PB85-216505

Strategies for Water and Waste Reduction in Dairy Food Plants

Ohio State Univ., Columbus

Prepared for

Environmental Protection Agency, Cincinnati, OH

Jun 85

U.S. Department of Commerce
National Technical Information Service
NTIS

PB85-216505

EPA/600/2-85/076
June 1985

STRATEGIES FOR WATER AND WASTE REDUCTION IN DAIRY FOOD PLANTS

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U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1 REPORT NO EPA/600/2-85/076	2.	3 RECIPIENT'S ACCESSION NO PB85-216505
4 TITLE AND SUBTITLE Strategies For Water and Waste Reduction in Dairy Food Plants		5 REPORT DATE June 1985
		6 PERFORMING ORGANIZATION CODE
7 AUTHOR(S) W.J.Harper*, R.A.M. Delaney*, I.A. Igbeka*, M.E. Parkin*, W.E. Schiffermiller**, T.E. Ross**, R.A. Williams**		8 PERFORMING ORGANIZATION REPORT NO
9 PERFORMING ORGANIZATION NAME AND ADDRESS * The Ohio State University, Columbus, OH 43210 ** The Kroger Co., Cincinnati, OH 45202		10 PROGRAM ELEMENT NO
		11 CONTRACT/GRANT NO Grant No. R 803374
12 SPONSORING AGENCY NAME AND ADDRESS Water Engineering Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Cincinnati, OH 45268		13 TYPE OF REPORT AND PERIOD COVERED Final
		14 SPONSORING AGENCY CODE EPA/600/14

15 SUPPLEMENTARY NOTES

Project Officer: Kenneth Dostal (513)684-7502

16 ABSTRACT

A study was undertaken to reduce water and waste discharges in a complex, multi-product dairy food plant through management control and modifications of equipment and processes. The objectives were to develop approaches that would be broadly applicable throughout the dairy industry and to determine the economic and environmental impacts of the programs instituted.

Detailed studies were made to determine the plant areas contributing major waste loads and the economic feasibility of reducing these loads. A Management control program was developed and implemented over a 6-month period. This program included major increases in direct supervision of waste control. A Computer linear program was applied to the four processing areas to determine economic factors involved in waste-water discharges and to help select the most economical process and equipment changes that could be made.

The Study concluded that material reduction can be achieved economically in dairy food plants that have not previously given attention to this matter.

17. KEY WORDS AND DOCUMENT ANALYSIS

a DESCRIPTORS	b IDENTIFIERS/OPEN ENDED TERMS	c COSATI Field/Group
Inplant Study Minimize Water Use Minimize Waste Loads	Food/Dairy/Processing Water Wastewater	13B

18 DISTRIBUTION STATEMENT Release Unlimited	19 SECURITY CLASS (This Report) Unclassified	21 NO OF PAGES 313
	20 SECURITY CLASS (This page) Unclassified	22 PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

DISCLAIMER

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under Grant No. R 803374 to the Kroger Company and The Ohio State University. It has been subject to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water systems. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. The Clean Water Act, the Safe Drinking Water Act, and the Toxic Substances Control Act are three of the major congressional laws that provide the framework for restoring and maintaining the integrity of our Nation's water, for preserving and enhancing the water we drink, and for protecting the environment from toxic substances. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Water Engineering Research Laboratory is that component of EPA's Research and Development program concerned with preventing, treating, and managing municipal and industrial wastewater discharges; establishing practices to control and remove contaminants from drinking water and to prevent its deterioration during storage and distribution; and assessing the nature and controllability of toxic substance releases to the air, water, and land from manufacturing processes and subsequent product uses. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

The information presented here will help industry arrive at meaningful or achievable solutions to environmental problems by the sudy of methods for the inplant reduction of wastes through a management control program. The achievement of these goals requires a complete dedication on the part of industry management and a sufficient promotion by industry and government to provide the needed motivation for success.

Francis T. Mayo, Director
Water Engineering Research
Laboratory

ABSTRACT

A study was undertaken to reduce water and waste discharges in a complex, multiproduct dairy food plant through management control and modifications of equipment and processes. The objectives were to develop approaches that would be broadly applicable throughout the dairy industry and to determine the economic and environmental impacts of the programs instituted.

The Kroger Dairy Company at Indianapolis, Indiana, was the study site. This plant was chosen because it was well engineered, discharged its wastes to a municipality, was under average management control. and had not previously had an extensive waste control program. As such, it was typical of more than two-thirds of the dairy plants in this country.

Detailed studies were made to determine the plant areas contributing major waste loads and the economic feasibility of reducing these loads. A management control program was developed and implemented over a 6-month period. This program included major increases in direct supervision of waste control. A computer linear program was applied to the four processing areas to determine economic factors involved in wastewater discharges and to help select the most economical process and equipment changes that could be made.

The study concluded that material reduction can be achieved economically in dairy food plants that have not previously given attention to this matter.

This report was submitted in fulfillment of Grant No. R 803374 by The Ohio State University and the Kroger Company under the sponsorship of the U.S. Environmental Protection Agency.

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ACKNOWLEDGMENTS

This study was conducted by the Kroger Company of Cincinnati, Ohio, in collaboration with the Department of Food Science and Nutrition of The Ohio State University at Columbus, Ohio. Mr. Ron Rice, Mr. Jack Cornette, and the Board of Directors of the Kroger Company are acknowledged for their recognition of the need to study methods for the inplant reduction of wastes. The project directors for this study were Mr. William Shiffermiller and Mr. Thomas Ross of Kroger, and Dr. W.J. Harper of Ohio State University.

This study was conducted at the Kroger Dairy in Indianapolis, Indiana. The support and assistance of the two Plant Managers - Mr. Harold Wall and Mr. John Morrison - is gratefully acknowledged. In addition, valuable assistance was received from all of the plant employees and supervisory personnel, with special thanks to Mr. Ernie Lippert, Mr. Joseph Salimbene, Mr. Art Rush, Mr. Norman Clark, and Mr. Eric Perkins.

Technical assistance is acknowledged for analyses conducted at Ohio State University by Mr. Kevin Brown, Mr. Thomas Laahman, Mrs. Lee Reichenbach, Mr. Bill Schreiber, Mr. Mark Smith, and Dr. C.R. Lee.

The work of Dr. Roy E. Carawan on computer linear programming, funded by The Ohio State Water Resources Laboratory, was conducted simultaneously with the study, and the approaches were adapted to the specific applications required in this study.

Mr. Alfred B. Craig was the project officer for the major portion of this study, and his suggestions, moral support, and assistance are gratefully acknowledged.

SECTION 1

INTRODUCTION

PURPOSE

This investigation was undertaken to develop, implement, and evaluate strategies for reducing water and waste discharges in a complex, multiproduct dairy food plant through a combination of management control and modification of equipment and/or processes. The purposes were to develop approaches that would be broadly applicable throughout the dairy industry and to determine the economic and environmental impacts of the programs instituted. The results may be used to help reduce wastes at other dairy food plants.

To make the results as appplicable as possible, a plant was chosen that was well engineered, discharged its wastes to a municipality, was under average management control, and had not been previously engaged in an extensive waste control program. Such a plant was considered to be typical of more than two-thirds of the dairy plants in this country.

The Kroger Dairy at Indianapolis, Indiana, met these criteria. In addition, it was a large, complex, multishift, multiproduct, union-labor-operated plant. If this plant could successfully demonstrate waste reduction through management control and equipment or process modification, these approaches should be usable across the industry. The plant was constructed in 1973 and incorporated the latest in engineering design available at that time, including computer control of the separation processes and some waste recovery techniques. Fluid milk products, cultured products, cottage cheese, ice cream, and frozen novelties were manufactured under one roof. The plant operated 5 days a week on a three-shift basis, with some processing going on during all three shifts. The wastes were discharged to the Indianapolis Municipal Treatment Plant, which charged for volume and added a surcharge for biological oxygen demand (BOD) and suspended solids (SS) levels in the wastewater above municipal sewage strength.

The results were evaluated with respect to the extent of wastewater reduction and its economic impact on the plant. Results were also evaluated with regard to the reduced environmental impact of dairy food plant wastes.

OBJECTIVES

The project was divided into three phases: (1) determination of a baseline for water use, wastewater discharge and waste characterization, (2) development, implementation, and evaluation of methods for management control and (3) determination of economically feasible changes in unit processes and/or equipment for further waste reduction in the plant and implementation of feasible changes.

The specific objectives for Phase 1 were:

1. To construct sampling stations for monitoring the waste from individual departments.

2. To determine a mass balance for water and product through the plant.

3. To determine the volume and composition of the waste being discharged from the plant.

4. To establish the waste components that were inter-

dependently and independently related.

5. To determine specifically whether the relationships between COD (chemical oxygen demand), BOD, and SS were constant enough for the total plant wastewater to use COD as a predictive measure of BOD and SS.

6. To determine the amount of preventable and unavoidable water and organic discharges from the plant and from each department. (The unavoidable waste is that associated with the design of the plant processes and can not be reduced without making physical changes.)

7. To compare losses measured from production records with those measured in the wastewater and to determine the reasons for previously reported underestimates of losses by the use of production records.

8. To determine the major factors involved in the loss of water and organic material.

9. To determine water and waste coefficients for major unit operations.

The specific objectives for Phase 2 were:

1. To develop a comprehensive management waste control program for reducing at least 75% of the preventable water and organic waste load.

2. To use a computer system to monitor water, wastewater recovery systems and product processing as a managment tool in the control program.

3. To implement the control program, evaluate its effectiveness, and make modifications to optimize the program.

4. To prepare a waste control management handbook for the dairy industry as a separate document.

The specific objectives for Phase 3 were:

1. To investigate the specific changes in unit processes or equipment that would significantly reduce losses of water or ingredients.

2. To adapt a computer linear analysis system for modeling the waste-related costs of milk products,

cottage cheese, ice cream and frozen novelties and thereby determine the economics of changing the unit process or the equipment or both to reduce waste loads.

3. To apply the LP model to the proposed project changes and select those that would recover the cost of the changes within an 18 month period.

4. To implement the process and/or equipment changes for reducing water or waste loads and to evaluate the actual versus the predicted effectiveness.

BACKGROUND

As regulations on the effluents from municipal water treatment plants become more restrictive, major contributors of organic matter, such as dairy plants, will face considerable pressure to reduce their loads, increase pretreatment, and/or provide full secondary treatment. User charges for municipal treatment will become a major economic factor requiring good management control of fluid wastes in dairy food plants.

Historically, dairy plants that have not been subjected to

prior pressure as point dischargers of wastewater or as overloaders of the municipal system have given little attention to water or organic waste loads. Such plants' waste loads have generally included about 50% preventable wastes under average management control. The investigators considered that a majority of the plants located in large cities would fall under this category, including the dairy at Indianapolis. With the continuing trend for further consolidation of the dairy industry, these large plants probably contribute about 50% to 60% of the total organic waste load contributed by the dairy industry.

The Kroger Dairy at Indianapolis is typical of the large dairy plants that have been built over the past decade and that process more than 1 million lb of milk a day and generate organic waste loads equal to those of a city of more than 50,000. Most of these plants and those built in the future will be located near a municipal waste treatment facility that can effectively treat the compatible wastewaters generated by dairy product processing. Such plants will be major contributors of organic waste loads. Reduction of these waste loads may have a significant impact on the efficiency of the municipal treatment works in many instances, though the degree of impact will vary in different locations.

Observations made before the plant was chosen for study indicated that (1) large, preventable losses occurred, (2) the

plant was not achieving water or waste control in keeping with its engineering design capability, (3) the management was concerned about waste control, (4) the city sewer charges were relatively low and thus made sewer costs basically invisible as an economic cost, and (4) the plant provided a challenge for developing an effective control program.

At the time this study was initiated, the Kroger dairy received up to 1.5 million lb of milk per day and discharged approximately 500,000 gal of wastewater per day with an average BOD load of 10,000 to 12,000 lb. The amounts of BOD and water (wastewater coefficients) per 100 lb of BOD processed were 6.3 lb of BOD and 370 gal of wastewater, respectively. (These data were based on a preliminary survey of time composite samples over 1 week within 6 months of the opening of the plant.)

SECTION 2

CONCLUSIONS

The study of the Kroger Dairy at Indianapolis, Indiana has led to the conclusion that material reduction can be achieved economically in dairy food plants that have not previously given attention to this area. The conclusions have been divided into three categories: (a) those relating to the composition of dairy food p .nt wastes, (b) those relating to reduction of preventable wastes, and (c) those relating to process and/or equipment modification to reduce unavoidable waste levels.

DAIRY PLANT WASTE COMPOSITION

1. The following waste parameters were interrelated: COD, BOD, SS, volatile suspended solids VSS), total solids (TS), protein, fat, carbohydrates, and phosphorus. Sodium, calcium, and chloride varied independently of the other components. These results are expected where the related organic components are all derived from ingredient losses; Na and Cl would also be contributed by cleaning and sanitizing solutions, and calcium chloride would be discharged in large quantities from the freezing of stick novelties.

2. About 95% of the organic matter in the waste from the Kroger dairy plant was derived from food ingredients, and the remainder was derived from acid cleaning compounds.

3. The BOD/COD ratio for the total plant waste at the Kroger dairy was found to be 0.46 $\pm$ 0.06. This suggests that for a given plant, where there is no change in the Cleaned-in-Place (CIP) system or in the relative amounts of different products processed, the BOD/COD ratio remains relatively constant. Therefore, either BOD or COD can be used to estimate the other once the relationship has been established for a particular process.

4. The composition and waste coefficients for the Kroger dairy were typical of those obtained for dairy plants that had no previous record of extensive study.

5. The EPA-recognized methods for determining fats, oils, and grease in municipal wastes were not reliable for determining them in dairy food plant wastes. Acid hydrolysis before extraction was essential for providing a reproducible, routine method to determine fats, oils, and grease. The fat recovery by this method was 37% $\pm$ 3%.

6. The standard Technicon method for determining carbohydrates in fluid wastes was not reliable for dairy wastes, since

it failed to measure more than 80% of the lactose in the samples. A modified procedure was developed that gave more than 90% recovery of sucrose, lactose, glucose and fructose, which are all found in dairy plant wastes.

7. Because of the short time required for analysis, COD was the preferred method for estimating loss and product yield for wastewater analysis. COD analyses of products and ingredients increase the accuracy of this approach. This involved COD analysis of the wastewater, COD analysis of all ingredients, and calculation of pounds of COD processed by multiplying the amount of each ingredient used by the pounds of COD per pound of ingredients and summing the total pounds of COD processed: % loss = (pounds COD in wastewater/pound of COD processed) x 100.

8. Determination of losses by COD and/or BOD analysis of the wastewater was more accurate than that obtained from production figures, since the latter were frequently based on reference to established standards and production goals that were not reflected in actual practice.

MANAGEMENT CONTROL OF WATER AND WASTE DISCHARGES

1. Approximately one-third of the water and one-half of the organic load wasted in the Kroger dairy were found to be

preventable wastes subject to reduction through managment control.

2. The computer installed for monitoring production, water, and wastewater was of limited value because of inability of project personnel to program it. The cost of software revision was not economical.

3. Raw waste must be transformed into an economic impact format (such as dollars of loss/day) for management to fully understand the situation.

4. Data interpretation is a major problem in developing management understanding. The data generated by waste analysis required extensive calculations to put it in a form that management could readily understand and act on. The basic problem was that the output was in a form that was too technical for management use. A cheaper alternative to speeding up calculations by buying more software for the computer installed in the plant was to obtain a low-cost micro-computer that could be programmed in basic to calculate and format reports specifically for management.

5. This and other studies show that plant management does not have an adequate background in waste and waste control to be able to develop an effective control program without specialized assistance.

6. The control management procedure that included education and daily evaluation was effective in reducing water and wastes to about the level predicted. A waste control manager with no other duties was the best approach.

7. The management control handbook that resulted from this investigation should be of value in assisting management to develop a control program. This handbook should also apply to other areas of the food field.

8. Plant operators are motivated more by social and environmental goals than by economic considerations. The operators in the Kroger dairy developed interest in the control program, and about 10% were highly motivated as long as there was visible interest on the part of their immediate supervisors.

9. A detailed analysis of the water use, production scheduling, plant preventive maintenance, equipment operation, and waste loads by department and unit process is essential to understanding how to structure a waste control program and establish realistic goals.

10. The management control program can be an effective way of reducing wastes and will more than pay for the costs involved.

11. Control of preventable wastes is a management function. Effective control requires the full-time effort of at least one individual who has no other responsibilities and who answers directly to the general manager.

12. The LP computer models developed for this study are applicable to any dairy plant that has adequate information on water and waste coefficients. The program was useful in delineating the factors associated with economic losses that were waste-related, showing the difference between design and actual losses. Loss-associated costs were for ingredients, water, wastewater, surcharges for BOD and SS, packaging materials, labor associated with lost product, and energy associated with lost product.

EQUIPMENT AND/OR PROCESS CHANGES

1. The LP computer program provided a basis for determining the projected effect of process and/or equipment changes and was used in making final decisions about the changes that were economically feasible.

2. Process and equipment changes in the Kroger Dairy results in a savings of 100,000 gal per day (20%) and a reduction of 1000 lb of BOD (10%) per day.

