrium so that the vapor-line heaters reclaim the maximum amount of heat possible from the milk vapors.

When the total solids content of the concentrate reaches 40 percent, the 5,774-pound-per-hour evaporator discharge pump starts and the flow throttles back slightly while the solids build up to 42 percent. The flow is then directed to the spray-drying equipment, which has been made ready to receive the concentrated skim milk while the solids were building up in the second effect of the evaporator.

Spray Dryer

The spray dryer (50) is started while the solids content is being brought up to 40 percent in the evaporator by starting the secondary fan (72), primary fan (68), collector fan (73A), and gas furnace (69). When the temperature of the air discharged from the furnace reaches 390° F. and the spray-dryer chamber is thoroughly heated, the rotary valves and powder sifter (52) are started. The dryer is now ready for the concentrated skim milk.

The tubular preheater recorder-controller is set at 165° F. and the steam to this preheater is turned on. Dryer infeed high-pressure pump (49) is turned on, with the bypass open to allow most of the skim milk concentrate to be recirculated. The evaporator discharge pump (45) is started. Then, the flow of concentrated skim milk starts through the preheater, where the temperature is raised to 165° F. This increase in temperature is a form of repasteurization to make certain that any bacteria buildup which might occur in the evaporator is controlled.

From the dryer preheater (48) the high-pressure pump picks up the concentrated skim milk and forces it through atomizing nozzles in the top of the dryer. Here the fine spray is intermixed with the heated air from the dryer furnace, and enough of the water in the concentrated skim milk is removed to produce a powder with about 3-percent moisture.

As the total solids in the evaporator build up, the bypass around the high-pressure pump gradually closes, resulting in more skim milk concentrate being fed to the dryer. In a short time, the system balances out with the capacity of the evaporator.

The powder passes from the drying chamber (50) to the primary collector (70), where most of it is withdrawn through a rotary valve at the bottom of the collector. Any powder and air remaining pass to the skimmer collector (71), where the powder is separated from the air. The air is exhausted to the outside through a roof stack by the secondary fan (72).

A pneumatic conveying system moves the powder from the rotary valves on the bottom of the two collectors (70, 71) to the powder cooler collector (73). The pneumatic conveying system is under a partial vacuum produced by air being drawn through a cooling coil with the collector fan (73A). During warm weather, the air at the entrance is maintained at 80° F. or below by circulating well water through the coil. In moderate and cool weather, well water is not required, as the ambient temperature is 80° or below. This system removes sensible heat, insuring that the powder temperature is 90° or below when it reaches the storage hopper (74). Cooling in this way has been beneficial in producing high-quality low-heat powder, as well as powder that is to be instantized.

The cooling coil is equipped with an electrical heating element to reheat the air slightly after it is cooled. This reheating of air insures that as the air enters the system it is not saturated with moisture, thus preventing stickiness in the powder and its subsequent downgrading for lumpiness.

From the cooling collector (73) the powder passes through a rotary valve where it is picked up by a pneumatic conveyor under partial vacuum and passed to the final collector (51). The air used is drawn from the collector fan (73A) by a branch line and cooled in a way similar to that used in the first powder cooling system. The air is discharged by the collector fan back into the skimmer collector so that the collecting system can pick up any powder not caught in the previous collectors.

The powder is discharged from the final collector (51) by a rotary valve onto a powder sifter (52), a vibrating stainless steel screen, which rejects any oversized particles. It then passes through the screen into a 10,000-pound stainless steel storage hopper (74) for bagging. Since the hopper has 4 hours' drying capacity, bagging may be intermittent, if desired. The bagging operator may then perform other duties, such as getting supplies and relieving other workers for a "break," as he can stop the bagging operation for a prolonged period. Without the use of the hopper, the bagging operator would need a relief man, since the system will produce one bag of powder every 2 minutes 24 seconds.

To package the powder the operator first places liners in the bags. The bagging apparatus (53), consisting of two tubes with a damper so as to pass powder down first one tube and then the other, is connected to a rotary valve on the bottom of the powder hopper (74). A bag is placed on the scale beneath each tube. The scale has an automatic cutoff which will divert the flow of powder to the other bag when approximately 99½ pounds have been added. The operator then slides the filled bag to the check scale (119) where the exact amount of powder is added to make 100 pounds. The two-stage filling is necessary because of the slightly irregular way the powder passes through the rotary valves and bagger. When the scale automatically diverts the flow to the opposite bag, the powder remaining in the tube between the bag and the damper passes into the filled bag, and this amount of powder in motion varies to some extent so that exact shutoff is not feasible.

After check weighing, the bag liner is closed and tied. The bag is then slid into the stitcher (120) and the top closed. The stitcher is equipped with a belt conveyor that carries the bag through the machine. The finished bag ends up adjacent to a pallet. It is then placed on the pallet by the operator.

Since low-heat powder should be aged for at least 48 hours before it is instantized, it is stored in 1,500-pound-capacity aluminum tote bins. The automatic cutoff scale on the dual bagger is slid back, permitting the tote bin to be placed under the bagger tube. After the bin is filled it is weighed on the tote bin scale (121) in the powder storage room. The tare weight of the tote bin is subtracted, and the net weight of the powder is recorded for inventory control.

Buttermilk is evaporated and dried using the same procedure as for skim milk.

High-heat bakery powder is dried similarly to low-heat powder except that the cooling coils on the powder cooling system are turned off.

The evaporator and dryer are supervised by one worker since the operation is automatic after startup and requires only periodic checking of instruments to insure proper working. A second worker does the bagging and can alternate with the evaporator-dryer operator to even out the physical workload.

Since the instantizing system operates at nearly the same capacity as the spray dryer, the instantizer should be operated at the same time low-heat powder is being collected in tote bins. Since the tote bins require 36 minutes to fill, the bagging operator, with the help of the evaporator-dryer operator, can run the instantizer at the same time. The importance of the powder hopper (74) is again evident as the tote bin does not have to be changed immediately upon being filled but can be done at the convenience of the operator.

The spray dryer controls include a recorder-controller to modulate the gas input so that a constant hot-air temperature is delivered to the drying chamber. The gas furnace is equipped with a safety device to shut off gas flow if ignition fails or if the primary fan should cut off for any reason. The airflow through the unit is adjusted by fan speed upon installation—no further control is required.

Instantizing Process

To begin the instantizing operation, the stainless steel recirculating fan (64), secondary fan (61A), shaker table (62), air filter, fan and cooling unit (66), pneumatic conveyor (55), and rotary valves are started. If the outside air temperature is 70° F. or more, the Freon condensing unit (67) is also started, since the cooling air must be 70° or less. The induction fan (65) and steam air heating coil (59) are started. The system is now ready to receive low-heat powder for instantizing.

A tote bin, containing approximately 1,500 pounds of low-heat powder, is moved onto the powder hopper (54) and the drain door of the hopper opened. This door admits powder to the pneumatic conveyor (55) which transfers it to the infeed collector (56). The steam injector is turned on, which raises the humidity to the point where the fine particles of powder agglomerate into clusters between one-fourth and one-half inch in diameter. The clustering takes place in the agglomerating section (57) while the powder is traveling to the wet collector (58). At this point the clusters are separated from the humid air, which returns to the recirculating fan (64). The clusters drop into the heated (270° F.) air stream coming from the air heating coil (59) and travel through the redryer (60) to the final collector (61), which reduces the moisture content back to 3 percent. The air is exhausted through the roof by a secondary fan (61A).