3. The elimination of whey was not considered economically feasible at this time. The cost of discharging whey to the municipal treatment plant was 40 ¢/lb of dry curd. More detailed information is needed to determine the economic feasibility of converting whey to baker's yeast.

SECTION 3

RECOMMENDATIONS

Recommendations based on this study are divided into those specifically pertaining to the Kroger Dairy's future operations and those that apply to the dairy industry at large.

KROGER DAIRY RECOMMENDATIONS

1. Continue the management waste control program using a single individual who has no other responsibilities and who reports directly to the plant manager.

2. Institute a daily loss/cost analysis program of the wastes from the ice cream and from the total plant operations, using COD determinations.

3. Modify the current computer system to:

   a. exclude production data,

   b. include counters from milk and ice cream fillers.

   c. include stick counters and package counters for the four-stick novelty machines.

d. include mathematical calculations to convert raw data into usable form.

4. Improve maintenance capability to ensure that the preventive maintenance program is actually carried out as scheduled and includes those items specifically related to waste control.

5. Conduct further study to determine process and/or equipment changes that would further reduce cost and recover the cost of the changes in 3 to 5 years.

6. Conduct further study to determine the technological and economic cost of achieving zero discharge in this plant.

INDUSTRYWIDE RECOMMENDATIONS

1. The management waste control program instituted at the Kroger Dairy should be used by other dairy plants as a viable means of reducing waste loads.

2. The LP program used for this study should be made available for general dairy food plant use.

3. Each dairy plant should institute a

waste monitoring program using COD as the basic analytical method to monitor wastes and plant yields.

4. All dairy plants should institute an evaluation of the potential changes in process and/or equipment that would achieve further reductions in waste loads.

SECTION 4

FACILITIES AND METHODS OF STUDY:

This section discusses the Indianapolis Kroger dairy plant in detail to provide an understanding of the subsequent findings and alterations made in process equipment; a description of the sewer drain system and provisions for monitoring flow and sampling; and a description of the analytical methods that were utilized.

DESCRIPTION OF DAIRY PLANT

The Kroger Dairy at Indianapolis, Indiana was utilized for this investigation. The plant, which was constructed in 1973, is a multi-product plant producing fluid milk products, cottage cheese and frozen desserts. A typical day's production would be:

- Fluid milk received	1,500,000 lb
- Fluid milk products	1,200,000 lb
- Cottage cheese	19,000 lb

- Ice Cream	90,000 lb
- Novelties	56,000 lb
- Wastewater volume	650,000 gal
- Waste as BOD	10,000 lb
- Waste as SS	4,000 lb

The products manufactured in this plant are as follows:

Fluid milk products:

-3.25% homogenized milk	-2.0% milk
-Lo Fat milk, 0.5%	-Chocolate drink, 2%
-Fortified skimmilk	-Imitation chocolate
-Egg nog	-Buttermilk
-Half & Half	-Coffee cream
-Cheese skimmilk	-Cheese dressing
-Sour Cream	-Imitation sour cream
-Fruit yoghurt	-Old Fashioned yoghurt
-Orange drink	-Lemon drink
-Orange juice	-Grape drink

Cottage cheese:

-dry curd	-creamed cottage cheese

Ice Cream products:

-10% fat ice cream

-12% fat ice cream

-Ice milk

-Ice Cream Sandwich

-Sherbet

Frozen Novelties:

-Ice pops

-Ice cream bars

-Ice milk bars

-Fudge bars

-Specialty bars

-Root beer floats

The fluid products are produced in a variety of package sizes and the frozen deserts are in a variety of different flavors. Altogether, the plant produces over 124 different packages of products.

Description of Plant Operations:

A diagramatic description of the plant and equipment layout is presented in Figure 1. Specific equipment is described by number and letter in this figure. Specific descriptions of

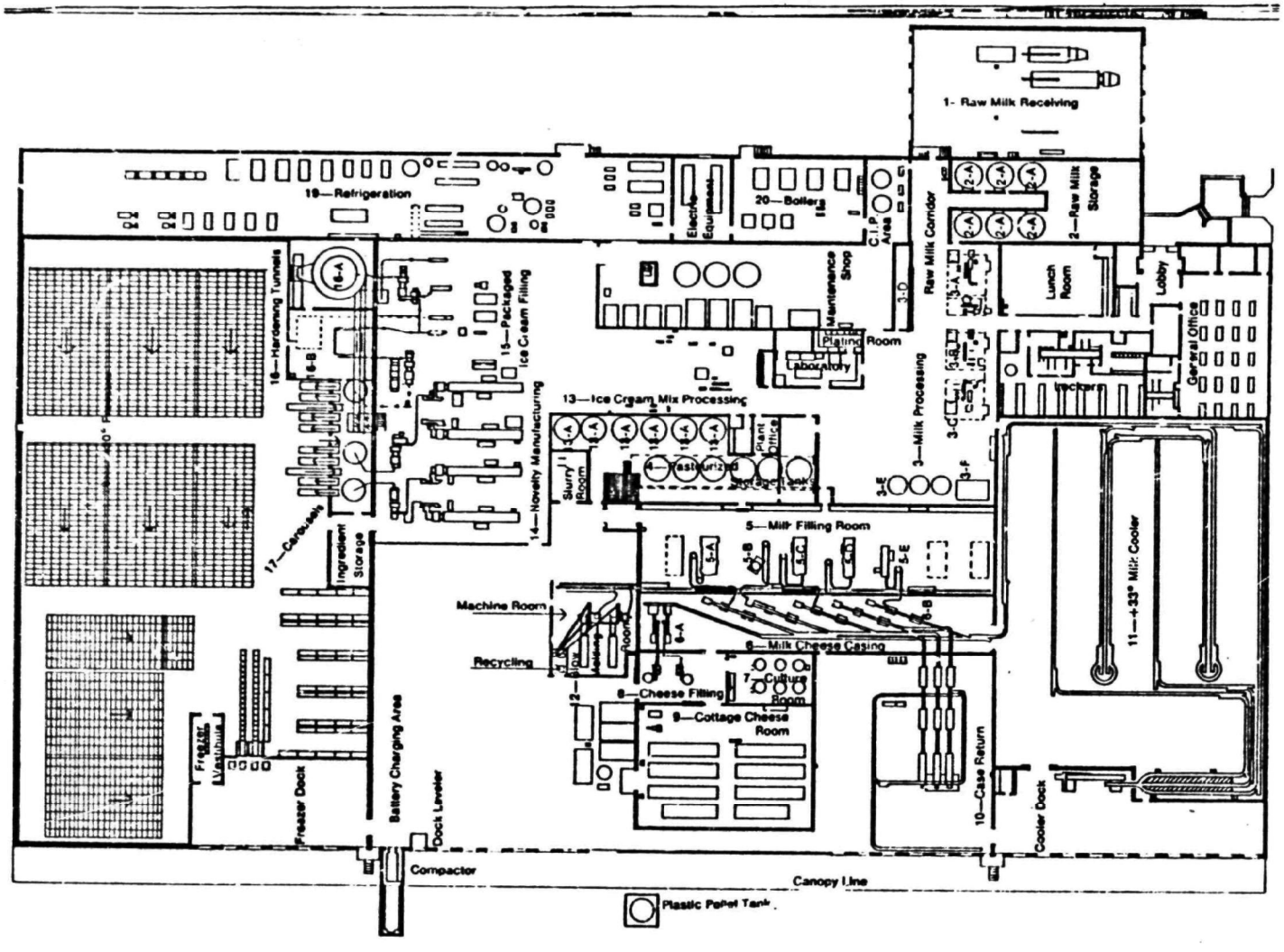


Figure 1. Floor Plan of Indianapolis Kroger Dairy

the various areas numbered in the figure are as follows:

1. Raw milk receiving:

The four-bay receiving room permits the unloading of four 6,000 gal tankers at one time. The total raw milk pumping capacity is 400 gal a minute or 200,000 lb an hour which matches the plant's High Temperature Short Time (HTST) capabilities. Incoming tankers are weighed on a 70 ft ground scale just before entering the room. In addition to raw milk, the central receiving area accepts corn and cane syrup, cane sugar, bulk chocolate coating, condensed milk, cream and bulk cleaning solutions. Each bay has its own CIP system for washing the trucks. All rinses and washings are discharged to the sewer.

2. Raw Milk storage tanks:

The plant is equipped with (2-A) five, 30,000 gal Mueller and one 25,000 gal Cherry Burrell raw product cold wall silo storage tanks, providing a total capacity of 175,000 gal (1,505,000 pounds).

3. Fluid milk processing:

Total rated capacity is 190,000 lb per hour. Equipment includes (3-A) 89,000 lb per hour Crepaco (modified

to 50,000 pounds per hour to provide processing of special products and decrease processing time), with homogenizer; (3-B) 55,000 lb per hour A.P.V. HTST with a Gaulin homogenizer. Two SAMM-25006 Westfalia 55,000 lb per hour CIP Separators are tied into the 50,000 lb. units and a 27,000 lb. per hour Westfalia CIP Separator (Model SAMM-12006) is tied into the third 50,000 lb per hour unit; (3-D) The control panel directs all fluid product processing; (3-E) Batching area for by products; and (3-F) Mueller square tanks.

4. Pasteurized storage tanks:

The plant has six, 10,000 gal Crepaco pasteurized storage tanks that are cleaned and sanitized with a Klenzade single pass CIP unit.

5. Milk filling room:

At the beginning of the project, the filling room was equipped with (5-A) Cherry Burrell G-60 gal. paper filler; (5-B) a Remy gal plastic filler; (5-C &5-D) Ex-Cell-O TP half-gal fillers; (5-E) and a NNL aseptic Ex-Cell-O unit for by-products. The room is air filtered with a laminar air filter system.

6. Milk and milk casing:

This area has five milk lines and one cheese, yoghurt and sour cream line for automatic casing and stacking.

7. Culture room:

The room is equipped with one, 1,000 gal. Mueller and two, 1,500 gal. cone bottom Cherry Burrell vats for yoghurt and sour cream. The room also has three 600 gal. all purpose flat bottom round processors for culture or cultured products.

8. Cheese filling room:

The filling room is air filtered and has an Auto Pak cheese filler and two Akra Pack fillers for yoghurt and sour cream.

9. Cottage cheese room:

Six 30,000 pound and two 15,000 pound Damrow cheese vats are used for cottage cheese production. The room has one 3,000 gal., three-compartment Cherry Burrell cheese dressing tank. Three 9,000 gal. Cherry Burrell rectangular tanks store skim milk for cheese making. Two other tanks are used to store chilled water, which is used to wash the cottage cheese.

10. Case return area:

The case return area is equipped with Conveyor Speciality unstackers and case washers. The in-floor conveyors do not require lubrication.

11. Milk cooler:

The cooler holds about 50,000 cases, with an in-floor, double loop conveyor that allows continuous circulation of cases until they are placed in inventory. A milk recovery tank is located in the cooler to recover product from damaged cartons. No lubrication is required for the conveyors.

12. Blow mold room:

This area is equipped with two Uniloy gallon blow molders and a plastic recycle system. A 10,000 gal silo tank stores plastic pellets for container manufacturer on site

13. Ice cream processing:

The equipment includes one 4,000 gal per hour A.P.V. Gaulin HTST unit for ice cream products; one Batch-O-Matic ice cream mix blending-weight system; 24 Cherry Burrell ice cream flavor tanks; two 1,000 gal 3 barrel Crepaco ice cream freezers for packaged products; two 800 gal 2-barrel Crepaco ice cream

freezers for novelties; one 500 gal. 2 barrel Cherry Burrell freezers. There are 10 mix storage tanks. In addition, in the ice cream processing area are located 4 cream storage tanks, one tank for rinse recovery, one for buttermilk slurry and two for whey slurry. All of these supply the Batch-O-Matic mix tank.

14. Novelty manufacture:

Four 12-wide Vitaline stick novelty machines that are brine fed are used in the production of stick novelties. The system uses Anderson Brothers bar wrappers, box formers and polywraps.

15. Ice cream packaging:

This area has a 555-4 Anderson half gal. filler, 325 Anderson filler, and a Lynch Mopack sandwich machine. The boxer is a Mastercraft. An Auto Pak round container filler for gallon packages is also used. The sandwich packaging machines are from R. A. Johnson Co. and operate at 1500 to 1800 gals. per hour.

16. Hardening tunnel:

The hardening tunnels are a Gram (16-A) and an Americo (16-B).

17. Carrousels:

Three carrousels palletize and transfer product from the hardening tunnels to storage freezers.

18. Frozen dessert storage:

The storage area holds one million gals of packaged ice cream and two million dozen novelties.

19. Refrigeration:

This area contains the compressors and sweet water tanks.

20. Boilers:

This area contains three 300 hp vapor heating boilers.

Special features in this plant that relate to water used and waste loads are:

1. Automated CIP system:

Seven CIP units serve the plant. The units are single use, supplied with liquid chemicals. A stainless steel trough is located below the chemical feed pumps to collect any leakage of full strength chemicals and these troughs are rinsed

automatically to dilute any spilled chemical to prevent damage to the drains.

2. Continuous processing of by-products:

Computer-controlled standardizing clarifiers separate the milk into cream and skim which can be automatically metered to produce products of any desired fat content, thus eliminating batch operations and reducing the start-up and shut-down of the HTST units.

3. Rinse recovery:

A rinse recovery system is installed for the three milk HTST units to automatically save water-milk blends during the start-up and shut-down of the pasteurizers. The rinses are stored in a 3,000 gallon tank for subsequent use in ice cream manufacture.

4. Damaged carton product recovery:

Covered stainless steel containers are located adjacent to the milk fillers and in the milk cooler to collect the product from damaged cartons. An automatic vacuum system is used to transfer the product to the rinse recovery tank.

5. Segregated sewer lines:

There are three separate process sewer lines in the plant (See Figure 2): (a) one for the milk receiving, processing, filling and storage areas, (b) one for the ice processing, novelty processing and packaging and ice cream packaging filling and (c) one for high concentration wastes including the CIP system, cottage cheese and hub drains for the HTST units - for separator sludge CIP solutions of these systems. These exisiting lines provided a basis for setting up sampling stations to determine the waste loads from the different departments.

GENERAL PRODUCTION SCHEDULING:

The plant operates on a three shift basis:

7am-3pm

3pm-11pm

11pm-7am

General scheduling for the various departments is as follows;

Receiving:

Milk is received in 6,000 gallon tankers between 7 am

and 9 pm. Generally from 20 to 40 tankers are scheduled on a staggered basis.

Milk Processing:

Pasteurization of milk begins between 4 and 6 am and continues until about 11 or 12 pm. Clean up is scheduled between 12 and 4 am.

Milk Filling:

Milk packaging operation begins at 7 am and continues until 11 pm. Equipment clean-up is between 12 midnight and 6 am.

Ice Cream Processing:

Pasteurization of frozen desserts starts from between 4 and 6 am. Processing is completed on most days by 8 pm.

Ice Cream Packaging:

Ice Cream packaging begins about 7 am and continues until 11 pm.

Clean-up is from 12 midnight until 4 to 5 am.

Novelty Operations:

The novelty machines are on the same schedule as the ice cream packaging.

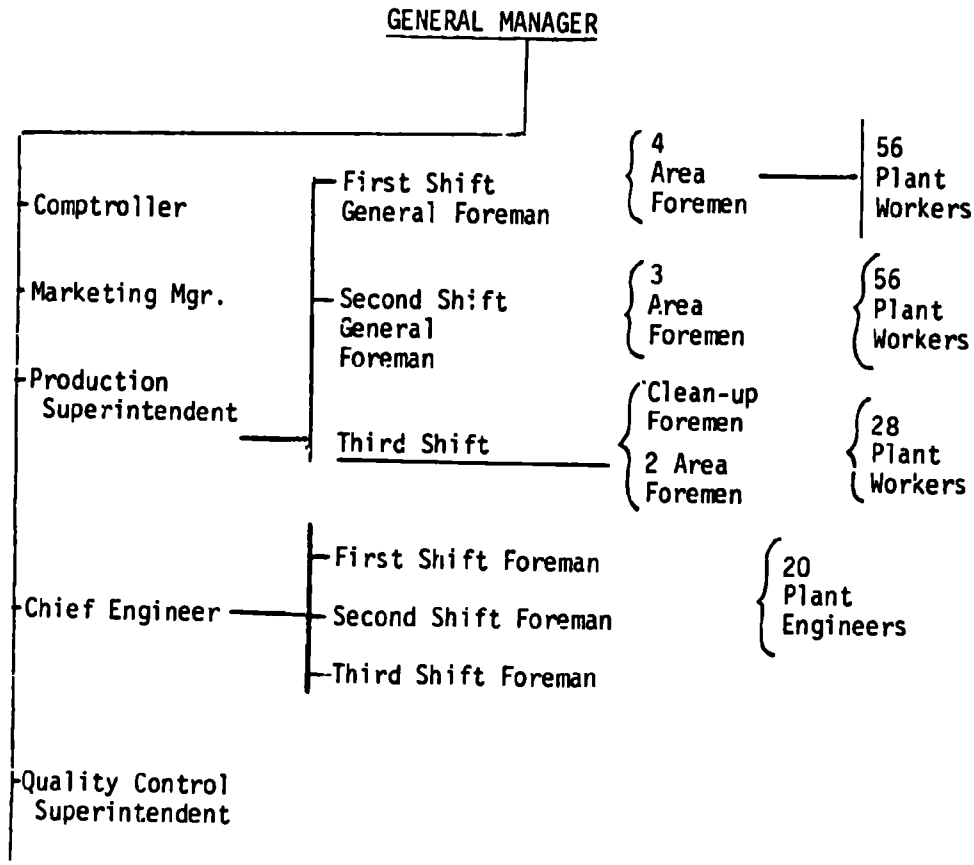
Cottage cheese:

Skim milk is pasteurized during the morning and the vats are filled in sequence beginning about 3 to 4 pm. The whey is drained from the vats between 11 pm and 2 am. Washing continues until about 5 am.

The curd is creamed in the vats and the cleaning of the cheese vats starts about 11 am and continues until 3 pm.

MANAGEMENT STRUCTURE

The management structure of the Kroger dairy is shown as follows:



FLOW MONITORING AND SAMPLING:

Description of sewer lines:

A diagram of the sewer lines and designation of the location of sampling stations is shown in Figure 2. There are four separate sanitary sewer lines discharging from the plant and connecting to a 12 inch line that connects to the city sewer system by means of a lift station. A storm sewer line (not shown) is separate for clean water discharges.

The separate sewer lines are: (a) an eight inch line connecting the floor drains for the ice cream processing and packaging and the novelty processing and packaging operations; (b) a six inch line connecting the floor drains for the cottage cheese processing, the trash compactor, the special drains from the 7 CIP systems and the hub drains from the HTST pasteurizers that collect separator sludge and CIP solutions; (c) an eight inch line connecting the floor drains for milk receiving, milk processing, milk packaging and the milk cooler and (d) a six inch line from the rest rooms.

Description of the sampling stations:

The sampling stations were designated as Drains #1, #2,#3

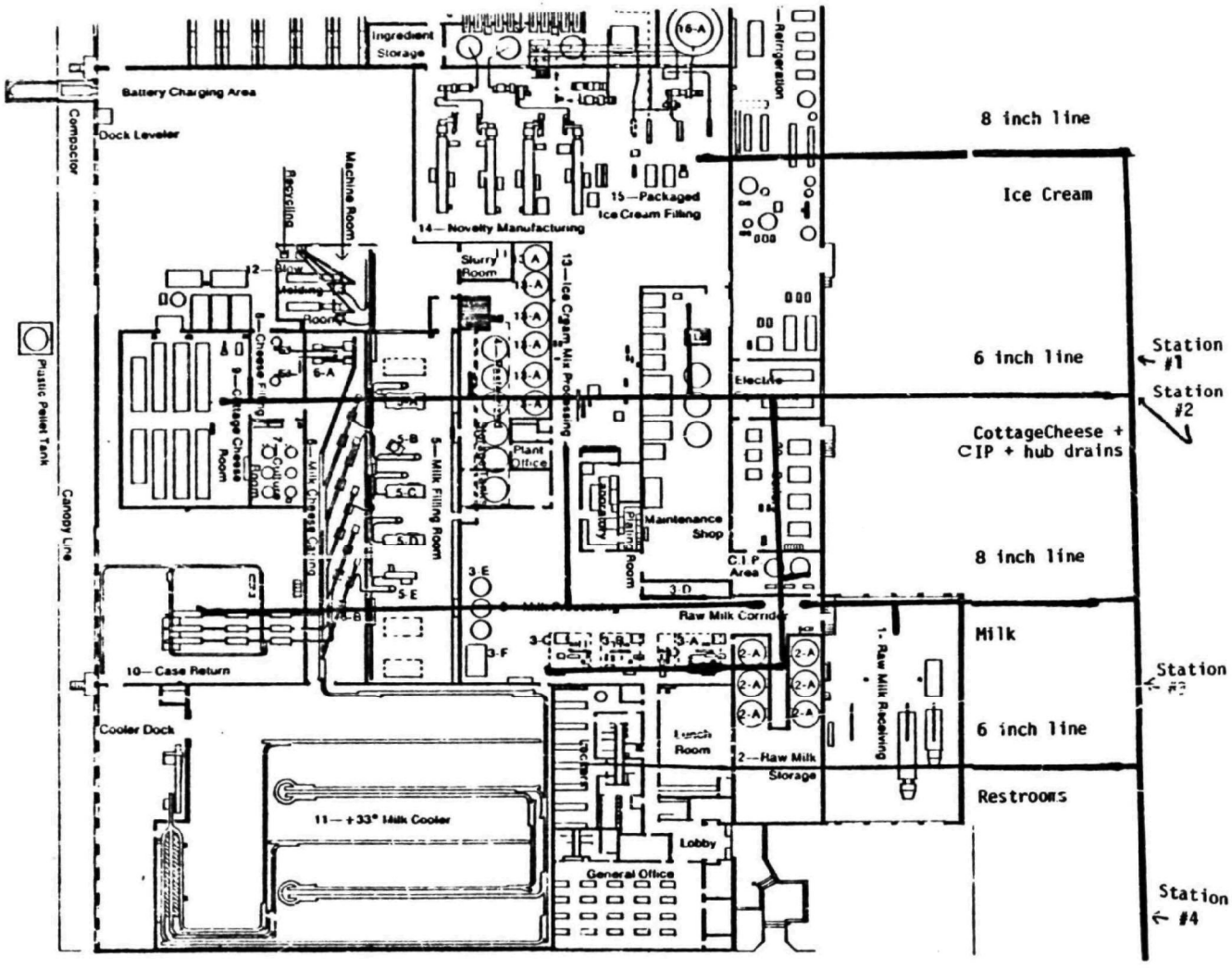


Figure 2. Drain Plan and Sampling Stations at Indianapolis Kroger Dairy

and #4. Station #4 (the lift station) already existed prior to the study and included all four sewer lines from the plant. It is located at the corner of the property and approximately 500 feet from the last point of entry of the sewer lines from the rest rooms. During very wet weather, there was a suggestion of infiltration in the last 400 feet of the line, and samples were not taken routinely from this station. An initial survey made over five processing days showed that the contribution of domestic wastes from the rest rooms contributed less that 0.3% of the COD or BOD and less than 0.4% of the hydraulic load. For the above reasons, station #3 was selected as being most truly representative of the plant's processing wastes.

An existing man-hole was used for station #3 and a new man-hole was dug at the junction of the lines from the ice cream area and the cottage cheese-CIP drain (see Figure 3). The latter was four feet at the top and 6 feet in diameter at the bottom, whereas the former was four feet in diameter. Drain #1 was for the ice cream and novelty area; drain #2 was for the cottage cheese-CIP lines; and drain #3 was just beyond the point of entry for the milk floor drains and contained all of the processing wastes. The waste from the milk area was determined by difference (Drain #3 - [Drain #1 + Drain #2] = milk wastes).

The sampling stations were equipped with permanently installed weirs. The construction of the weirs was changed after

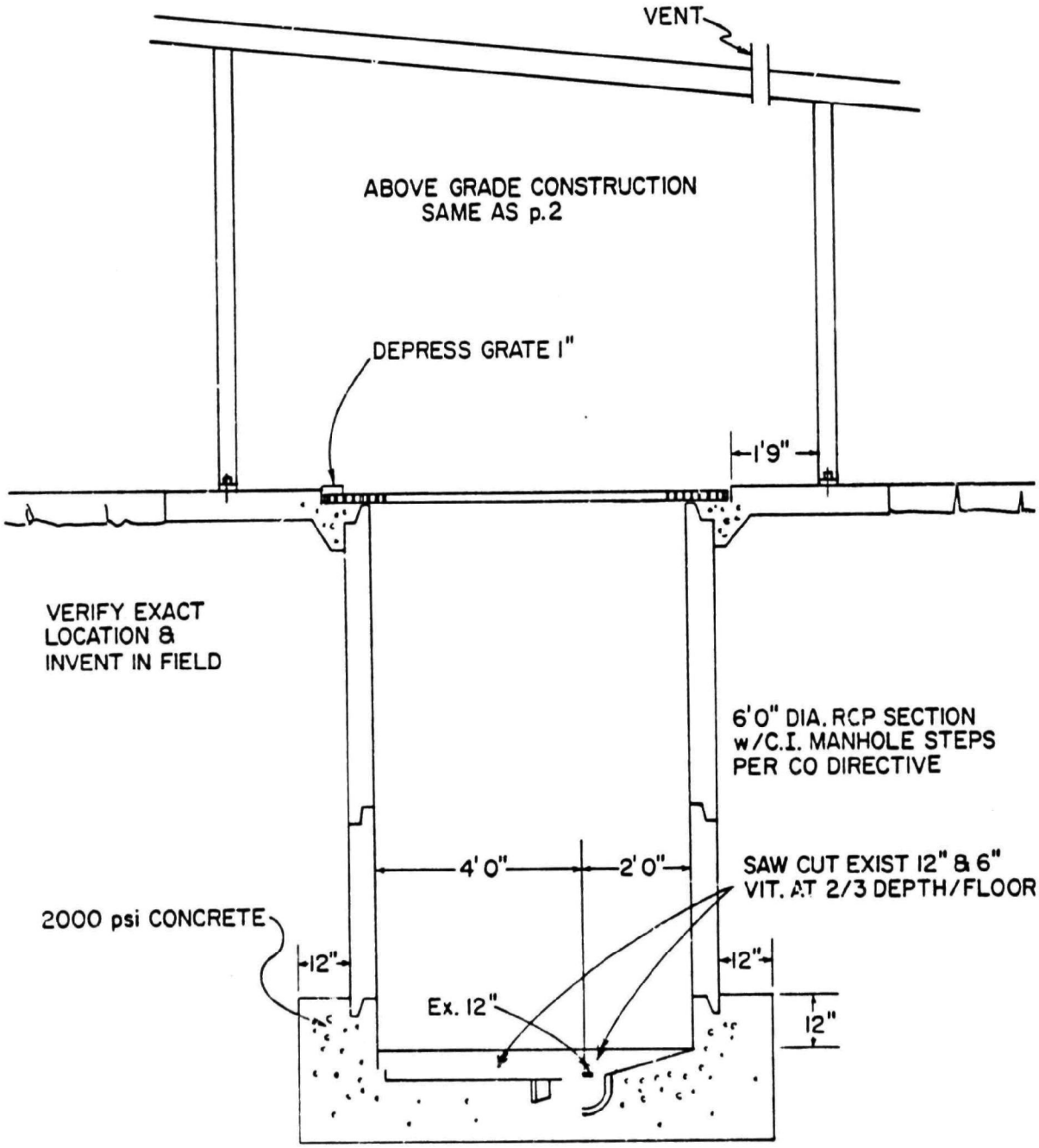
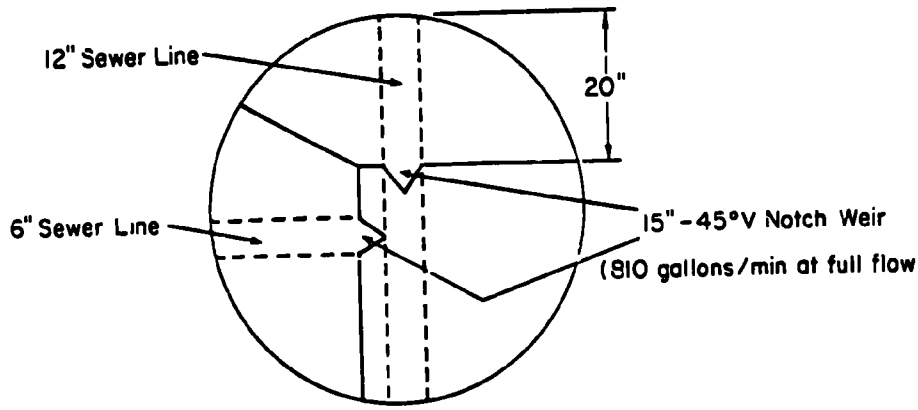


Figure 3. Plan Drawing of Waste Sampling Station at the Indianapolis Kroger Dairy

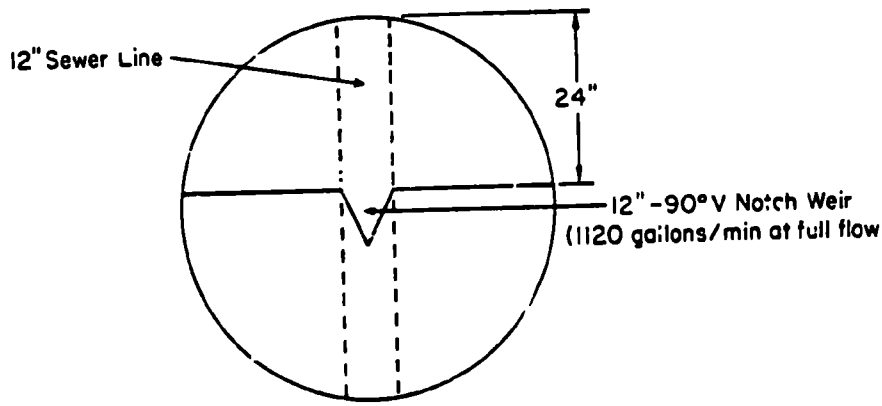
initial evaluation and the final design is shown in Figure 4. The weirs provided a satisfactory means of measuring flow in most cases. An exception was for drain #2 when more than two cheese vats were drained at the same time. In this case the 6 inch line was not adequate to carry the flow and an error in reading existed for a short time. However, based on calculation from known flows through drain #2, the error did not exceed 5%. Because of the drop in the line, a flume would not have been satisfactory either. Chart records showed when multiple cheese vats were being emptied and data for these situations were not included in this report.

Based on experiences gained in this study, flumes were determined to be more satisfactory for use in monitoring dairy plant wastewaters - primarily because they are self cleaning. Frequent cleaning of the weirs was essential to avoid recording unreliable data, because of debris backing up behind the weir. In the ice cream drain, for example, as many as 1000 sticks could accumulate behind the weir in a weeks time. Daily review of water meter flow and wastewater flows could be used to monitor any abnormal readings.

Three Manning model F-3024 portable dipping type flow meters were used to monitor flow. The meters operated continuously, and repair was necessary on each meter about once a year. Three Manning Model S-4000 discrete portable samplers were



SAMPLING STATION No. 1 (6' diameter)



SAMPLING STATION No. 2 (4' diameter)

Figure 4. Plan Drawing of Weirs from Sample Stations #1, #2, and #3.

used. They were capable of taking 24 samples in either time or flow composite mode. The minimum time for a single sample was 3.75 minutes and the minimum flow for taking one sample was 910 gallons for drains #1 and 1120 gallons for drains #2 and #3. Ice or dry ice was used in the sample case as a refrigerant when the ambient temperature was above 45°F. Manning recording pH meter was rotated between the three drains as required. Normally pH was monitored routinely on Drain #3.

Sample handling:

Discrete or composite samples were generally refrigerated and shipped to the Ohio State University for analysis. Refrigerated samples were shipped in refrigerated trucks within two-three hours after collection. They were maintained at 2-4° C and analyzed within 48 hours from time of sampling. (See Section 5)

During the second and third phases of the study, some samples were frozen immediately after collection. Frozen samples were shipped in dry ice. They were analyzed within 14 days after receipt. No suspended solids analyses were made on frozen samples. (See Section 4 for validation of the use of frozen samples)

Samples were thawed and analyzed as discreet samples or

composited. Frozen samples were thawed, tempered at 38° C and mixed in a Waring type blender to obtain a representative sample.

Analyses:

Analyses were conducted by Standard Methods unless modified as described in Section 5. Analyses conducted during the course of this investigation included the following:

-BOD_5

-COD

-Total solids

-Total suspended solids

-Dissolved solids

-Settleable solids

-Kjeldhal nitrogen

-Ammonia nitrogen

-Lipids (fats,oil and grease)

-Carbohydrates

-Chloride

-Phosphate

-Sodium

-Calcium

-Magnesium

-pH

-Conductivity

Where applicable, the methods used were those from Standard Methods for the Examination of Water and Wastewater (1976) or the EPA Handbook on Analytical Methods (1973). The EPA Handbook on Control in Water and Wastewater Analysis was followed as a guide in the evaluation of methods used in this study.

BOD: The 5 day biological oxygen demand, referred to as BOD in this report, was determined routinely by the standard bottle method, using a YSI oxygen meter to measure dissolved

oxygen. The Hach manometric method was used to study effects of variables on the oxygen utilization as a function of time.

A seed was obtained from the Indianapolis municipal treatment plant, and was used fresh or was reactivated from a freeze dried stock. The activated freeze dried stock and the fresh seed gave the same results. Analyses were made of multiple dilutions of waste water and a standard skim milk (9% solids reconsitituted from non fat dry milk) was used as a control. The control gave 72,000 $\pm$ 3,000 mg/l.

COD: Standard Methods COD was used in this study as the reference method. Routine analyses were made with the Technicon Model II Autoanalyzer, using five concentrations of freshly prepared glucose as a standard. Unknown standards were analyzed on a routine basis to serve as a control. During the final phase of the study, the Hach digestion unit and pre-prepared reagents were used and the results were found comparable to the Standard Reference Method.