The powder then passes through a rotary valve onto the shaker table (62). This is an oscillating nylon-mesh-covered apparatus through which the cooling air from the filter, fan, and cooling unit (66) passes, reducing the temperature of the powder to 110° F. or less. A series of sizing rolls at the end of the shaker table reduce large clusters to small, more uniform sized ones. From the sizing rolls, the powder passes into the dual bagging system (63). The bagging, weighing, sewing, and palletizing operations are the same as previously described for the spray dryer.

The air temperature from the heating coil (59) is controlled by a recorder-controller which modulates the steam into the heating coil. The steam is admitted to the agglomerating tube (57) by a hand-operated needle valve, which has a steam pressure regulator upstream to maintain a constant pressure on the valve.

The first powder to pass through the system is rejected until equilibrium is established. During this relatively short period, the desired humidity is built up in the agglomerating section.

Cleaning Equipment

The automatic CIP units (81, 82, 83) clean by circulating chemicals over the surfaces of milk processing equipment that come in contact with the product. The temperature of the cleaning solution and elapsed time for each phase of the cleaning cycle is controlled automatically. A CIP recorder-controlling instrument records the cleaning procedure for review by management and health regulatory agencies. The time of circulation and temperature and pressure of the CIP cleaning, rinsing, and sterilizing solutions are recorded here. An illustration of the CIP controls for CIP units (81) and (82) is shown on the drawings of the receiving-control panel (113) and the process-control panel (114). The controls for CIP unit (83) are similar to these.

Coupled with the recorder-controller is an electropneumatic punchcard program selector. This device automatically sets the elapsed time, circulating temperature, and proper valve sequencing for each piece of equipment that is to be cleaned by CIP methods. To clean a piece of equipment, the proper punchcard is selected from the file and inserted into the program selector. The program may be changed by making up a new punchcard. Once the program is established, however, there is no need for a variation unless some factor, such as the type of cleaning compound, is changed.

Valve sequencing is necessary to insure proper cleaning of valve parts as well as branch lines. The program controller sets the valves in the proper position for cleaning and sequences the proper valves to clean branch lines.

The "Off-On" pushbutton turns on the power to the control system. The "Start" button initiates the program selected by the punchcard. The "Stop" button shuts off the program at any point, should the operator wish to do this; the program may be started again by the "Start" button. If the operator desires to start the program from the beginning, he presses the "Reset" button, followed by the Start button.

To clean the raw milk, skim milk, weigh, and cream storage tanks, a swing elbow connection must be made at the proper CIP hookup station (84, 84A). Station (84) serves storage tanks (6, 30, 31, and 32) and station (84A) storage tanks (3, 4, 18, and 19). This swing elbow connects the pipeline between the CIP unit and the spray balls in the tank to be cleaned. To do this, the manhole of the tank to be cleaned must be opened to obtain a key that unlocks a cap covering the swing elbow connection leading to the spray balls in the tank. This procedure insures that the operator checks the tank to make certain there is no product in it. After the tank is cleaned, the operator reinserts the key into the manhole-closing mechanism to close it; thus, there is a check against the key getting lost or mislaid. Use of the key also insures proper venting during cleaning by making certain that the manhole is open. During the final rinse cycle, cold water sprayed into the tank condenses the warm vapor present and lowers the air temperature, creating a partial vacuum. The open manhole relieves this pressure differential, preventing the tank from collapsing.

CIP unit (82), used primarily for cleaning tank trucks, can be connected manually to CIP hookup station (84) or (84A) to clean tanks (3, 4, 6, 18, 30, 31, and 32), after all the trucks are cleaned. Use of two CIP units on plant equipment permits faster cleanup.

Two type of circuits, open and closed, may be cleaned by CIP units. The closed circuit is a recirculated pipeline, such as the raw milk receiving line and the sanitary line manifold in front of the weighing storage tanks. The open circuit is a storage tank using the pump on the CIP unit to deliver the cleaning solution to a spray ball system mounted in the storage tank and a separate pump (85) to return the solution to the CIP unit.

Closed Circuit Cleaning

A typical cleaning cycle for a closed circuit is the raw milk lines leading from the receiving dock to the weighing tanks (3,4). Hose jumpers are used to complete the circuit. The CIP Selector Switch in control panel (114) is turned to "Lines," the proper punchcard for raw milk lines is inserted in the program selector of CIP unit (81), and the Start pushbutton actuated to begin the process, which proceeds as follows:

Prerinse

1. The rinse tank automatically fills with fresh water.

2. For 2 minutes water is pumped through the lines and discharged to the drain. At this time the discharge should be clear and the water is automatically returned to the rinse tank.

3. This rinse water is recirculated for 5 minutes, during which time the temperature of the water is automatically raised to 100° F.

Wash

1. If the wash tank is empty, it is automatically filled with water and the operator adds

washing powder. (This is done for the first washing procedure each day. Subsequent cleaning cycles reuse the solution, and the operator normally adds a predetermined amount of cleaning compound after each item of equipment is washed.

2. The washing solution is automatically heated to 140° F. and held at this temperature while it is circulated through the raw milk lines back to the solution tank.

3. The circulation continues for 20 minutes, during which time the sanitary valves are automatically sequenced to clean stems of the valves and branch lines. The cycles ends with all the solution returned to the wash tank.

Rinse

1. The rinse tank is full from the last prerinse return. This water is circulated automatically through the lines for 5 minutes, during which time the sanitary valves are automatically sequenced, and then discharged to the drain.

2. The rinse tank is then automatically filled with fresh water, which is circulated through the lines for 10 minutes and then returned to the rinse tank. This water will be used for prerinse on the next cleaning cycle.

Open Circuit Cleaning

To clean an open circuit, the following procedure is used. As an example, assume that a 10,000-gallon raw milk storage tank (6) is empty and ready for cleaning.

The manhole is opened and washed manually, together with the manhole gasket. The manhole is left open, resting against the inside of the front head.

The key, obtained when the manhole was opened, is used to remove the cap at CIP hookup station (84) covering the CIP line which leads to the spray balls in tank (6), and the swing elbow connection is made. The locked cap prevents the operator from inadvertently running the CIP solution into the wrong tank.

The swing elbow connects the outlet valve of tank (6) to the solution return line leading to CIP return pump (35). The punchcard with the cleaning program for tank (6) is inserted in the programer. The CIP selector switch in control panel (114) is turned to CIP hookup station (84), and the Start button actuated. The cleaning procedure is as follows:

Prerinse

1. The rinse tank fills automatically.

2. The CIP pump delivers three "burst" rinses of 10 seconds each, with 15 seconds between rinses for draining. CIP return pump (85) returns this water to the CIP unit where it is discharged to the drain.