Solids Analysis: All solids analyses were by Standard Methods without modification.

Kjeldhal nitrogen: The Kjeldhal method was employed using the Technicon Autoanalyzer II for the determination (Technicon method 334-74A/A76). The dye binding

method of protein determination was employed as a screening technique, using the Udy method and a Foss Electric Pro-Milk Tester. The latter procedure was evaluated as a means of estimating protein in waste water for in-plant quality control. For adequate accuracy, it was necessary to concentrate the samples by a factor of 10. The comparison to protein values determined by the Kjeldahl method was ± 10%.

Lipid (fats,oil and grease): Analysis of lipid in dairy food plant wastes has been recognized as a problem in a number of investigations. A number of different methods were evaluated, and the Werner Schmidt method was found to be most satisfactory for routine analysis. A chloroform-methanol extraction method applied to freeze dried samples was most precise, but required too much time for routine use. Standard Methods procedures for fats,oils and grease were unsatisfactory, underestimating the total lipid by from 30 to 50%. The automated Milko-Tester procedure was also evaluated as an in-plant quality control procedure and gave non-reproducible results on dilute dairy waste-water. Concentration of samples by a factor of 10:1 and mixing with a milk of known fat content gave results that were within ± 10% of those obtained by the Werner-Schmidt procedure. Of the methods evaluated, the Technicon procedure was the least satisfactory.

The Werner Schmidt procedure differed from others in that

it included an acid hydrolysis step. The procedure was as follows:

1. A 20 ml sample (or known weight) is added to a Majonnier flask, followed by 8 ml of concentrated HCl. The contents are mixed and place in a boiling water bath until digested, at which time the sample will be chocolate brown. Generally about 15 minutes of digestion are need for dairy wastewater samples.

2. Add 8 ml of ethanol and gently invert tubes.

3. Add 25 ml of of diethyl ether and stopper with wet corks. Mix, but do not shake vigorously.

4. Remove corks and add 25 ml of petroleum ether. Stopper and shake contents.

5. Centrifuge the tubes in a suitable container for one minute at approximately 700 rpm to separate layers.

6. Pour off the solvent layer into a clean 250 ml erlenmeyer flask and repeat the extraction process, but using 50 ml of a 1:1 mixture of ethers.

7. Proceed as for the standard Majonnier procedure (MIF 1968)

Carbohydrates: Initially the EPA approved Technicon Autoanalyzer method was employed (Technicon method 302-74A). In making material balance of components contributing to BOD, discrepancies were traced largely to the carbohydrate method. Experimentation revealed that the method, while reproducible, gave only a 20% recovery of lactose at the same time it gave over 93% recovery of glucose and sucrose. Subsequently the method of Dubois as modified by Lawrence (1968) and Clark (1977) was used. The method is briefly as follows:

1. A known sample containing from 25-75 micrograms of carbohydrate is added to a 100 ml flask and then filled half-way with distilled water. To this is added 2.5 ml of lead acetate solution (10%w/v) and 9 ml of saturated sodium flouride. Make to 100 ml with water, mix and allow to stand for 10 minutes.

2. Filter through Whatman No 40 filter paper.

3. Pippette 1 ml of phenol solution (5% w/v) into a clean glass stoppered test tube. Add 1 ml of filtrate.

4. Add 5 ml of concentrated sulfuric acid from a burrett, running the acid down the side of the tube. Insert stopper, mix and cool.

5. Measure O.D. at 490 nm. Read against a standard lactose

solution containing 0, 25, 50 and 100 ug/ml, treated as above.

Phosphorous: This was determined with the Technicon Autoanalyzer (Technicon method 334-74a/a-76).

Chloride: Chloride was determined by use of an Orion chloride ion electrode, using four concentrations of sodium chloride as a reference each time.

Sodium: Sodium ion was determined by both the sodium ion electrode and by atomic absorption spectroscopy.

Calcium: Calcium was determined by atomic absorption spectroscopy.

pH: pH was monitored with a Manning pH meter and/or determined with an Orion pH meter equipped with a wide pH range electrode.

Conductivity: Conductivity was measured with a Hack conductivity meter calibrated against sodium chloride standard solutions at 6 concentrations.

SECTION 5

DEVELOPMENT AND EVALUATION OF ANALYTICAL METHODS

EFFECT OF REFRIGERATED AND FROZEN STORAGE ON ANALYTICAL RESULTS:

Because of the distance between the Kroger Dairy and the analytical laboratory at the Ohio State University, the handling of samples was a major consideration. A study was made of the effect of both refrigerated (2 4°C) and frozen storage (-28°C) on methods reported to be sensitive to sample storage. The effects of refrigeration and frozen storage on BOD, COD, carbohydrate, suspended solids, and microbial population was determined.

Refrigerated storage:

Twenty samples of wastewater were analyzed immediately upon receipt and after 24, 48 and 72 hours of storage at 2°C. The results are presented in Table 1. On the basis of mean values, the data for all four analyses were essentially unchanged for the first 48 hours. Individual analyses showed both positive and negative difference with a maximum variance of 9.5%. After 72 hours of storage, there was a decrease in the BOD and carbohydrate, an increase in SPC and suspended solids and no

Table 1. Effect of refrigerated storage on mean COD, BOD, carbohydrates, suspended solids and standard plate count

Age (hrs)	Mean Values COD (mg/l)	BOD (mg/l)	Carbohydrates (mg/l)	SS (mg/l)	SPC* (Number)
0	3500	1650	750	850	2,100,000
24	3700	1800	780	900	1,500,000
48	3400	1500	760	880	5,600,000
72	3000	1200	550	1100	35,000,000

*Standard plate count.

statistically significant change in COD.

Since these samples were 24 hour composites and had an additional 6 to 12 hours of delay in shipment, a series of hourly samples (taken at various times) were iced and taken directly to the OSU laboratory and analyzed with a maximum storage time of 6 hours. These results showed no significant differences over 72 hours of storage at $4^{0}C$.

Frozen Storage:

In a later stage of this project, the frozen storage of samples was considered desirable. Because of the statement in the EPA Handbook on Analytical Methods for Wastewater Analysis that freezing was unsatisfactory, a study was undertaken to determine the possible validity and limitations of holding dairy wastewater in a frozen state for up to 20 days.

Initial studies indicated unreliable and non-reproducible results for COD in frozen samples, especially those with COD levels over 2000 mg/l. The cause of the lack of reliability was determined to be related to sample preparation of the frozen samples. Elimination of the problem was achieved by thawing the frozen samples, tempering them at $38-40^{0}C$ for at least 30 minutes to melt the milk fat and then mixing in a Waring type blender for one minute.

Subsequently, 24 samples varying in COD levels from 1000 to 10,000 mg/l were frozen and returned to the OSU laboratory. Samples were stored for 0, 1, 5, 10 and 20 days at -28°C. COD analyses were made on all samples. BOD, suspended solids and standard plate counts were made after 0, 1, 5 and 10 days of storage. The average results are shown in Table 2. The results indicated that the tempered-mixed samples gave COD analyses that were comparable to fresh samples (correlation coefficient =0.945) over the entire 20 day period. BOD analyses were reliable up to 10 days (correlaton coefficient =0.934). A key to the success of the BOD results was the use of freshly activated seed. Manometric BOD results showed an increase in the lag period, which was minimized by using freshly activated seed.

In all cases the suspended solids were reduced in the fresh samples from 20 to 50%. This was caused by the use of the Waring blender that was essential for obtaining a uniform sample. Based on these results, suspended solids analyses were made only on non-frozen samples.

Microbial counts (SPC) showed reduction in all samples after 10 days of storage.

Analyses of ten of the frozen samples for lipid, carbohydrate and total nitrogen shown no significant differences.

Table 2. Effect of frozen storage on COD, BOD, SS and standard plate count.[a]

Age (days)	Mean Values COD (mg/l)	BOD (mg/l)	SS (mg/l)	SPC (Number)
0[b]	3200	1400	550	1,800,000
1	3100	1200	330	1,500,000
5	3300	1500	300	1,000,000
10	3250	1100	350	1,200,000
20	3000	1300	280	700,000

[a]No significant difference in fat, total N or carbohydrate on frozen storage.

[b]Before freezing.

Lipids (fats, oil and grease):

Many dairy wastewaters, especially those from butter and ice cream operations, are high in fat content. There has been a concern in respect to measuring lipid in dairy wastewater and also concern over observations that with very high lipid levels, the COD and BOD values are depressed (Carawan, et al 1973 and Harper, et al. 1971). Both of these problems were investigated.

A number of different methods were evaluated for use in this investigation: (a) standard methods for lipids (fats, oil and grease) as outlined in the Standard Methods for the Examination of Water and Wastewater, (b) the standard Majonnier procedure as applied to milk, (c) the method of Carawan et al.(1973), (d) the Werner Schmidt method as modified by the New Zealand Dairy Research Institute, (e) the Milk-o-tester and (f) the Technicon autoanalyzer turbidometric method.

Of these methods, the Werner Schmidt, Majonnier, Carawan and Milk-o-tester methods showed some promise. A comparison of these methods is shown in Table 3. The Werner Schmidt method was most reproducible and gave the best recovery for added lipid.

Table 3. Reproducibility and recovery of added lipid by three procedures for fats, oils and grease.

Lipid Concentration	Number of Samples	Majonnier		Carawan		Werner-Schmidt	
		Mean % Recovery	σ of Mean	Mean % Recovery	σ of Mean	Mean % Recovery	σ of Mean
		%	%	%	%	%	%
100-200 ppm	5	78	5.6	82	12.3	85	4.2
300-500 ppm	5	81	5.1	80	9.2	87	3.7
500-1000 ppm	5	80	3.5	85	5.4	88	2.4
1000-2000 ppm	5	83	4.2	83	5.0	87	2.2

Although recovery of added fat was above 75% for all of the extraction methods, there was continued concern as to the true total lipid content of the samples. For this reason, ten high lipid containing samples (5 from ice cream and 5 from total plant wastewater) were investigated. A 500 ml sample was concentrated 10:1 in a roto-evaporator, freeze dried and then exhaustively extracted with 2:1 methanol-chloroform, using a Soxhlet extractor. This approach was based on previous work with whey protein concentrates that exhibited difficulty in total lipid extraction. In this method the recovey of added lipid was 99% ± 3%. The results are shown in comparison to the Majonnier, Werner Schmidt and Milk-o-tester in Table 4. The Milk-o-tester was shown to be unsatisfactory, even when wastewater was added to a milk sample of known fat content. Concentration of samples 10:1 did improve the Milk-o-tester method so that it could be used as a screening method.

Based on these findings the Werner Schmidt procedure was the best of those methods suitable for routine analysis and was adapted as the standard method for this investigation.

The chloroform methanol procedure, while most accurate, was too time consuming for routine use.

A study was made to determine the effect of lipids on COD and BOD analyses. Sample ranging from 150 to 5000 mg/l lipid were

Table 4. Comparison of lipid methods

Sample	Soxhlet $CHCl_3$:MeOH (mg/l)	Majonnier (mg/l)	Werner-Schmidt (mg/l)	Milk-o-tester (mg/l)
1	125	90	118	50
2	186	150	176	70
3	223	176	213	110
4	276	230	280	130
5	325	270	319	220
6	625	647	626	320
7	1050	900	1000	860
8	2005	1800	2000	1800
9	2700	2275	2685	2600
10	3600	3250	3500	3500
Mean	1111.0	979	1080	804
r		0.92	0.96	0.83

analyzed for BOD and COD. The results are shown in Table 5. When the lipid content of the waste sample was in excess of 2000 mg/l there was an apparent reduction of both BOD and COD. Attempts were made unsuccessfully to determine the reason for the reduction in values. COD analyses of pure milk fat did not indicate any interference with the method at concentrations up to 3000 mg/l. Addition of carbohydrate or protein had no effect on COD. In the case of BOD the supression of BOD values was associated with added lipid with a marked increase in the lag value and reduction in generation time. This inhibition was thought to be associated with free fatty acid content of the high lipid samples.

Further work in this area is needed to clarify the problem and its solutions.

Carbohydrate analysis:

The initial procedure used was the EPA approved Technicon autoanalyzer II method for sugars. It was not until attempts were made to calculate BOD from organic analyses that discrepancies were noted in the carbohydrate data. Analysis revealed a markedly different concentration response between lactose and sucrose, glucose or fructose (See Figure 5). Lactose data were reproducible but the response was 1/12.4 that for sucrose.

Table 5. Effect of lipid level in Dairy Waste on COD and BOD.

Mean Concentration of Lipid[a] (mg/L)	Number of Samples	Mean COD (mg/L)	Mean BOD (mg/L)
211	5	1250	560
520	4	3000	1260
1360	3	4500	2100
2700	4	5100	1750
4500	2	6200	1550
2250[b]	2	6600	2640

[a]Determined by Werner-Schmidt.

[b]Same as 4500, diluted 1:2 with distilled water.

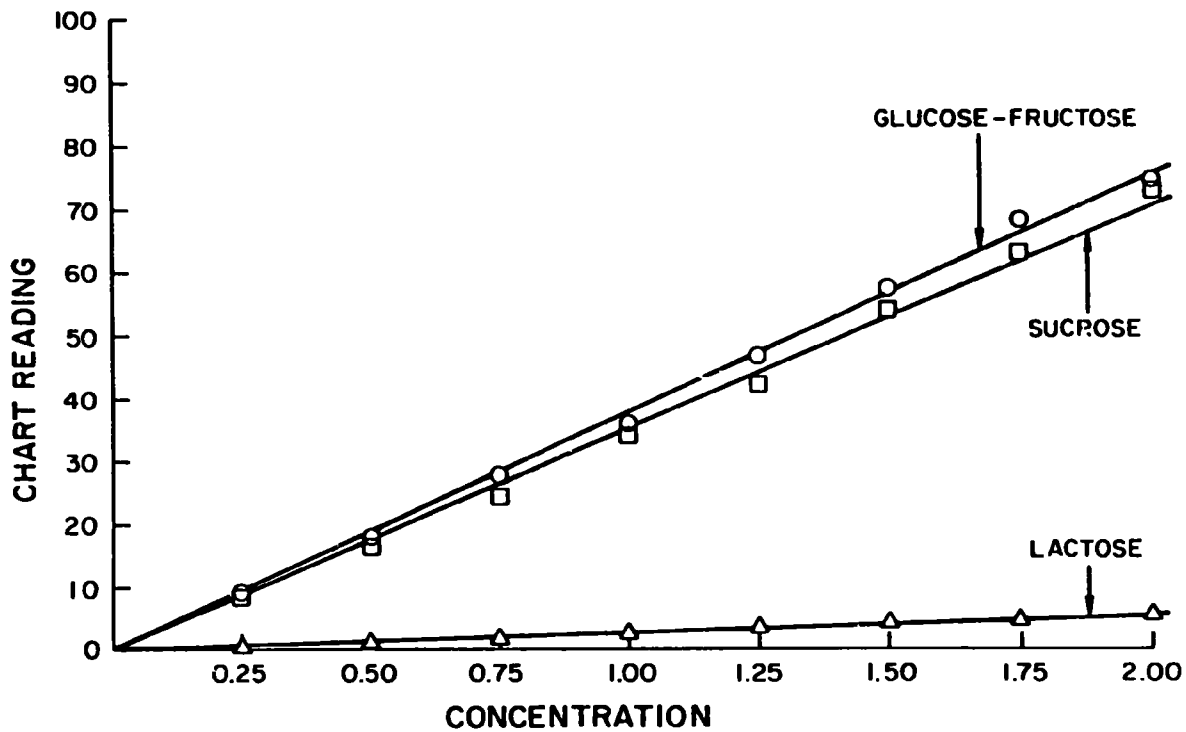


Figure 5. Standard Curves for Autoanalyzer Analysis of Selected Carbohydrates.

In order to salvage the data, the various waste streams were analyzed for carbohydrate distribution by high pressure liquid chromatography on a Waters HPLC using a carbohydrate column, a flow rate of 1.0 ml/minute and a solvent of 75:25 acetylnitrile-water. The average carbohydrate distribution from the ice cream operations was 59:37:08:04 lactose:sucrose:fructose:glucose. The average carbohydrate distribution from drain #2 was 92:8 lactose:sucrose - with no detectable fructose or glucose. The carbohydrate distribution in the total wastewater was 79:20:1:1 lactose:sucrose:fructose:glucose. Knowing the ratio of carbohydrates in the wastewater (by HPLC analysis) made it possible to correct the initial data to within ± 10% of the true value. It was necessary to change to a method that would more nearly measure all of the carbohydrates. While HPLC was reliable, the method was not adapted to routine anlaysis. The method of Dubois, as modified by Lawrence (1968) and adapted by Clark (1977) to dairy wastewater, was utilized. The Clark procedure was investigated for 30 samples. The results in comparison with uncorrected and corrected Technicon Autoanalyzer results are shown in Table 6. The Technicon values for dairy wastes were consistently low. The DuBois method was used as the standard procedure after the initial studies.

Calculated versus actual BOD:

Table 6. Comparison of Autoanalyzer and Modified Dubois.

Sugar	Number of Samples	True Mean (mg/l)	Measured Mean (mg/l)		
			Autoanalyzer		Modified Dubois
			Corrected	Uncorrected	
Sucrose	6	500	510	510[a]	490
Lactose	6	500	130	485	515
Fructose	6	500	400	493	485
Fructose & Sucrose (1:1:1)	6	500	341	496	490
Dairy Waste	30	-	440	863[b]	-

[a]Based on standard curve using sugars noted.

[b]Based on standard curve using ratio of carbohydrates found in total waste water from Kroger Dairy (lactose:sucrose:fructose:glucose = 60:23:6:10).

BOD was calculated from the sum of organic compounds found in the dairy wastewater. Fat, protein, carbohydrate, lactic acid and citric acid were the major organic constitutents. Fat and carbohydrates were determined by the methods developed in this study. Standard methods for this study were used. Lactic acid was measured by the method of Randolph and Harper (1958). Citric acid was determined from records of use. Mean values for 30 samples is shown in Table 7. The correlation coefficient was 0.902. The variance between measured and calculated BOD was 15.2%.

Table 7. A Comparison of BOD and organic compound analysis

	Mean* (mg/L)
BOD Measured	1900
Fat	261
Protein	444
Carbohydrate	1445
Lactic Acid	205
Citric Acid[a]	100
BOD Calculated[b]	1917

[a]Determined from use data.

[b]Using factors of .9, 1.03, and .07 for fat, protein and either lactose, lactic acid or citric acid.

*Thirty samples.

SECTION 6

WATER AND WASTEWATER CHARACTERIZATION FOR TOTAL PLANT

This section presents data for a nine month period from January through September for the water use, wastewater discharge and wastewater characteristics for the total Kroger Dairy at Indianapolis, Indiana. Attention was given to determining the water balance for the plant, overall water use, wastewater characteristics and coefficients for water use and waste parameters per unit of product processed.

WATER BALANCE

A comparison was made between the monitored wastewater as measured at Drain #3 with that calculated from water meters and production records for product water use. The amount of water being discharged as wastewater should be equal to the total water metered into the plant minus the water consumed within the plant. Water used in the plant and either recycled, discharged to the storm sewer, or used in product included: (a) water used to reconstitute solids for use in product, (b) boiler feed water, (c) cooling tower water, (d) refrigeration compressor water, and (e) air compressor water. Meters were installed on all water coming into the plant, on the line supplying the cooling tower, and on the two

soft water lines that supplied the boiler, air compressors and refrigeration compressors. Water used in product was determined from production data .

The calculated wastewater and measured wastewater were determined and compared. The variation between these two values is summarized in Table 3. Data is presented for mean calculated and measured wastewater flows, mean difference between these values, variance, standard deviation and the standard error of the means. The mean differences were within good agreement, but variance in the data was a function of both the time during the study and the inclusion or elimination of weekend data. The data is separated into three periods; the first three months of the study, the second three months and the third three months. The data is also separated into that including all days and that just including the five processing days. The results show that the variance in the measured and calculated values decreased as the study progressed and that the variance for processing days was less than for that data that included weekends. The decrease in variance with progression of the study could be directly related to correction in problems with initial monitoring of flow, revision of weirs and increased familiarity with the care required to obtain reliable data. The decreased variance by eliminating weekend data was related to much more variation in flows on week ends and also to a tendency of the flow monitor to overread when flows were zero or less than 100,000 gallons per

Table 8. Variation in Calculated and Measured Wastewater

Period	A Mean Calculated Wastewater (gal/day)	B Mean Measured Wastewater (gal/day)	Mean Difference (A-B)/A %	Variance %	Standard Deviation %	Standard Error of the Mean %
ALL DAYS						
Jan-March[a]	383,650	396,333	-3.2	33.5	7.8	1.56
Apr-Jun	484,405	479,040	1.12	21.18	5.30	0.89
Jul-Sept	636,560	638,980	-0.38	10.60	3.25	0.58
PROCESSING DAYS[a]						
Jan-March[a]	442,408	430,777	2.7	28.3	5.7	0.93
Apr-Jun	536,909	532,356	0.87	11.75	3.40	0.61
Jul-Sept	718,166	711,635	0.92	6.22	2.49	0.45

[a]Limited data.

day for Drain #3. During the first period, the weekend flows varied from 45,000 to 287,000 gal/day; for the second period, this difference was from 89,500 to 278,000 gal/day; and for the third period, the difference was from 166,000 to 320,000 gal/day.

Water use increased from 383,000 gallons in the first period to 635,500 gal/day in the third period, or a 66% increase. Over this same period the amount of milk received by the plant increased from 1,100,000 to 1,600,000 pounds per day for a 45% increase.

WATER UTILIZATION:

In plant water use (water used for cooling tower, water used for compressors and boiler feed and water used for product) is summarized in Table 9 for the second and third periods of study. Means values are presented and average percentage of use for all days, processing days and weekends. Analysis of variance for this data is shown in Table 10. There was comparatively little change in the amount of total in-plant water use over the nine month period, whereas the percentage of water consumed in the plant decreased as the total amount of water use increased. There was also a change in weekend versus processing days use.

The daily variation of water use for processing during the months of May and August are presented together with

Table 9. In Plant Water Use

Period	Mean Values [a]							
	Cooling Tower		Boiler Feed & Compressors		Product use		Total Consumptive use	
	gal/day	% of Total	gal/day	% of Total	gal/day	% of Total	gal/day	% of Total
ALL DAYS								
Apr-Jun	17,700	3.6	16,700	3.4	4,300	1.0	38,700	8.0
Jul-Sept	24,800	3.9	9,600	0.6	5,500	0.9	39,900	6.2
PROCESSING DAYS								
Apr-Jun	17,700	3.3	21,700	4.0	6,000	1.1	45,400	8.5
Jul-Sept	20,200	2.8	13,500	1.9	7,700	1.1	41,400	5.8
WEEKENDS								
Apr-Jun	17,600	8.8	4,100	2.0	-	-	21,700	10.9
Jul-Sept	30,600	11.1	2,200	0.8	-	-	32,800	11.9

[a] Use rounded to the nearest hundred gal/day.

Table 10. Standard Deviation for In-Plant Water Use

	Mean and (Standard Deviation) in Thousands of gal/day					
	April-June			July-September		
	All Days	Processing Days	Week ends	All Days	Processing Days	Week ends
Cooling Tower	17.7(5.3)	17.7(3.3)	17.6(8.3)	24.8(5.9)	20.2(3.7)	30.6(10.3)
Boiler Feed & Compressors	16.7(8.0)	21.7(7.8)	4.1(1.8)	9.6(4.2)	13.5(4.6)	2.2(0.9)
Product Use	4.3(1.3)	6.0(1.8)	-	60(1.5)	7.7(2.1)	-
TOTAL	38.7(12.7)	45.4(13)	21.7(10)	39.9(12.3)	41.4(10.0)	32.8(12.1)

wastewater discharge on a probability graph in Figure 6. The data show some deviation from linearity, but correlation coefficients for a straight line are above 0.87 for all data presented. The slopes of lines of best fit for both total water use and wastewater discharge are similar, but the August data shows more total water and wastewater discharge that reflects an increase in production.

Bar graphs depicting the percentage of samples falling in various ranges of water use are presented in Figures 7, 8 and 9 for total water use, water consumed in the plant, and wastewater discharge. Each figure presents data for all days, processing days and weekends. For these figures, only the last six months, or defined base period are used.

WASTEWATER CHARACTERIZATION

Strength of waste components:

Data is based on 24 hour composite samples taken primarily as flow proportional samples. Time samples are based on samples taken every 7.5 minutes. A comparison of flow proportional and

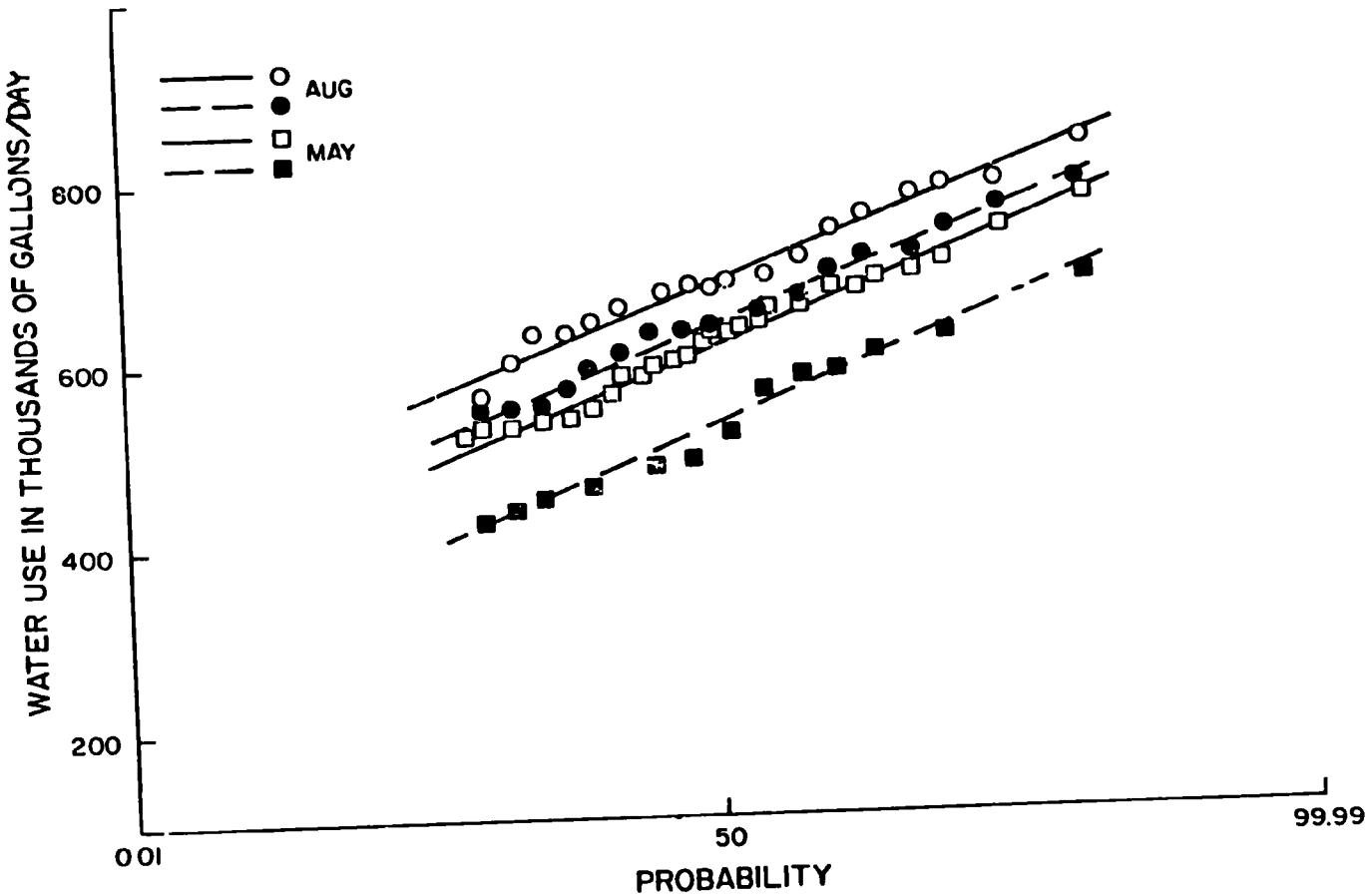


Figure 6. Probability Plots of Daily Water Use and Wastewater Discharge for the Months of August and May.

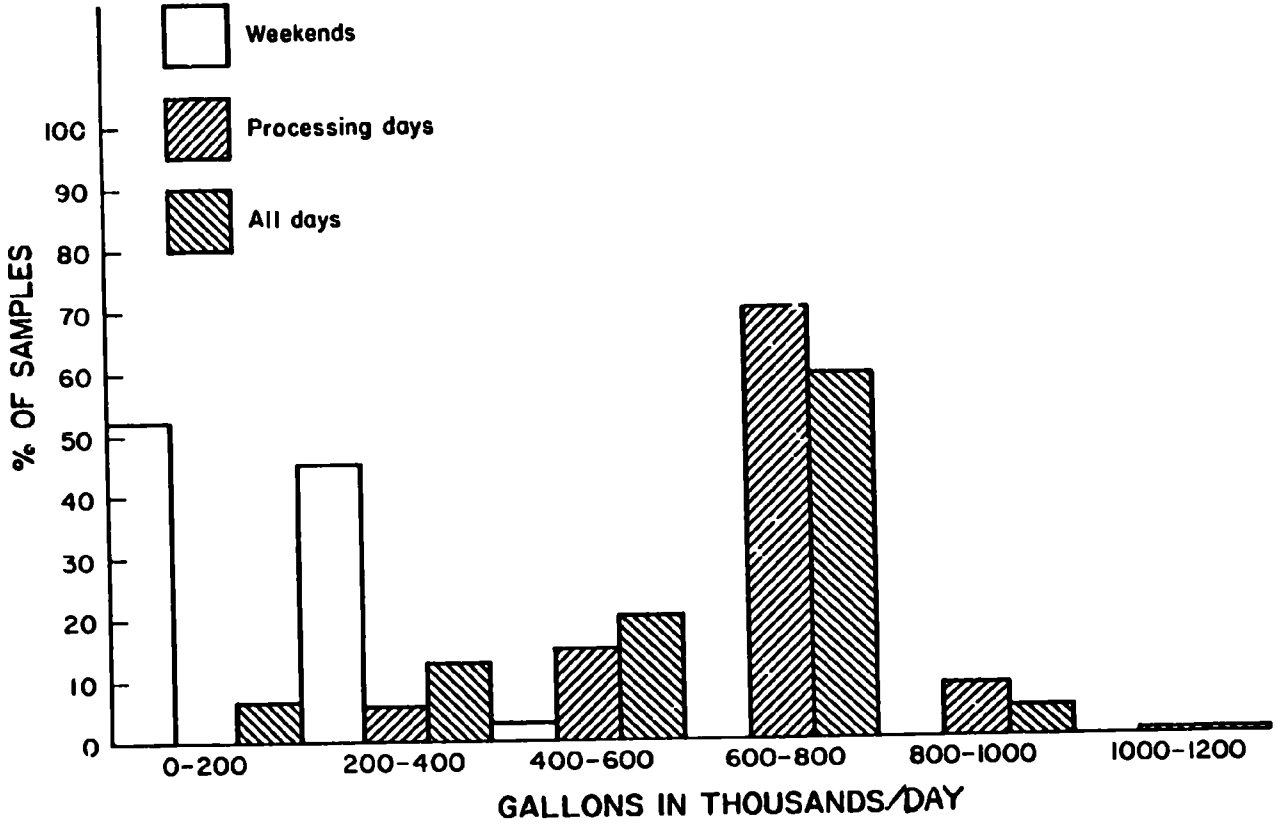


Figure 7. Variation in Total Water Use for All Days, Processing Days and Weekends for Base Period.

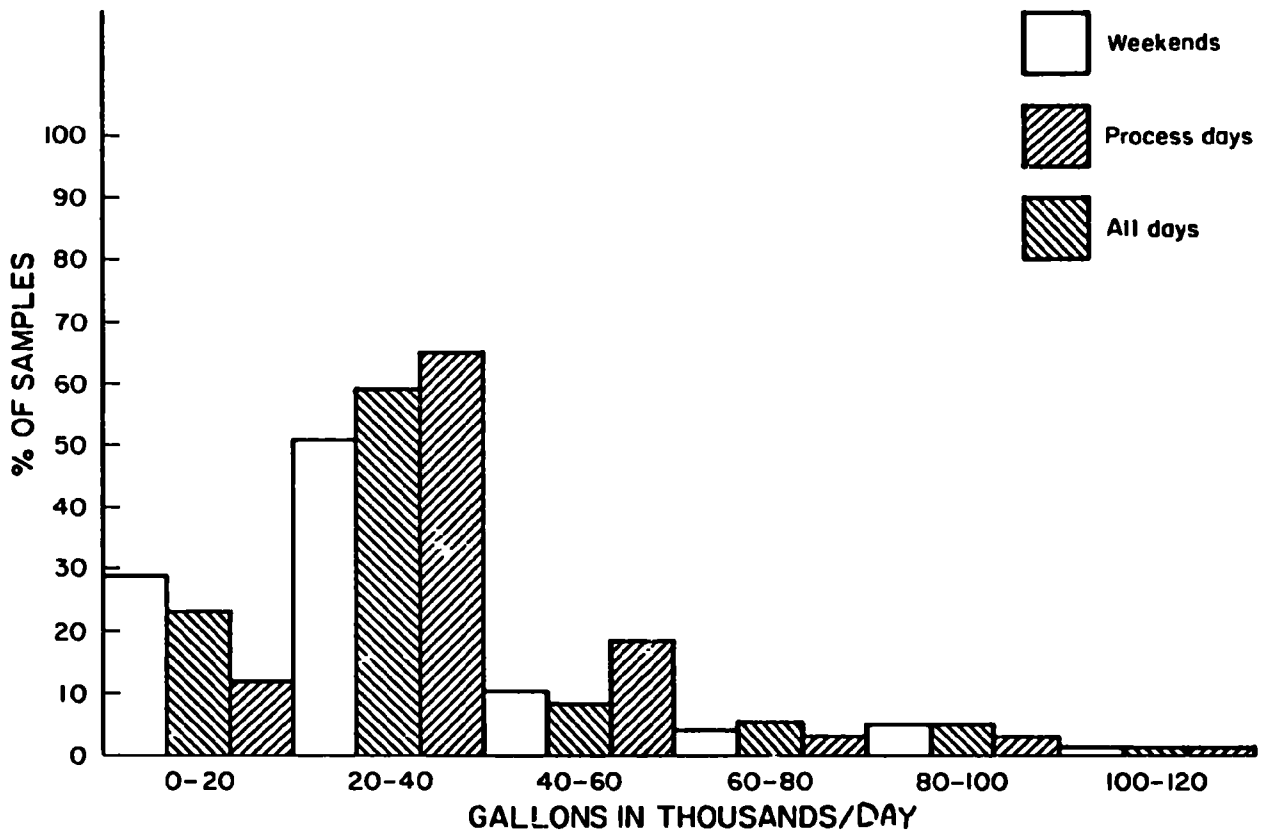


Figure 8. Variation in In-Plant Water Use for All Days, Processing Days and Weekends for Base Period.