Wash

1. The wash cycle is the same as that for raw milk lines except that the circulating time is 10 minutes.

Rinse

1. The CIP pump automatically delivers three burst rinses of 10 seconds each, with 15 seconds between bursts for draining. The rinse water comes from the rinse tank and is returned to the drain by CIP return pump (85).

2. The CIP pump next automatically delivers three burst rinses of 10 seconds each with 15 seconds between bursts for draining. This rinse water comes directly from the fresh water supply and is returned to the prerinse tank by CIP return pump (85).

The CIP units consist of two or three solution tanks, a circulating pump, and air-operated valves to control the flow of the solution, in addition to the control system located in the control panel. Ordinarily, two tanks (rinse water and alkali wash solution) are used for cold milk surfaces and three tanks (rinse water, alkali wash, and acid wash solutions) are used for hot milk surfaces. Both surfaces are stainless steel. Hot milk surfaces are those that come in contact with milk products that are being heated or being held at an elevated temperature for a prolonged time; cold milk surfaces are those that come in contact with cold milk products or products being cooled. A three-tank hot-milk CIP unit may be used for washing the cold milk surfaces by omitting the acid wash on the program punchcard.

For the plant described, three CIP units (81, 82, 83) are used.

Cleaning Schedule

For this plant the following schedule is used:

CIP Unit (81)

1. Raw lines including buttermilk plate cooler (26) and buttermilk lines.

2. Plate preheater and skim milk cooler (8).
3. Cream HTST system (12) .
4. Evaporator and skim milk lines.
5. 1,200-gallon, 20-minute holding tank (42).
6. Storage tanks (18, 19).

CIP Unit (82)

1. Bulk milk tank trucks.
2. Storage tanks 3, 4, 6, 30, 31, 32.

CIP Unit (83)

1. Spray dryer.
2. Instantizing system.

Equipment Not Cleaned by CIP Methods

The churn (23) is cleaned by preparing the necessary cleaning, rinsing, and sterilizing solutions in the churn and agitating it. After each operation is completed, the solution is discharged to the floor drain.

The separators (9, 10) must be dismantled to clean. The various parts are placed in COP (clean-out-of-place) washup tank (87), which is portable and can be pushed to the separators for loading. A pump in the tank circulates the washing solutions around the parts. The temperatures of the solutions are controlled automatically.

In addition to the separator, the following equipment must be disassembled to clean:

40,000-pound-per-hour positive displacement pump (7)
200-gallon, 20-minute cream holding tank (16)
Balance tanks (11, 38)
80,000-pound-per-hour positive displacement pump (21)
150 g.p.m. buttermilk positive displacement pump (25)
Buttermilk strainer (24)
Dryer infeed high-pressure pump (49)

Cleaning the Evaporator and Dryer

The evaporator's first and second effects (43, 44) are equipped with spray balls to clean all parts of the vapor separators. The tube nests are cleaned by additional sprays which distribute the cleaning solution through all the tubes. The vapor-line heater (36), interstage vapor-line heater (37), and preheater (40), as well as the sanitary piping, flow-diversion valve (41), and holder tube (40A), are cleaned by circulation. The 1,200-gallon holding tank (42) is equipped with spray ball system for cleaning.

The spray dryer is cleaned every 3 days, after buttermilk drying. This procedure insures that the dryer is free from buttermilk powder which might otherwise become mixed with skim milk powder. Cleaning after each day's use is not necessary, since the powder does not contain enough moisture to support bacterial growth.

To clean the spray dryer, the cover plates must be removed and spray balls inserted into the openings. Permanently installed spray balls would interfere with the airflow pattern necessary for dryer efficiency. The spray balls are inserted into the top of the following chambers: Spray dryer (50), primary collector (70), skimmer collector (71), cooler collector (73), final collector (51), and storage hopper (74). Additional spray devices are inserted into the interconnecting ductwork. All sprays are quickly connected to a permanent pipe connection adjacent to the cover plates. The cleaning solutions return by gravity to the CIP unit (83) by a series of pipes, most of which are permanently installed so that only final connections need to be made. CIP unit (83) follows a program similar to that used for cleaning cold milk lines, since the soil is easily removed.

The instantizing system is cleaned similarly. The only difference is that a CIP return pump (85) is required to return the cleaning solutions to CIP unit (83), since the elevation does not permit gravity return.

Sanitizing

The equipment is sanitized in the morning after it is assembled and ready for use. Sanitizing is performed either by (a) fogging, for such equipment as storage tanks, or (b) flooding, for such items as pipes and pumps.

A 200 p.p.m. chlorine solution is prepared in the CIP unit (82) rinse tank, and the selector switch turned to sanitize. The "Fill" switch on control panel (113) is turned to weigh tank (3), and the start pushbutton actuated which pumps the chlorine solution through the raw milk lines to weigh tank (3). After a few gallons of solution have been pumped into the tank, the selector switch is shifted to tank 4, and the rest of the chlorine solution is pumped into this tank. From tanks (3) and (4) the solution is pumped through the milk handling system following the same procedure used for milk. The chlorine solution ends up in an empty cream storage coldwall tank, from where it is pumped into the churn. Here a jumper diverts it to the buttermilk positive displacement pump, which pumps it into buttermilk tank 30. From this tank (30), it is wasted to the floor. Since chlorine is corrosive to aluminum, a quaternary ammonium bactericide solution is used in the churn.

While the chlorine solution is being pumped through the separator, a small amount of it is diverted to the skim milk storage tanks to sanitize the skim milk line.

A chlorine solution is prepared in the rinse tank of CIP unit (81) and pumped to the skim milk storage tank (31) via CIP hookup station (84) and the spray balls in tank (31). From here, the solution is pumped through the evaporator system, being wasted to the floor at the high-pressure dryer feed pump (49).

The dryer and instantizing system are sanitized by a similar procedure, using CIP unit (83). The spray balls are used, having remained in position after the cleaning procedure was completed.

The storage tank, except skim milk tank (31), are sanitized by fogging, using an atomized spray of chlorine. The fogging unit is a device similar to an ordinary paint sprayer. It is set in the tank manhole and connected to the compressed air supply with a hose. A solution of chlorine is put into the atomizer, and when the air is turned on, a mist of chlorine saturates surfaces of the tank, killing any bacteria that may be present.

Loading Out

Three loading-out docks are provided. One rail dock serves both the butter storage and the powder storage rooms. Each of these rooms also have a truck dock. The docks are arranged so that rail and truck loading are possible from both storage areas at the same time.

Pallets of butter and powdered products are put on trucks or into railcars by a forklift truck. Since the plant provides no delivery trucks and the trucks of the buyers differ considerably in capacity, volume loaded out varies from day to day. A forklift truck and operator are provided for loading as required.

LABOR REQUIREMENTS

Seventeen workers would be required to operate a plant of this size, not including the general manager and the office help (fig. 7). The plant will be opened 7 days a week, although workers will work on a 5-day basis. Plant workers can be classified as being in 5-day-a-week jobs or in 7-day-a-week jobs.

The tabulation that follows lists the types of workers, their principal duties, and their time schedules for the two classifications.