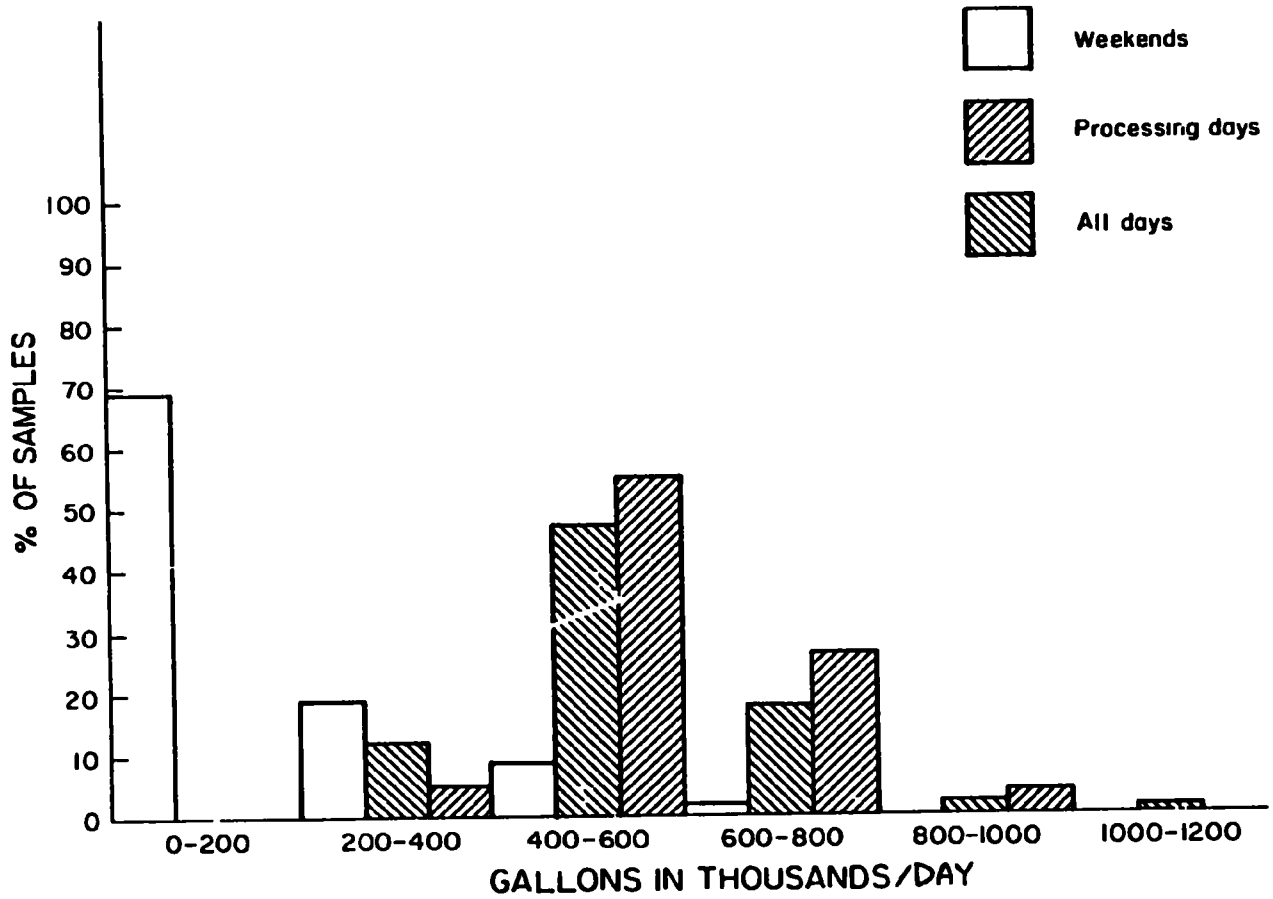


Figure 9. Variation in Wastewater Discharge for All days, Processing Days and Weekends for Base Period.

short time (less than 10 minutes per sample) composite samples showed comparable results for this plant. Time samples taken at time intervals greater than 7.5 minutes were consistantly lower in strength of all components than were flow proportional samples.

Monthly mean values in mg/l for the various parameters measured in the wastewater from the Kroger Indianapolis Dairy are presented in Table 11. This data represents the averages for all days. Overall the values of the various components appear to be similar to that expected from an average dairy plant processing milk, cottage cheese and ice cream. Inspection of the data indicates that the waste strengths of the various components were relatively constant over the nine month period.

The overall mean values of the monthly averages are compared to averages of the daily values for all days and for only processing days in Table 12. In general the means of the monthly averages and means of the individual data are in good agreement, with the latter being consistently lower by from 0.2 to 2%. As would be expected the standard deviations of the monthly averages show significantly less variance than the standard deviations for the daily values. Of interest is the relatively close agreement between the averages for all days and the average strength of the components in wastewater for only processing days. This reflects several things about the nature

Table 11. Monthly Averages of Waste Characteristics for Total Plant Waste Water from Indianapolis Kroger Dairy.

	mg/l								
	January[c]	February	March	April	May	June	July	August	September[c]
COD	4,297	4,396	4,541	3,606	4,085	4,436	4,001	4,560	4,656
BOD	1,984	2,044	2,073	1,776	2,003	2,040	1,936	2,100	2,147
Total Solids	-	-	3,174	3,269	3,511	3,751	3,663	3,550	3,417
Ash	-	-	1,064	1,125	1,082	1,156	1,121	1,076	1,131
Suspended Solids	841	513	610	472	641	621	576	650	710
Dissolved Solids	1,370	1,274	1,222	1,106	6	1,119	1,536	1,420	-
Settleable Solids	6.1	7.25	9.4	9.6	12.9	13.3	12.2	9.1	8.8
Carbohydrate	1,475[a]	1,224[a]	1,211[a]	1,051[a]	1,297[a]	1,260	1,200	1,265	1,318
Lactic Acid	-	-	-	-	-	-	212	227	247
Lipid	536[b]	250[b]	349[b]	327[b]	335	338	353	378	387
Protein	644	612	497	388	421	521	478	444	510
PO4	55	64	48	36	43	52	49	52	56
Chloride	422	412	558	365	370	396	434	420	365
Sodium	324	243	164	245	270	313	252	280	265
Calcium	113	166	186	152	161	183	141	134	156
Magnesium	37	30	34	33	31	33	35	35	38
Conductivity	1,202	1,722	1,782	1,642	1,641	1,906	2,191	-	-

[a]Corrected, Technicon Method [b]Corrected Majonnier Method [c]Data for Month Not Fully Complete

Table 12 Wastewater Characteristics. Means and Standard Deviations of Daily and Monthly Averages.[a]

	Monthly (all days)		Daily			
			All Days		Processing Days	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
COD	4,288	335	4,160	2,100	4,210	1,640
BOD	2,052	125	1,940	850	2,021	790
TOTAL SOLIDS	3,431	110	3,333	1,700	3,460	1,560
NON-VOLATILE TOTAL SOLIDS	1,108	35	-	-	-	-
SUSPENDED SOLIDS	620	35	580	200	620	170
DISSOLVED SOLIDS	1,370	150	1,250	310	1,320	200
Settleable Solids	9.8	2.5	10	8	10	7
CARBOHYDRATE	1,255	110	1,240	420	1,285	360
PROTEIN (N×6.38)	496	90	485	160	500	135
FAT	339	40	320	120	380	115
PHOSPHATE	64	8	52	18	47	15
CHLORIDE	421	55	410	185	400	200
SODIUM	261	45	230	110	220	130
CALCIUM	154	25	-	-	-	-
MAGNESIUM	34	2.5	-	-	-	-

[a] mg/l

of the plant operations:(a) whereas the total wastewater discharged on Saturday and Sunday is about one-third of full processing days, raw milk is received on both Saturday and Sunday, (b) processing often carries over into early Saturday morning with clean-up continuing until mid-morning and (c) cottage cheese making is started on Sunday night in most instances.

With the exception of sodium and chloride, all components of the wastewater were slightly higher in strength for processing days, as would be expected. In the case of sodium and chloride, the low values for processing days would reflect a greater contribution of cleaning and sanitizing to the weekend wastewater than during processing days.

The pH of the wastewater varied continuously through the processing day, reflecting cleaning, processing of cottage cheese (pH 4.6) and processing of sherbets and ice pops with a low pH (3.6-4.2). The mean pH for all processing days was 6.2. Figure 10 shows a typical chart for a processing week indicating the fluctuation of pH. High pH levels reflect alkaline cleaning solutions and low pH relects either cottage cheese processing or novelty operations.

Hourly and daily variation: The data showed the expected hourly and daily variation previously noted for dairy food plant

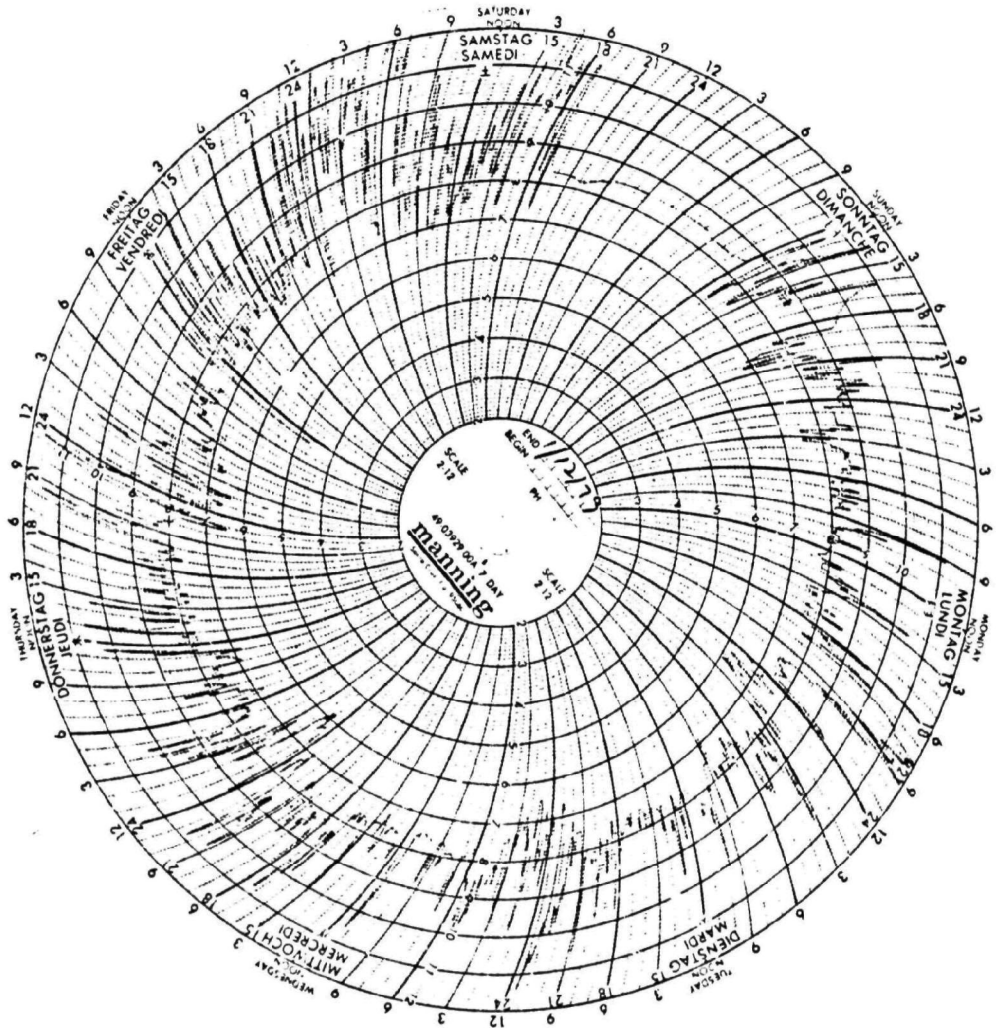


Figure 10. Typical pH Chart for Kroger Dairy Wastewater.

wastes. Probability plots for hourly values were typically "S" shaped, whereas daily variations were reasonably linear. Exceptions were noted when there was a marked change in the production scheduling, such as no ice cream processing or no cottage cheese processing. Because of overlap of departmental operations being reflected in the total wastewater picture, graphs do not provide much specific insight to causes of variation. Therefore, plots for the overall plants wastewater are not shown, but will be detailed in the next section of individual departments where the variability can be specifically related to unit process operations.

Relationship Between Wastewater Characteristics:

The monthly average values (Table 11) were used to evaluate which parameters of the wastewater were dependent and independent of each other using linear regression analysis. The data for February through September were used, since inclusion of the January data markedly altered correlation coefficients. For example the correlation coefficient between BOD and carbohydrate was 0.44 with the January data and 0.76 with this data excluded. Selected data are presented in Table 13, showing correlation coefficients, the linear regression equation and the standard error of the estimate. The parameter listed first was always X. Prediction of a given parameter from a dependent variable was considered feasible when the correlation coefficient was greater

Table 13. Linear Regression Analysis of Selected Waste Characteristics

PARAMETERS COMPARED [a]	Correlation Coefficient	Regression Equation	Standard Error of Estimate
COD/BOD	.87	593.2 + .03418X	76
COD/TS	.85	35 + 0.314X	120
COD/SS	.53	-226.7 + 0.2108X	124
COD/CHO	.72	$-19.3 + (8.36 \times 10^{-2})X$	77
COD/LIPID	.42	$285.44 + (3.1034 \times 10^{-2})X$	120
COD/PROTEIN	.21	-321 + 0.213X	78
BOD/COD	.87	5870.9 + (-0.7999X)	450
BOD/TS	.82	235 + 0.0341X	145
BOD/SS	.55	875.6 + (-0.1138X)	121
BOD/CHO	.76	-249.6 + 0.2785X	35
BOD/LIPID	.89	-37.614 + 0.1933X	15
BOD/PROTEIN	.24	-251.2 + 0.3709X	121

[a] First listed characteristic = X.

than 0.75 and the standard error of estimate was less than 10%.

As expected there was good correlation between BOD and COD and those parameters directly related to them: including total solids and carbohydrate. Surprisingly, the correlation coefficient for protein and either BOD or COD was less than 0.5. This suggests a disproportionate amount of protein remaining on soiled surfaces that is either carbohydrate or fat.

Based on the standard error of the estimate, COD was better for predicting BOD than was BOD for predicting COD.

Suspended solids were only poorly correlated to BOD or COD, but were correlated to total solids and protein.

Sodium and chloride were well correlated only to ash, and were not correlated to other constituents or to each other. Sodium ion concentration would reflect the use of alkaline cleaning compounds, whereas chloride would reflect the use of sanitizing solution and regeneration of water softeners.

Phosphate, a constituent of both milk and cleaning compounds, was not well correlated to calcium ion content. Also, the ratio of calcium to phosphorus was lower than expected based on milk composition. This suggests that much of the calcium

content was associated with protein films remaining on equipment, especially on heated surfaces.

Conductivity was not correlated to any other parameter by a correlation coefficient greater than 0.5 and its use was considered to be of limited value and was dropped as an analytical method.

Based on these data, characterization of dairy plant wastewater may be made from limited analyses. COD or BOD, suspended solids, Kjeldahl nitrogen (protein), chloride, and sodium ion would be the most useful parameters. For organic matter COD and suspended solids measurements would provide the minimum analyses.

Wastewater Coefficients:

The determination of wastewater coefficients was considered essential to interpret the results in respect to other dairy plants and to provide a basis for comparison among departments and also to provide baseline data for use in the latter stages of the project.

Two approaches were used during this study to determine coefficients: (a) calculation of the amount of BOD processed from production figures and (b) determination of the amount of COD

processed through analysis of the COD of all ingredients and calculation of COD processed from ingredient use figures. The former approach was used in the initial phases of the study and the latter evolved during studies of losses in invididual departments and unit processes on a daily basis.