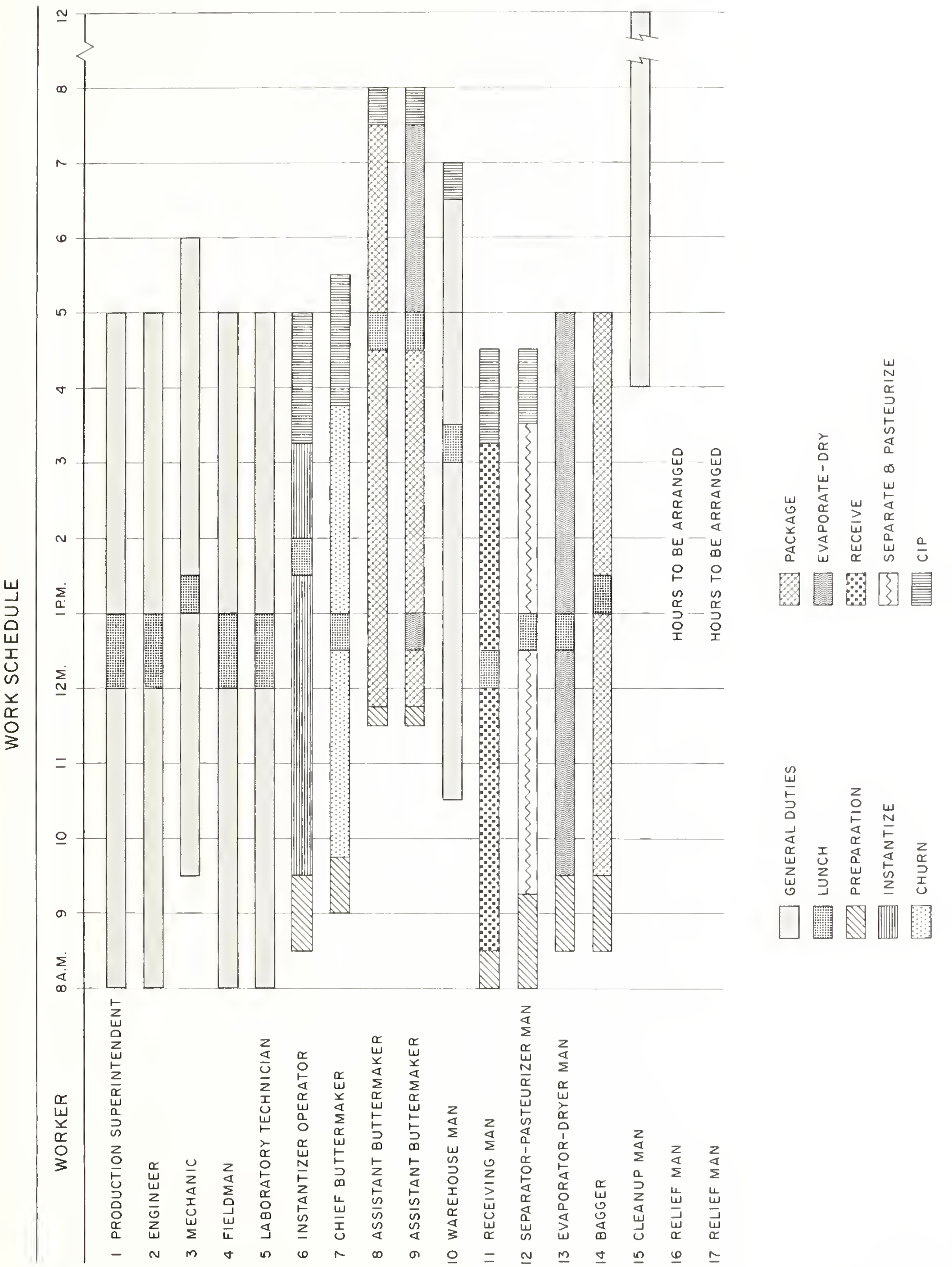

FIGURE 7.—Suggested work schedule for 17 workers needed to operate an automated butter and dried products plant handling 250,000 pounds of milk daily.

5-day workweek

Type of worker	Duties	Hours of workday	Days off
Production superintendent	Plans production, trains new employees, is occasional relief for absentees.	8:00 a.m. to 5:00 p.m.	To be arranged.
Engineer	Maintenance of all equipment and operation of boilers and refrigerated equipment.	8:00 a.m. to 5:00 p.m.	To be arranged.
Mechanic	Assists the engineer.	9:30 a.m. to 6:00 p.m.	Staggered with engineer (mutually arranged).
Fieldman	Works with producers on their production problems to maintain the quality of the raw milk supply.	8:00 a.m. to 5:00 p.m.	Saturday and Sunday.
Laboratory technician	Conducts all quality-control tests, butterfat tests on producer samples and routine quality checks on products produced in the plant.	8:00 a.m. to 5:00 p.m.	Wednesday and Sunday.
Instantizer operator	Operates instantizing system, including startup, bagging, powder feeding, and cleanup.	8:30 a.m. to 5:00 p.m.	Saturday and Sunday.
Chief buttermaker	Churns cream and maintains quality of butter produced, assembles butterboxes with butter liners, palletizes butter, and stores it in coldroom.	9:00 a.m. to 5:30 p.m.	Saturday and Sunday.
Assistant buttermaker	Assists chief buttermaker in boxing, weighing, palletizing, and storing butter. Completes bagging operation after bagger leaves at 5:00 p.m. Cleans bagging room. Assists in cleaning of evaporator and dryer.	11:30 a.m. to 8:00 p.m.	Wednesday and Sunday.
Assistant buttermaker	Same as assistant buttermaker above.	11:30 a.m. to 8:00 p.m.	Wednesday and Sunday.
Warehouse man	Moves palletized powder and tote bins into the warehouse. Receives supplies and loads out butter and dried milk products.	10:30 a.m. to 7:00 p.m.	Monday and Thursday.

7-day workweek

Type of worker	Duties	Hours of workday	Days off [1]
Receiving man	Receives and weighs milk. Washes trucks and weigh tanks.	8:00 a.m. to 4:30 p.m.	Varies.
Separator-pasteurizer man	Separates whole milk and pasteurizes cream. Assists in storing products manufactured in plant. Starts cleaning of processing room.	8:00 a.m. to 4:30 p.m.	Varies.
Evaporator-dryer man	Operates evaporator and dryer.	8:30 a.m. to 5:00 p.m.	Varies.
Bagger	Fills bags, weighs, and palletizes powder.	8:30 a.m. to 5:00 p.m.	Varies.
Cleanup man	Cleans processing room, bagging room, and evaporating and drying room.	4:00 p.m. to 12:00 p.m.	Varies.
Relief man	Replaces workers listed above so each of them can have 2 days off each week.	To be arranged.	To be arranged.
Relief man	Same as relief man above.	To be arranged.	To be arranged.

[1] 7 workers are required for the 5 positions which must be filled 7 days a week. Such an arrangement allows these workers 2 consecutive days off each week. Each week the days off advance 1 day; thus, a worker with Monday and Tuesday off 1 week would have Tuesday and Wednesday off the next week, resulting in 3 days off consecutively every 7th week.

COSTS AND POSSIBLE BENEFITS OF LABOR-SAVING DEVICES

Use of automatic controls can reduce labor costs and improve the quality of butter and dried milk products. With an automated heating process, temperatures can be controlled accurately and uniformly. An accurate, uniform temperature is vital in making concentrated skim milk because of the time and temperature relationships of the heating process to protein denaturation. This concentrated skim milk is used in the manufacture of high-heat powder, used in bakery products, and low-heat powder, used in cottage cheese or instantized skim milk, for household use.

The major items of equipment that will be needed to automate the plant and their costs are as follows:

	Estimated cost
3 CIP units	$21,000
Additional sanitary lines	20,000
Air-actuated valves	6,000
Level controls	2,800
Load cell systems	16,000
Refrigeration and boiler controls	6,000
Control panels	7,000
Powder weigher and bagger	8,000
Powder storage bins	6,000
Total	$92,800

Fewer workers will be needed to operate the automated plant compared with a nonautomated one. Those replaced by automation are as follows:

Receiving room	1
Churn room	1
Cleanup	4
Bagging room	1
Engineer	1
Total	8

A total of 17 workers are needed for the automated plant and 25 for the nonautomated one.

Labor costs vary widely, but in this study the average yearly salary of plant workers, including fringe benefits, was estimated at $6,500. Therefore, the yearly savings in labor costs by automating would be 8 times $6,500, or $52,000. From this figure, costs of owning and operating the additional equipment must be subtracted. If these costs are assumed to be 20 percent of initial investment, then the actual savings would be $52,000—($92,800 × 0.2), or $33,440.

An important advantage of automation is that the drudgery is removed from much of the plant labor. In nonautomated plants, lifting and walking about on wet, slippery floors and performing difficult cleaning jobs are routine. In modern automated plants, much of this type of work can be done automatically by actuating pushbuttons on panels.

More technical skill and knowledge will be needed by those working in such plants, and workers will need special training if they are to perform their duties satisfactorily.

APPENDIX: REFRIGERATION, HEATING, VENTILATION, AND AIR CONDITIONING

Refrigeration System

The refrigeration system (fig. 8) for the automated plant must be adequate to cool milk and cream products and to maintain the required coldroom temperature. Milk and cream products will be cooled by sweet water from an ice builder circulating through a plate heat exchanger. An ice builder is a refrigerant evaporator coil immersed in a tank of water. A reserve of ice is built up during slack periods of refrigeration to provide an adequate source of refrigeration when needed. Water enters the tank, circulates around the ice-covered coils, and leaves the tank cold. Using an ice builder to cool milk is frequently referred to as "cooling with sweet water."

The coldroom will be refrigerated by two direct expansion cooling units. Each unit has coils in which ammonia evaporates, cooling them. Air is blown over these coils by a fan in the unit, thereby cooling the air, which in turn cools the room. The refrigeration data given here are based in part on information contained in the "Mechanical Engineers' Handbook," "Heating, Ventilating and Air Conditioning Guide," "Refrigeration Engineering Application Data," and "Air Conservation Engineering."[2]

[2] Marks, Lionel S. mechanical engineers' handbook. 4th ed., illus. 1941; American Society of Heating and Ventilating Engineers. heating, ventilating and air conditioning guide. 1947; Segal, S. Charles. refrigeration load calculations—II, temperatures below 32° F.—Refrig. Engin. Appl., Data 12. Refrig. Engin. Vol. 39, No. 4, Sec. 2. April 1940; W. B. Conner Engineering Corp. air conservation engineering. 81 pp. 1944.

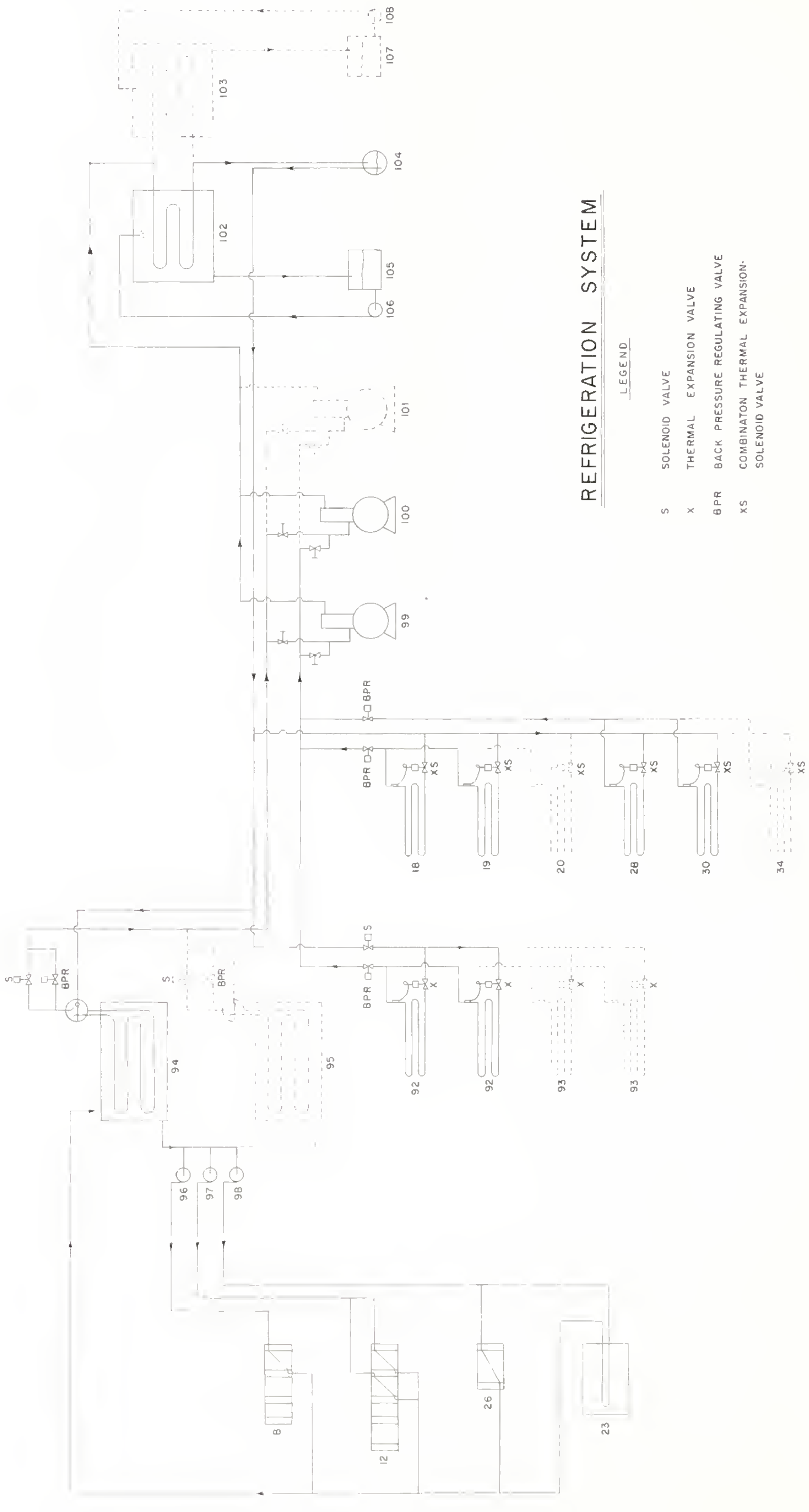

FIGURE 8.—Suggested refrigeration system for an automated butter and dried products plant handling 250,000 pounds of milk daily.