Calculation of BOD processed was based on the use of standard values for protein, fat and carbohydrate:

-protein = 1.03 pounds of BOD/pound of protein

-lipid = 0.9 pounds of BOD/pound of lipid (fats,oil and grease)

- carbohydrate = 0.7 pounds of BOD/pound of carbohydrate.

The amount and composition of milk, cream, non-fat dried milk, whey solids, buttermilk solids, and various carbohydrates were used to compute the amount of BOD processed. This approach was valid for weekly or monthly average data, but because of the bookkeeping system used, it was not practical or convenient on a daily basis. For daily data, the use of COD was much more convenient and proved to be more reliable. For working with weekly or monthly averages, both approaches gave comparable results.

To determine yields, it was also necessary to convert waste strengths into mass weight values. The pounds of a given waste component were calculated by the formula:

pounds of component = gallons of wastewater x 8.34 x (mg/l)/1,000,000

The pounds of four constitutents of concern are shown in Table 14. The data are present as averages for the three separate three-month periods. Whereas the waste strength was relatively constant over the nine-month period, there was a continual increase in the pounds of COD, BOD, SS and phosphate during this time. This was reflected in an increase in wastewater volume that was noted previously, as well as an increase in production. The data are shown for all days and for processing days. Again the differences are not as great as might be expected because of some processing on both Saturday and Sunday.

Wastewater volume coeffients in terms of gallons of wastewater/100 pounds of BOD processes and coefficients for COD, BOD, SS and phosphate in terms of pounds/100 pounds of BOD processed are presented in Table 15. The data are given for the three separate three-month periods and for both the entire nine months and the last six months. The last six months data were used as the base for comparison, although a comparison of coefficients with the last three months was made also. The increase in coefficents during the nine-month period indicates an increasing difficulty in waste control with increased production. Average daily pounds of BOD processed were:

Table 14. Pounds Discharged Per Day of Selected Wastewater Components

Characteristic	Mean, Pounds/Day					
	All Days			Processing Days		
	Jan-Mar	Apr-Jun	Jul-Sept	Jan-Mar	Apr-Jun	Jul-Sept
COD	14,5[illegible]	16,108	23,298	15,847	17,945	25,947
BOD	6,720	7,922	11,590	7,304	8,804	12,908
SS	2,156	2,309	3,437	2,350	2,566	3,828
PHOSPHATE	185	175	277	201	195	308

Table 15 Wastewater Coefficients in Gallons of Wastewater and Pounds of Components/100 Pounds BOD Processed

PERIOD	Gallons of Wastewater 100 lb BOD Processed		Lbs/100 Lbs Processed[a]							
			COD		BOD		SS		PHOSPHATE	
	All Days	Processing Days	All Days	Processing Days	All Days	Processing Days	All Days	Processing Days	All Days	Processing Days
Jan-Mar	296	287	10.8	10.5	5.0	4.1	1.6	1.5	0.14	0.14
Apr-Jun	333	327	11.0	10.3	5.5	5.1	1.6	1.5	0.12	0.12
Jul Sept	412	409	15.0	14.9	7.4	7.3	2.2	2.2	0.17	0.17
Jan-Sept	347	341	12.3	11.9	6.0	5.5	1.8	1.7	0.14	0.14
Apr-Sept	373	368	13	12.6	6.5	6.2	1.9	1.9	0.15	0.15

[a]Calculated from Production Data

January - March	1,200
April - June	1,455
July - September	1,738

During July to September, the plant was processing more products than it was originally designed for.

Coefficients for water and waste parameters were also in general agreement with what would be expected in an average multiproduct dairy plant.

The baseline coefficents used in later phases of the study were:

Wastewater	=	368 gallons/100 pounds of BOD processed
COD	=	12.6 pounds/100 pounds of BOD processed
BOD	=	6.2 pounds/100 pounds of BOD processed

SECTION 7

DEPARTMENTAL WASTE CHARACTERIZATION

The departments and their contributing sub-units that are covered in this section are:

1. Ice Cream

   a. Mix processing

   b. Ice cream freezing and packaging

   c. Novelty freezing and packaging

2. Cottage Cheese and Cleaning

   a. Cottage cheese processing and packaging

   b. Cultured products processing and packaging

   c. CIP cleaning operations for entire plant

   d. Separator sludge discharge and HTST start-up,

shut-down and cleaning

3. Milk

a. Milk receiving

b. Milk processing

c. Milk packaging and storage

The departmental contribution to the total plant's waste water volume and major characteristics is shown in Table 16. Data are presented for all days and for processing days in both average amounts discharged to the drain and the percentage of each department's waste discharge to the total for the plant. Data are for the base period of the study.

The percentage wastewater volume and amount of COD, BOD and suspended solids were quite similar on a departmental basis. For a processing day, the milk receiving, processing, packaging and storage contributed an average of about 19% of the hydraulic load and 16% of the BOD load. The ice cream and novelty operation contributed about 39% of the hydraulic load and 38% of the BOD load. The cottage cheese-CIP department contributed 42% of the volume and 46% of the BOD load. Only abut 60% of this load is

Table 16. Departmental Contribution to Mean Daily Wastewater Values for Total Plant

DEPARTMENT	Wastewater Volume		Wastewater Characteristics					
			COD		BOD		SS	
	Gallons/ day	% of Total	Pounds/ day	% of Total	Pounds/ day	% of Total	Pounds/ day	% of Total
All Days								
Ice Cream	217,822	39	7,146	38	3,731	38	1,193	42
Cottage Cheese	245,748	44	9,486	50	4,677	48	1,068	38
Milk	96,000	17	2,244	12	1,383	14	567	20
TOTAL	559,570		18,876		9,791		2,828	
Processing Days								
Ice Cream	242,567	39	7,958	38	4,155	38	1,328	34
Cottage Cheese	261,235	42	10,084	48	4,971	46	2,000	52
Milk	117,000	19	3,094	14	1,738	16	536	14
TOTAL	620,802		21,136		10,864		3,864	

*For base period.

from cottage cheese operations and the rest can be assigned to cleaning of ice cream and milk equipment and operation of the HTST pasteurizers.

ICE CREAM

The mean waste strength and standard deviation of the various wastewater parameters for the ice cream department are shown in Table 17 for all days and for processing days. Using fat, carbohydrates, protein and citric acid values, a mean calculated BOD was 2,109 as compared to 2,054 mg/l.

Comparison of these data with the total plant wastewater reveals some distinguishing characteristics that would be expected from the ice cream and novelty operations. A higher fat and carbohydrate content and a lower protein concentration was to be expected because of the composition of the products being manufactured. Lower phosphate reflects the absence of milk salts in many of the novelty products. The markedly higher chloride and calcium ion content reflects the fact that the Vitaline discharges calcium chloride to the ice cream drain. The data indicate that approximately 38,000 pounds of calcium chloride brine are discharged each month. This compares favorably with the purchase records of 40 tons of calcium chloride per month.

Table 18 presents regression analysis of pairs of waste

Table 17. Mean Waste Strength of Characteristics of Ice Cream Department Wastewater

Parameter	All Days		Processing Days	
	Mean	Standard Deviation	Mean	Standard Deviation
COD	3,943	516	5,520	722
BOD	2,054	607	2,876	850
TOTAL SOLIDS	3,541	712	4,957	998
ASH	1,667	378	2,333	529
SUSPENDED SOLIDS	657	130	920	182
DISSOLVED SOLIDS	1,596	373	2,234	530
SETTLEABLE SOLIDS	13	3	18	5
CARBOHYDRATE	1,294	232	1,810	322
CITRIC ACID	154	45	215	63
LIPID	780	242	1,092	336
PROTEIN	382	158	535	224
PHOSPHATE	38	8	53	11
CHLORIDE	888	432	760	370
SODIUM	214	91	298	127
CALCIUM	817	367	720	300
MAGNESIUM	31	3	43	4
CONDUCTIVITY	2,084	121	2,053	63

*mg/l.

Table 18. Regression Analysis of Selected Wastewater Characteristics for the Ice Cream Department

Parameters Compared	Correlation Coefficient	Regression Equation	Standard of Error of Estimate
COD/BOD	0.86	421.6 + 0.4150X	342
COD/SS	0.92	-16.88 + 0.1942X	58
COD/TS	0.93	3827 + 0.02761X	225
COD/CHO	0.56	8.10 + (-9.960X)	187
COD/LIPID	0.04	776.5 + (-2.639X)	903
COD/PROTEIN	0.86	-31.82 + 0.0233X	18.7
BOD/COD	0.86	238.8 + 1.798X	712
BOD/SS	0.39	447.9 + 0.1115X	137
BOD/VOL.SS	0.99	-2.79 + 7.685E-3X	6
BOD/CHO	0.12	507.8 + (-2.434E-2X)	200
BOD/LIPID	0.39	-392.4 + 0.5184X	833
BOD/PROTEIN	0.70	-20.24 + 3.897E-2X	27
DISSOLVED S/CHO	0.87	-279.2 + 0.4697X	107
DISSOLVED S/COND.	0.83	293.4 + 1.129X	176
SS/CHO	0.92	609.7 + 4.353X	279
SS/SET SOLIDS	0.73	8.2952 + 1.225E-3X	3.6
SS/TOTAL N	0.86	-78.7 + 0.1978X	17

parameters. The correlation coefficient between COD/BOD was 0.86, and both COD and BOD were well correlated with both total solids and suspended solids.

In contrast to the total wastewater, the best correlation with organic components is protein with very poor correlation with lipid and carbohydrate. This can be explained on the basis of relatively constant protein level in both ice cream and novelties, but markedly different fat content and carbohydrate. Lack of correlation then would reflect large differences in the amount of loss of ice cream and novelties on different days, which would be in agreement with observations.

Multiple regression analysis of COD and BOD with protein plus lipid plus carbohydrate gives a multiple correlation coefficient of 0.83 and 0.88, respectively.

The pounds per day of the various waste characteristics are shown in Table 19.

Waste coefficients for the ice cream operation are shown in Table 20 for processing days. Based on processing days coefficients, the ingredient loss averaged 5.3% compared to a computed loss of less than 2% on the basis of production data.

Selected coefficients per 100 pounds of BOD processed for

Table 19. Mean Selected Wastewater Characteristics Waste Loads for Ice Cream Department

PARAMETER	POUNDS/DAY	
	All Days	Processing Days
COD	7,146	7,958
BOD	3,731	4,155
SS	1,193	1,328
TS	6,417	7,162
SETTLEABLE SOLIDS	23	26
SOLUBLE SOLIDS	2,850	3,174
CARBOHYDRATE	2,352	2,426
LIPID	1,437	1,601
PROTEIN	689	721
PHOSPHATE	68	76
CHLORIDE	1,613	1,797

Table 20. Mean Wastewater Coefficients for Ice Cream Department [a]

PARAMETER	Per 100 lbs of BOD Processed	
	All Days	Processing Days
WASTEWATER VOLUME	572	457
COD	18.8	15.0
BOD	9.8	7.8
SS	3.1	2.5
TS	16.9	13.5
CARBOHYDRATE (CHO)	6.2	6.0
LIPID	3.8	3.0
PROTEIN	1.8	3
PHOSPHATE	0.18	5
CHLORIDE	3.46	4

[a]Water volume in gallons; other values in pounds.

the period of July to September were as follows:

PARAMETER	ALL DAYS	PROCESSING DAYS
Water, gallons	453	388
COD, lb	14.9	12.7
BOD, lb	7.8	6.6
SS, lb	2.5	2.1

In interpreting these results, the fact must be kept in mind that the above coefficients do not include the total waste load that is associated with ice cream operations. Wastes associated with pasteurization of mix and CIP of processing equipment, storage vats, flavor vats and ice cream freezers are not included.

COTTAGE CHEESE PLUS CIP

The mean strength of various characteristics of the waste water from the cottage cheese-CIP drain is presented in Table 21. The wastewater is high in carbohydrate and protein and low in lipid content, reflecting the cottage cheese manufacturing process from skim milk and the discharge of whey to the drain.

Table 21. Mean Waste Strength Values for Characteristics of Cottage Cheese CIP Department Wastewater*

PARAMETER	All Days		Processing Days	
	Mean	Standard Deviation	Mean	Standard Deviation
COD	4,615	1,800	4,829	1,917
BOD	2,076	1,050	2,282	1,150
TOTAL SOLIDS	4,053	1,449	4,455	1,526
ASH	975	509	1,070	565
SUSPENDED SOLIDS	495	110	521	125
SOLUBLE SOLIDS	960	172	1,009	179
SETTLEABLE SOLIDS	5	0.5	5.3	0.5
CARBOHYDRATE	1,850	418	2,120	490
LACTIC ACID	540	80	548	87
LIPID	280	142	302	158
PROTEIN	520	136	578	172
PHOSPHATE	45	15	60	20
CHLORIDE	320	120	321	132
SODIUM	231	219	243	37
CALCIUM	79	15	85	22
MAGNESIUM	29	5	31	5
CONDUCTIVITY	1,261	99	1,389	105

*mg/l.

The lactose is the major whey component and the elevated protein level indicates the loss of casein in the form of curd fines. The fines do not appear to show as suspended solids. The waste strength values show more variability than those for the total wastewater or for ice cream. The reasons for this will be discussed later when detailed studies of this department are presented in unit process investigations.

Table 22 expresses the regression analysis of selected pair of data. The BOD/COD correlation coefficient was 0.94. BOD was also correlated (r=>0.8) with carbohydrate, lactic acid, lipid and protein. Multiple regression analysis showed COD and BOD related to protein, lipid and carbohydrate with correlation coefficient of 0.97 and 0.98, respectively. SS correlated with protein (0.99), carbohydrate (0.93) and lipid (0.87). Inclusion of lactic acid increased these coefficients to 0.92 and 0.95, respectively. The higher correlation between BOD/COD and components relates to less variability in composition of the wastewater from this department.

Table 23 shows the mean waste loads for selected wastewater characteristics from the cottage cheese-CIP department. The load of settleablesolids is much lower than might be expected because of the presence of solid curd particles in the wastewater.

Table 22. Regression Analysis of Selected Characteristics in Cottage Cheese Department Wastewater

PARAMETER	Correlation Coefficient	Regression Equation	Standard Error of Estimate
COD/BOD	.94	-329.8 +0.5642X	453
COD/SS	.87	-16.5 [illegible].1081X	151
COD/CARBOHYDRATE	.86	16.7 + 5.9823X	75
COD/LIPID	.87	-76.3 + 7.2096E-2X	89
COD/PROTEIN	.94	6.38(28.8 + 1.3344X)	10.3
BOD/COD	.94	1055.1 + 1.5659X	755
BOD/SS	.69	124.7 + 0.1553X	219
BOD/CNO	.96	7.3 + 0.1108X	40
BOD/LIPID	.96	49.9 + 0.1316X	53
BOD/PROTEIN	.84	6.38(45.3 + 1.9828X)	16.9
PROTEIN/SS	.99	-328.8 + 8.858X	46.2
PROTEIN/PO_4	.99	-7.3 + 0.7495X	3.3

Table 23. Mean Loads for Cottage Cheese-CIP Department
Selected Wastewater Characteristics

PARAMETER	Pounds/Day	
	All Days	Processing Days
COD	9,486	10,084
BOD	4,254	4,971
SS	1,014	1,136
TS	8,306	9,378
Settleable Solids	11	11
Carbohydrate	3,792	4,615
Lipid	573	658
Protein	1,065	1,256
Phosphate	92	132
Chloride	659	700

Waste load coefficients for the cheese-CIP department are presented in Table 24. The coefficients are relatively low on the basis of hundred pounds of BOD processed, since the BOD processed through this department includes all cottage cheese plus milk plus ice cream processed in the plant as a result of the CIP operations. Detailed studies reported later will clarify these coefficient values, which have relatively limited value in assessing major waste problem areas in the cottage cheese-CIP department.

MILK DEPARTMENT:

The characteristics of the wastewater from the milk floor drains was determined by difference in the total-(ice cream + cottage cheese-CIP). The wastewater reported for this department did not include that associated with cleaning tankers, storage tanks or lines of pasteurizers. Nor did it include the waste from the separators or start-up or shut down of the HTST systems. The wastewater is primarily clean water, whereas the organic matter is almost entirely associated with preventable wastes.

The mean waste strength of the various parameters of the milk department wastewater is in Table 25. Because they are determined by difference, the values should be considered only as estimates. Component composition (fat, protein, carbohydrate)

Table 24. Mean Wastewater Coefficients for Cottage Cheese-CIP Department[a]

PARAMETER	Per 100 lbs of BOD Processed	
	All Days	Processing Days
Wastewater Volume	163	155
COD	6.3	5.9
BOD	3.1	2.9
SS	0.7	0.7
TS	5.8	5.4
Carbohydrate	2.8	2.7
Lipid	0.4	0.4
Protein	0.8	0.75
Phosphate	0.43	0.41
Chloride	0.08	0.08

[a]Water volume in gallons; other values in pounds.