The factors determining the sizes of refrigeration equipment suggested for the plant are explained below. These requirements are offered as a guide only since many local conditions, such as temperature differences, types of building materials used, and equipment arrangement, affect the requirements of a particular plant. Operators planning to build new plants or remodel their present facilities should consult local refrigeration engineers regarding their particular needs.

Skim milk and cream cooling refrigeration.—The cooling load of the ice builder may be determined by dividing the daily British thermal unit (B.t.u.) requirements for each load by the latent heat of fusion of ice, which is 144 B.t.u. per pound. For example, the specific heat of milk is considered to be 1.0, which is the value usually used by industry in sizing refrigeration equipment. The actual specific heat of milk, skim milk, and similar low-fat products is about 0.93. For 40-percent cream, the specific heat used is 0.85.

The formula for daily B.t.u. requirements is:

B.t.u. = Weight of product × Temperature change × Specific heat.

Refrigeration loads handled by sweet water are as follows:

Equipment number	Product	Pounds of product	Temperature change (° F.)	Specific heat	B.t.u. per day
8	Skim milk	227,500	49°–40°	1.0	2,047,500
12	Cream	22,500	123°–42°	.85	1,549,125
26	Buttermilk	22,500	52°–35°	1.0	382,500
23	Cream in churn	45,000	5° rise	.85	191,250
	Total ice builder B.t.u. load per day				4,170,375
	Plus 10% for line and agitation losses				417,037
	Total daily B.t.u. requirements				4,587,412

$$\text{Pounds of ice required} = \frac{4.587.412}{^{3}\,144} = 31,857$$

[3] The latent heat of fusion of ice is 144 B.t.u. per pound.

A 32,000-pound ice builder (94) is suggested. The size of the ammonia compressor required to build up 32,000 pounds of ice in a 12-hour operating period is:

$$\frac{32,000 \times 144}{^{4}\,12,000 \times 12} = 32 \text{ tons.}$$

To handle this load, a 32-ton, 40 hp. ammonia compressor (99) is needed. It would operate at 25 pounds suction pressure and 185 pounds condensing pressure.

In the tabulation, a 5° F. rise in temperature of the cream in the churn was assumed. This heat is absorbed by the churn-tempering tube through which sweet water is circulated.

Refrigeration requirements for the coldroom.—Refrigeration requirements for the coldrooms are determined by (a) heat gain through walls, ceiling, and floor, (b) heat gain through air changes in the coldroom, (c) heat gain from electrical energy, and (d) heat gain from butter placed in the coldroom. A heat gain would also be incurred from workers in the room, but for the proposed plant this would involve only one or two persons, depending on the packaging operation and the load-out situation at the time. Thus, the heat gain from workers would be comparatively small and dealt with by the assumed safety factor. To determine the peak average load per hour for the room, the peak average load per hour must be calculated for each factor except for (d), the heat gain from butter entering and being held in the room. For this factor, the average of a 24-hour period is used.

(a) Heat gain through wall, ceiling, and floor is calculated by the following formula. The calculations are based on a coldroom temperature of 35° F. and an outside temperature of 95° F. An average overall coefficient of heat transmission for walls, floor, and ceiling of 0.0756 B.t.u.

[4] One ton of refrigeration equals 12,000 B.t.u. per hour. MECHANICAL ENGINEERS' HANDBOOK, p. 2145 (reference listed in footnote 2).

per hour per square foot per degree F. temperature difference is assumed. This coefficient is based on a wall section of 8 inches of brick and 4 inches of insulation. The coldroom for the plant will have a surface area of:

	Square feet
Walls = (55 × 16 × 2) + (31 × 16 ×2)	= 2,752
Ceiling = 55 × 31	= 1,705
Floor = 55 × 31	= 1,705
Total	= 6,162

Heat gain through wall, floor, and ceiling = Surface area (sq. ft.) × 0.0756 × temperature difference (° F.)
= 6,162 × 0.0756 × 60
= 27,950 B.t.u./hr.

(b) Heat gain through air changes is calculated by the following formula. In making this calculation, a room of this type is assumed to have one air change every hour.

Heat gain from air changes = Volume of room (cu. ft.) × 2.53 B.t.u. gained/hr./cu. ft. × No. of air changes per hour
= 20,720 × 2.53 × 1
= 52,421 B.t.u./hr.

(c) Heat gain from electrical energy is from electric motors and lights. It is assumed that 1 hp. is used on the two cooling units and 1 hp. on the forklift truck each hour, or a total of 2 hp. For this calculation, 1 hp. equals 3,700 B.t.u. per hour.

Heat gain from motors (B.t.u./hr.) = Number of horsepower × 3,700
= 2 × 3,700
= 7,400 B.t.u./hr.

It is assumed that 900 watts of electricity are used for lights; 1 watt equals 3.42 B.t.u. per hour.

Heat gain from lights (B.t.u./hr.) = Number of watts × 3.42
= 900 × 3.42
= 3,078 B.t.u./hr.

Total heat gain from electrical energy = 10,478 B.t.u./hr.

(d) Heat gain for butter entering the room is calculated for a peak production day of 22,444 pounds. To determine the refrigeration need, the temperature of butter entering the room is assumed to be 55° F. With butter at this temperature coupled with the specific heat factor the heat gain due to products entering the room can be accurately estimated. The formula for determining the heat gain from products entering the room is:

$$\text{Heat gain from product (B.t.u./hr.)} = \frac{\text{Weight of product} \times \text{temperature change} \times \text{specific heat}}{24}$$

$$= \frac{22{,}444 \times (55\text{–}35) \times (0.5)}{24}$$

= 9,352 B.t.u./hr.

Summary of heat gained (B.t.u. per hour) by the butter storage room:

	B.t.u. per hour
Walls, ceiling, floor	27,950
Air changes	52,421
Electrical energy	10,478
Butter entering room	9,352
Total	100,201
10% allowance for safety factor	10,020
Total design requirements	110,221

Since the room cooling units (92) will operate 16 hours per day to provide 8 hours for automatic defrosting, a load of 110,221 B.t.u. must be removed from the room in two-thirds of an hour. Therefore, the cooling units must remove 110,221 × 3 ÷ 2, or 165,332 B.t.u. per hour.

The total refrigeration load would be:

$$\frac{165{,}332}{12{,}000} = 13.78 \text{ tons.}$$

Two cooling units (92) with a capacity of 7 tons each, or a total of 14 tons, would be used.

Refrigeration requirements for cold-wall storage tanks.—Cold-wall storage tanks, 6,000-gallon capacity (18, 19), are used to cool cream from 42° to 40° F., as well as to remove the heat of crystallization of the butterfat. Data of manufacturers indicate that 6 tons of refrigeration are required per tank to handle a load of this capacity over a 6-hour period. Since the tanks are used on alternate days, only one tank will normally be refrigerated at a time. The water-cooling tank (28) is designed to cool 300 gallons of water from 75° to 35° in 4 hours. The formula for the average refrigeration requirement is:

B.t.u. per hour = Weight of water × Temperature change × Specific heat

$$= \frac{300 \times 8.3 \times (75\text{–}35) \times 1.0}{4}$$

$$= \frac{24{,}900}{12{,}000} = 2.08 \text{ tons.}$$

The 6,000-gallon buttermilk storage tank (30) is equipped with cold-wall surface to keep the buttermilk cold, as it will be stored for as long as 4 days before it is dried. Since the buttermilk enters the tank at 35° F., the only refrigeration required is that needed to hold it at this temperature. Two tons of refrigeration are estimated to be sufficient for this purpose.

Summary of the refrigeration needs for the tanks and cold storage room are:

	Tons
Cooling units for butter storage room (92)	14
6,000-gallon cold-wall tanks (18,19)	6
300-gallon water-cooling tank (28)	2
6,000-gallon buttermilk tank (30)	2
Total	24

To handle this load, a 32-ton, 40-hp. ammonia compressor (100) will be used. The compressor will operate at 25 pounds suction pressure and 185 pounds condensing pressure. A unit of this size will be completely interchangeable with the compressor handling the ice builder.

Automatic refrigeration controls.—The cold storage room is controlled by a room thermostat which is set to turn on at 38° F. and off at 35°. This thermostat controls the solenoid valves which admit the refrigerant to the cooling units (92) thus starting and stopping their refrigeration effect. When the refrigerant is off, the coils are pumped down and automatically defrosted by a fan circulating room air over them.

The solenoid valves which admit refrigerant to the cold-wall tanks (18, 19, 28, 30) are operated from the control panel (114) by "Agitate and Cool" pushbuttons. The 300-gallon water-cooling tank (28) is equipped with a thermostat which automatically controls both the refrigerant and tank agitator.

The ice builder is regulated by an ice thickness control, which automatically turns off the ammonia compressor (99) when the proper thickness of ice is built up on the coils. At this time the refrigerant inlet solenoid valve is closed and the suction line bypass opened, which will hold a 30° F. ammonia temperature in the coil by the back pressure regulator which is set at 45 pounds. This regulator aids in holding the ice on the coils. The ice builder is started manually and must be checked each day, which is a desirable feature.

The two 32-ton compressors (99, 100) are multicylinder type with 50-percent capacity controls. Thus, the two compressors provide a variable capacity from 16 to 64 tons at 16-ton increments. This capacity control is automatic by a pressure switch, which will maintain the suction pressure in a range of 20 to 25 pounds. As a load increases in the butter cold storage room, or on a cold-wall tank, the suction pressure will rise. This is sensed by the pressure switch, which adjusts the capacity controls to suit the condition. After the compressors are turned on, the operation becomes fully automatic.

To condense the ammonia, one 65-ton evaporative condenser (102) is located on the roof so that the liquid ammonia will drain by gravity to the 20-inch by 12-foot receiver (104). Since many plants are located in areas having very cold winters, it is suggested that the water from the sump pan on the evaporative condenser (102) be drained by gravity to sump tank (105). This will prevent the pump and water from freezing, since they are located just inside the refrigeration room. During seasons of rapid changes in temperature, this method of draining is advantageous as the condenser can run dry at night when it is cold and the water pumps will start automatically during the day when the outside temperature rises. The pumps and piping will not freeze because when the machines are not operating all the water will drain to the sump (105) located in the heated room.

The condensing pressure is controlled by pressure switches which start the fan and pump motors on a rise in pressure. The evaporative-condenser fan will turn on at 150 pounds per square inch (p.s.i.) and off at 135 p.s.i. The pump is set to turn on at 165 p.s.i. and off at 150 p.s.i.

Air cooling for instantizing powder.—For instantizing, 1,000 cubic feet of air per minute at 70° F. or less is needed for cooling the powder as it passes through the shaker table (62). Assuming the maximum outside temperature in summer reaches 95° dry bulb (DB) with humidity creating a wet bulb (WB) temperature of 80°, the air must be cooled sufficiently to remove sensible heat and to condense sufficient moisture so that the resulting air is not saturated with water. If this is not done, the powder forms into sticky clusters. To remove the moisture, a 1,000-cubic-foot-per-minute air-cooling and filtering unit (66), which utilizes outside air cooled by condensing unit (67), is used.

A psychrometric chart shows the heat content of the air before and after cooling, as well as the grains of moisture that must be condensed. In this case the air is to be cooled to 50° F., at which time it is saturated. It is then heated to 65°, which will reduce the relative humidity to approximately 60 percent. The amount of heat removed from the air is calculated as follows:

Heat removed = Heat content at 95° F. DB, 80° WB − Heat content at 50° DB, 50° WB + Heat content of moisture.

The psychrometric chart shows that the heat content of air at 95° F. DB and 80° WB is 42.51 B.t.u. per pound. At 50° DB and 50° WB the heat content of air is 20.13 B.t.u. per pound. At 95° DB, 80° WB, there are 131 grains of moisture per pound of dry air. The difference in the two wet bulb temperatures is 30° (80°–50°). Therefore, the heat content (B.t.u.) of the moisture to be removed from the air is equal to:

$$\frac{131 \text{ (grains moisture per pound dry air)}}{7{,}000 \text{ (number of grains per pound)}} \times 30 = 0.56.$$

Therefore, to reduce the temperature of air at 95° DB and 80° WB to 50° DB and 50° WB requires removing:

(42.51–20.13 + 0.56 B.t.u., or 22.94 B.t.u./pound of dry air.

The psychrometric chart shows that at 50° F. DB and 50° WB, the air volume is 12.98 cubic feet for each pound of dry air. Therefore, 22.94 divided by 12.98 equals 1.77, the B.t.u. of heat removed for each cubic foot. Since 1,000 cubic feet per minute (c.f.m.) of air is circulated, 1,000 × 1.77 equals 1,770, the B.t.u. removed per minute. The tons of refrigeration required would be:

$$\frac{1{,}770 \times 60}{12{,}000} = 8.85 \text{ tons.}$$

A 10-ton Freon condensing unit (67) is recommended. The air would be reheated to approximately 65° F. from 50° by using a small Freon condensing coil downstream from the cooling coil. This condensing coil would partly condense the Freon and reheat the air, with the rest of the heat removed by a shell-and-tube water-cooled condenser.

Heating System

The heating system in this plant is required to provide hot water and steam for heating milk and milk products, for cleaning, and for heating the building. The heating system should be adequate to handle the plant's peak heating requirements. These requirements depend, to some extent, on the climate of the area in which the particular plant is located. Thus, the heating data provided herein are offered only as a guide. Operators who plan to build new plants or remodel their present ones should contact local heating engineers regarding their individual needs.

The basic formula to determine the B.t.u. requirements for heating milk products is:

B.t.u. per hour = Pounds of milk × Temperature change × Specific heat

Since steam is used to heat all milk products, the total B.t.u. requirements may be converted to pounds of steam per hour and to boiler horsepower.[5]

Tabulated below are the B.t.u. requirements for heating the various milk products in the plant, based on this formula. Since the vapor-line heater (36) and interstage vapor-line heater (37) receive their heat from the double-effect recompression evaporator (43,44), they are not included in the tabulation. The B.t.u. requirements for the double-effect recompression evaporator are those recommended by the manufacturers.

[5] Boiler horsepower is the amount of heat required to evaporate 34.5 pounds of water in 1 hour. This is calculated as a heat requirement of 33,524 B.t.u. per hour; however, 35,000 B.t.u. is usually used as 1 boiler horsepower.

Heating requirements for processing operations

Equipment item number	Process	Pounds of product	Temperature change (° F.)	Specific heat [1]	Heat requirement per hour (B.t.u.)
8	Separating and preheating whole milk.	40,000	72.8°–85°	1.00	488,000
12	Pasteurizing cream.	3,600	142°–180°	.85	116,280
22	Preheating cream ahead of churn.	80,000	40°–48°	.85	544,000
36–44	Evaporating process.	26,884	–	1.00	6,900,000
48	Preheating concentrated skim ahead of dryer.	5,774	115°–165°	.95	274,265
109	Heating water for plant use.	25,000	60°–120°	1.00	1,500,000
57	Instantizing process.	2,000	–	–	1,188,000
Total processing requirements					11,010,545

[1] Approximate values.

Heating requirements for the building are estimated at 10 B.t.u. per hour per cubic foot of area to be heated. This estimate includes all areas except the hallway, which is a principal exhaust area, boiler room and evaporating-drying room, which are heated by boiler radiation and motor heat, and refrigerated storage areas. When the equipment in the boiler room and the evaporating-drying room is not operating, the reduction in the plant steam load more that offsets the heating requirements.

Total heat requirements are as follows:

	B.t.u.
Building	1,947,680
Processing	11,010,545
Total	12,958,225
Plus 10% radiation loss	1,295,822
Total	14,254,047

$$\text{Boiler horsepower required} = \frac{14,254,047}{35,000} = 407$$

Two 200-hp. boilers (88, 89) are suggested for the plant since the units may be operated at 50-percent overload continuously or 100-percent overload for short periods.

Some incidental steam requirements are not listed in the above tabulation, such as steam used in the laboratory and for the kettle to boil butterbox liners. These loads are insignificant when compared with the large loads listed above.

Heating requirements for building

Room	Area	Height	Volume
	Sq. ft.	*Ft.*	*Cu. ft.*
Receiving shelter	1,440	17.3	24,912
Processing room	3,697	14	51,758
Laboratory	240	10	2,400
Bagroom	990	14	13,860
Powder storage	3,022	14	42,308
Dry storage	1,733	14	24,262
Plant engineer's office	144	10	1,440
CIP room	192	14	2,688
Superintendent's office	120	10	1,200
Locker room, men's restroom	435	10	4,350
Parts storage, shop	585	14	8,190
Lunchroom, women's restroom	318	10	3,180
General office, manager's office	1,146	10	11,460
Fieldman's office, office supplies	276	10	2,760
Total			194,768

B.t.u. required per hour = 194,768 × 10
= 1,947,680

Ventilating and Air-Conditioning System

Three types of ventilation air-conditioning equipment are used in the plant. They are (a) roof and wall exhaust fans with ceiling-suspended unit heaters for winter heating, (b) recirculating type of air-conditioning units with provisions for heating, cooling, and filtering air, and (c) recirculating type of air-conditioning units with provision for heating and filtering air.

Roof and Wall Exhaust Fans (122) With Unit Heaters (123)

This type of ventilation equipment is suggested for the receiving shelter, evaporating-drying, refrigeration room, bagroom, shop, storage, and boiler room. Roof- and wall-mounted exhaust fans capable of giving one air change every 4 minutes should be located here, with supplementary roof exhaust fans in the boiler and refrigeration rooms to give an air change every 2 minutes. The supplementary fan in the boiler room would be used on very hot days to eliminate more of the radiant heat from the boilers, and in the refrigeration room on hot days to drive off the electric motor and switch gear heat given off by the electrical distribution panel. An additional function of the supplementary fan in the refrigeration room would be to increase ventilation if a serious ammonia leak in the refrigeration system should develop. The boiler room should have large windows with insect screens on the outside.

The repair shop should be equipped with a ceiling reversible exhaust fan, which can be operated in either direction according to the personal preference of the workers affected.

The unit heaters would be used for winter heating. They would utilize steam from the boiler, condensed in a finned coil by an air-circulating fan. The unit heaters are temperature-controlled by room thermostats.

Recirculating Air-Conditioning Units for Heating, Cooling, and Filtering Air (124)

A 7,000-c.f.m. unit of this type is used to heat the manager's office, fieldman's office, general office, lunchroom, locker room and restrooms during cool weather. It is equipped with a cooling coil and Freon condensing unit for cooling in warm weather. The ductwork for air distribution may be located on the roof or within a false ceiling. Return air ducts return the air to the unit for reheating or recooling. The unit is equipped with an automatic damper which will adjust itself by mixing fresh outside air with return air to yield a blend temperature of 55° F. to the heating coil, thus constantly introducing fresh outside air into the system.

Recirculating Air-Conditioning Units for Heating and Filtering Air (125)

A unit of this type is suggested for the processing room. The purpose of this unit is to control (1) air purity, thereby improving product quality by reducing the opportunity for bacterial contamination, (2) air temperature and humidity for worker comfort, and (3) humidity so as to prevent excessive moisture condensation on the walls, ceilings, and equipment.

Air is returned to the unit via ductwork, which has the inlets near the floor so as to pick up moisture-laden air at a low level. The unit is equipped with a fresh air inlet and automatic dampers to control the ratio of fresh to recirculated air. In the winter, these dampers automatically adjust themselves to deliver 45° F. air to the heating coil. Thus, when the outside air is 45° or above, all fresh air enters the plant and spent air is exhausted. The dampers are controlled by a thermostat in the air stream discharge from the dampers.

Next to the mixing chamber is a filtering section which removes most of the airborne-dust particles. After being filtered, the air passes through a steam-heated coil controlled by a room thermostat. A constant discharge temperature is maintained by a bypass around the heating coil, which is controlled automatically by a damper so as to maintain a set temperature after the heated and bypassed air are blended together.

The unit maintains a positive pressure on the processing room so that leakage of air is out of rather than into the room. This insures that air entering the room is filtered.

The circulating fan is two-speed, providing 30,000 c.f.m. circulation in summer and 15,000 c.f.m. in winter.

For plants located in very hot and humid regions, a cooling coil would be desirable for the air-conditioning unit in the processing room. The operation is the same as for heating except that in summer only a small amount of fresh air is added, most of the air being recirculated. The coil would be refrigerated by a Freon condensing unit. The cooling would be thermostatically controlled at 72° F. or, in periods of extremely hot weather, at a differential of inside to outside temperature of 15°.

For the plant superintendent's office, engineer's office, and laboratory, a wall-type air-conditioning unit (not shown) is suggested. The waste heat would be exhausted to the refrigeration room or to the outside of the building.

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