Table 25. Mean Waste Strength Values for Characteristics of Milk Department

PARAMETER	mg/l	
	All Days	Processing Days
COD	2,766	3,000
BOD	1,383	1,500
TOTAL SOLIDS	2,069	2,246
ASH	782	849
SS	567	615
SOLUBLE SOLIDS	1,057	1,147
SETTLEABLE SOLIDS	7	7
CARBOHYDRATE	860	933
LIPID	320	345
PROTEIN	400	434
PHOSPHATE	58	60
CHLORIDE	180	175
SODIUM	163	160
CALCIUM	76	82
MAGNESIUM	26	27

would be relatively constant from day to day, which accounts for the high correlation coefficients. Regression analysis of selected parameters for the milk department are shown in Table 26. COD/BOD and lipid showed the lowest correlation coefficient which suggests variability in usage. The characteristics of the wastewater are different than for either ice cream or cottage cheese and the organic components more nearly approach the composition of milk. As a basis of overall comparison, the following is the percentage of fat, protein, and carbohydrate in the total plant wastewater and that of the three departments:

	Fat	Protein	Carbohydrate
Total Waste Water	16	24	60
Ice Cream Department	22	16	53
Cottage Cheese Dept.	10	19	71
Milk Department	21	25	54
*Fluid Milk Products	23	27	50

*calculated average value of fluid milk products

Table 26. Regression Analysis of Selected Characteristics in the Wastewater from the Milk Department

PARAMETERS COMPARED	Correlation Coefficient	Regression Equation	Standard Error of Estimate
COD/BOD	0.95	484.4 + 0.3279X	153
COD/SS	0.96	-873 + 0.5817X	54
COD/CARBOHYDRATE	0.98	99.5 + 0.2735X	45
COD/LIPID	0.81	267.9 + 2.203 E-2X	14
COD/PROTEIN	0.87	286.0 + 4.060-2X	37
BOD/COD	0.95	-1290.7 + 2.909X	358
BOD/SS	0.89	378.0 + 0.1539X	112
BOD/CARBOHYDRATE	0.98	840.5 + 6.214E-2X	47
BOD/LIPID	0.58	404.9 + (-4.713X)	78
BOD/PROTEIN	0.83	223.7 + 0.1329X	84

Mean loads of selected characteristics are presented in Table 27. Waste coefficients are given in Table 28. The full impact of milk processing cannot be ascertained from these data, but it does have significance in that the organic matter is mostly preventable wastes.

Table 27. Mean Loads for Milk Department Selected Wastewater Characteristics[a]

PARAMETER	Pounds / Day	
	All Days	Processing Days
COD	2,191	2,926
BOD	1,359	1,462
SS	534	599
TS	1,448	2,191
SETTLEABLE SOLIDS	7	7
CARBOHYDRATE	641	910
LIPID	262	336
PROTEIN	328	423
PHOSPHATE	47	58
CHLORIDE	147	170

[a]Based on Waste Strengths of Characteristics for Milk Department.

Table 28. Coefficients for Selected Characteristics in Milk Department Wastewater[a]

PARAMETER	Per 100 Pounds of BOD Processed	
	All Days	Processing Days
WASTEWATER VOLUME	67	73
COD	1.5	1.8
BOD	0.95	1.0
SS	0.4	0.4
TS	1.0	1.4
CARBOHYDRATE	0.45	0.6
LIPID	0.2	0.2
PROTEIN	0.2	0.27
PHOSPHATE	0.03	0.04
CHLORIDE	0.10	0.11

[a]Water volume in gallons; other values in pounds.

SECTION 8

WASTEWATER CHARACTERISTICS OF UNIT PROCESSES

To more fully characterize the wastes from this plant and to establish the significant waste loads that could be targeted for reduction through either managment control or process/equipment modification, a number of detailed studies was made to establish the total water use and ingredient losses in frozen desserts, cottage cheese, culture products and fluid milk products:

- frozen dessert operations were separated into ice cream and stick novelty operations (drain #1) and included the wastewater associated with cleaning the ice cream storage tanks and lines and the start-up and shut-down of the pasteurizer (drain #2)

- cottage cheese operations included those processes associated with cheese making, cream dressing manufacture and cottage cheese packaging and the clean-up of associated equipment (drain #2).

- cultured products operation included the processing, packaging and cleaning of equipment used for the

manufacture of yoghurt, sour cream and buttermilk. (drain #2)

-Milk processing operations included the receiving of fluid milk, processing, packaging and clean-up. The wastewater associated with these operations was all of that generated in the milk department (drain #3- drain #1 -drain #2), plus that going out drain #2 from CIP cleaning and HTST operations.

The objective of these studies was to obtain base data for further study and there was no need for complete analysis. Based on previous data, analyses were limited in most cases to water volume and BOD and/or COD. In some cases SS was also determined.

These special studies generally involved a combination of individual observations and analyses over a least three separate processing days. Care was taken to choose days when the production in the area under study was typical. Where possible, the time was chosen to permit maximum interpretation of the wastewater from the product area under study.

The contribution of CIP operations to a specific product area could be isolated, since each of the seven CIP units served a specific area and the discharge to the sewer was metered. The designation of the CIP unit and the area served were as follows:

CIP unit	Area Served
1	Milk Receiving
2	Milk Receiving
3	Raw milk storage
4	Frozen desserts
5	Milk lines and tanks
6	Cottage cheese and cultured products
7	Frozen desserts

Water flows discharged to the sewer were either metered or flow was diverted into a container and timed with a stop watch. HTST units could be monitored individually and waste loads estimated on the basis of diversion times and flow rates.

Analyses were made of wastewater discharge on an hourly or half-hourly basis and correlated to observations of what was occuring in the plant at that time.

Loss studies generally were conducted by measuring COD in all the ingredients used and by measuring COD in the wastewater.

FROZEN DESSERTS:

The frozen dessert area could be separated into two major product areas: (a) ice cream, sherbets and stickless novelties and (b) stick novelties. In terms of COD processed about 35-45% was from stick novelties and 55-65% was from ice cream operations. The mean contribution to COD processed was 38 and 52% respectively.

Attention was given to: (a) wastewater volume and (b) COD.

Wastewater volume:

Overall mean wastewater flow for all frozen dessert operations for the base period of study was as follows:

floor drains	242,000 gallons	(87%)
CIP	11,560 gallons	(4%)
* HTST	24,600 gallons	(9%)
TOTAL	278,160 gallons/day	

* The daily water use for the pasteurizer varied widely, depending on the amount of time the unit was run on water with the flow diverted to drain. Water use ranged from 7,000 to

122,000 gallons /day. The former would be considered minimum water use and would include one start-up and one shut down.

The mean coefficient of wastewater for frozen dessert operations was 527 gallons/100 pounds of BOD processed.

Hourly wastewater flows (floor drains only) for a typical processing day are shown in Figure 11. Start-up, processing and clean-up areas are marked on the graph. During the operating day, the water flow was relatively constant at 9,600 gallons per hour.

Not included is about 15,000 gallons of water per day used for the cooling tower, boiler and compressors or about 7500 gallons/day of water used for product, since this water use is not discharged to the sewer.

Direct water use by unit operations can be summarized as follows:

Unit Operation	Gallons/Day	Gallons/ 100 lb BOD Processed
Mix processing	(41,220)	(78)
HTST heating	4,320	8

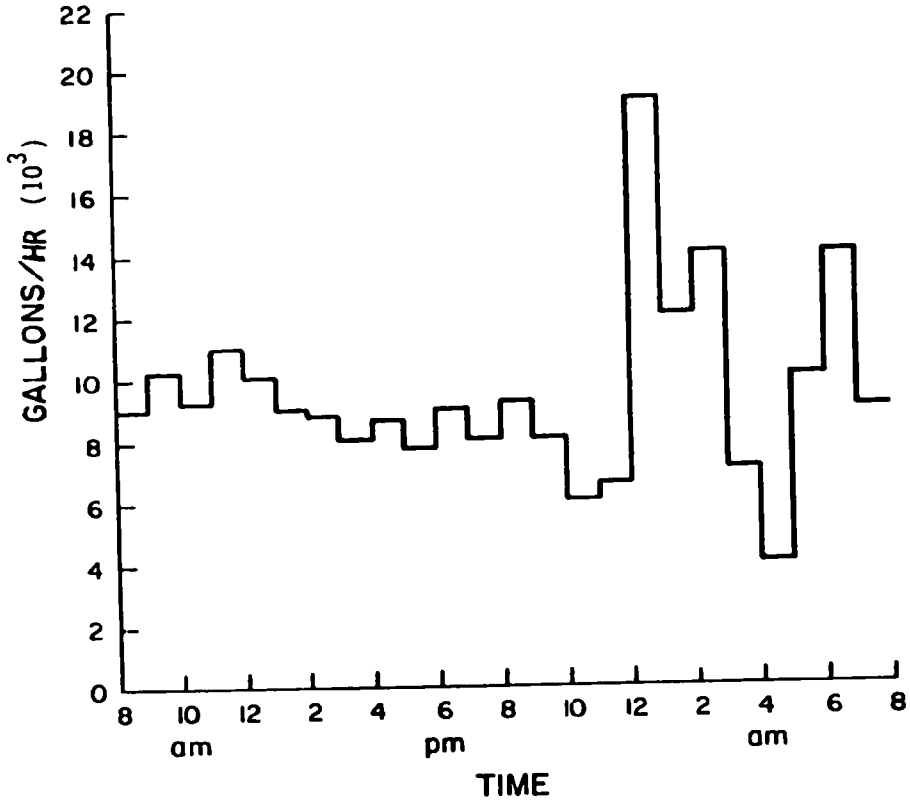


Figure 11. Hourly Wastewater Discharged for Floor Drains from Frozen Dessert.

HTST cleaning	26,000	49
HTST start-up and shut-down	10,000	19
water hose for washing spills	900	2
Ice Cream Processing	(48,700)	(148)
freezing and packaging	7,000	21
rinsing freezers and vats and lines	32,000	97
water hose for washing spills and clean-up	2,500	8
CIP	7,200	22
Stick Novelty Processing	(166,860)	(822)
4 Vita-freeze units	144,000	709
Rinsing freezers and equipment	16,000	79
water hose for washing spills and clean-up	2,500	12
CIP	4,360	22

The total waste water from frozen dessert operations was

256,780 gallons or a coefficient of 488 gallons for the three days studied. This was lower than for the base period and could be associated with the presence of project personnel in the plant.

Product Losses:

Product losses were measured in term of COD. Based on the COD/BOD ratio for the ice cream drain (0.53± 0.05), BOD values were calculated and reported as estimated values.

Overall COD and BOD losses associated with the processing of frozen desserts is summarized below:

	COD (lb/day)		BOD (lb/day)
Floor drains	7000	(83%)	3710
HTST	1000	(12%)	530
CIP	414	(5%)	220

This gives a total COD and BOD of 8414 and 4460 lb/day and coefficients of 17.7 and 9.4, respectively.

A graph of hourly discharge of COD for frozen dessert

operations is shown in Figure 12. The start-up, processing and clean-up times are indicated. Increased COD loss was observed during start-up, at several periods during the processing day and during clean-up. The increased losses during the processing day were related to equipment operations problems at either the vitaline or ice cream packaging machines and at 4 pm the peak loss was due to the loss of 25 gallons of 40% cream in the mix processing area.

A breakdown of COD losses by unit operation is as follows:

Unit Operation	pounds of COD/ day	Pounds of COD/ 100 lbs COD processed
Mix Processing		
HTST Start-up and shut-down	1000	1.89
Leaks and spills	183	0.35
Ice Cream Processing		
Start-up	800	2.5
Freezing	100	0.3

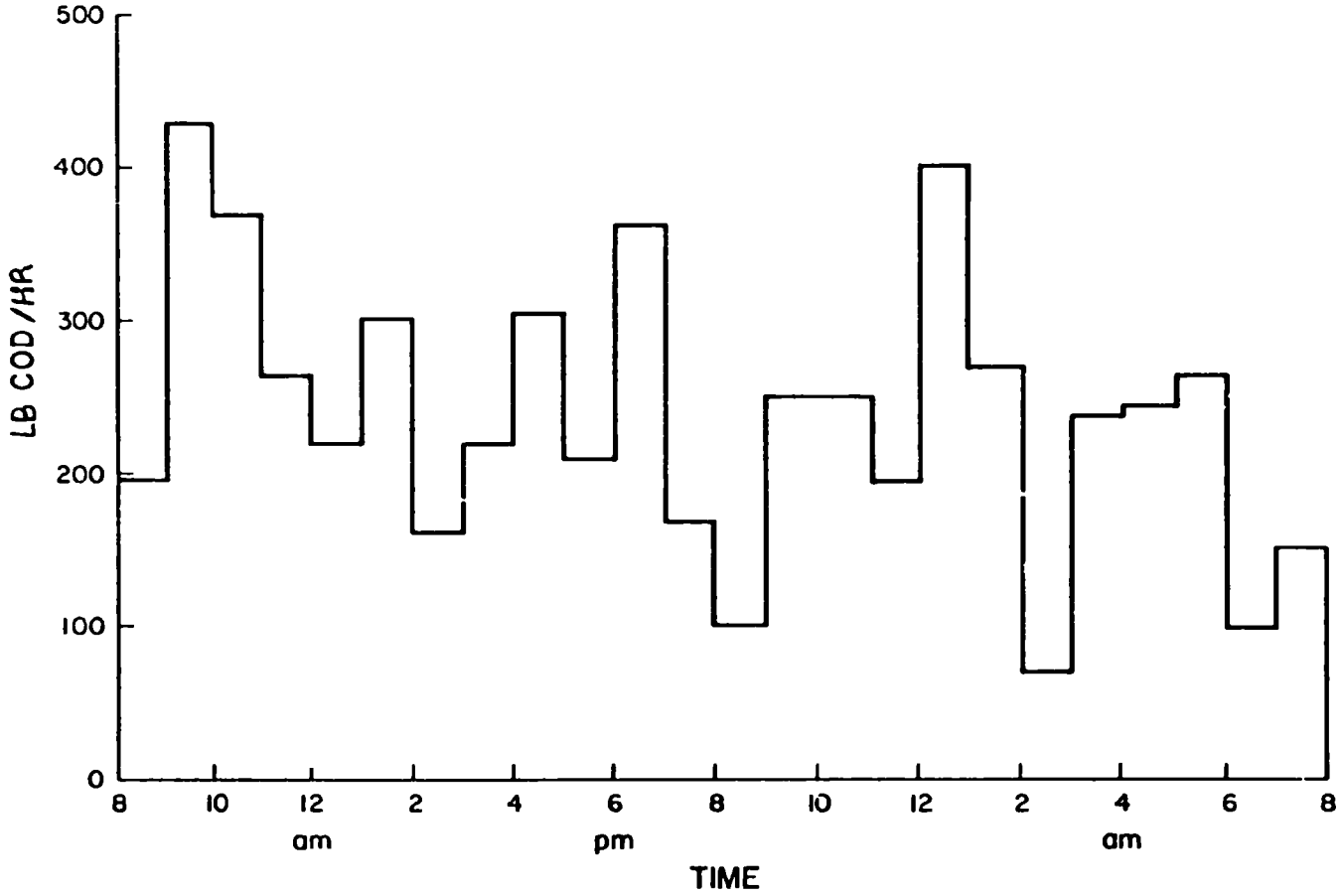


Figure 12. Hourly COD Discharge of Floor Drains for Frozen Dessert Operations.

Packaging	1120	3.41
Rinsing equipment	450	1.37
CIP	248	0.75

Novelty Processing

Freezing	56	0.28
Vita-freeze	2346	11.59
Packaging	1564	7.73
Rinsing equipment	380	1.16
CIP	165	0.5

In term of BOD processed the over-all loss during this study was 8.41 pounds of BOD per 100 pounds of BOD processed or a 8.4% loss. The loss for the stick novelty operation was 10.2% There was a marked difference in losses for various operating days. The range in COD discharged ranged from 3900 to 10,700 pounds/ day and an overall percentage loss of from 3.5 to 13.7. The mean percentage loss was 5.6%. High losses were generally associated with one or more of the following: (a) spoilage of product and dumping at start-up, (b) over production of products such as sherbet or ice pops that could not be used in overrun and dumping at end of production or (c) equipment malfunction, primarily in ice packaging equipment and/or the Vita-lines. The latter was the most common cause of large losses.

COTTAGE CHEESE AND CULTURED PRODUCTS

The basic cottage cheese making system involved the use of 6 three-thousand gallon vats and 2 sixteen-hundred gallon vats. During the period under study, from 15,000 to 19,000 gallons per day of skimmilk was set for cottage cheese manufacture. All cheese was sold as creamed cottage cheese with 4% milkfat obtained by blending 55% curd and 45% cheese dressing. The detailed cottage cheese study was made by investigating three vats on each of three separate processing days. The cheese was made by the short set method and three washes were used. Attention was given to both water volume and COD discharged. Analyses were made of whey and washwater for total COD, COD after the removal of fines and a casein balance was also made.

Wastewater discharge:

The following mean values were obtained for the discharge of whey and washwater for a 3000 gallon lot of cheese:

unit operation	volume discharge	% of milk volume
whey	2100 gallons	70%
first wash	2300 gallons	77%

second wash	2300 gallons	77%
third wash	1600 gallons	53%
total	8300 gallons	277%

Water was also used in the jackets of the vats and for a plate heat exchanger, which were used to adjust the temperature of the skimmilk to the desired setting temperature. Total mean water discharged to the drain was:

Unit operation	gallons of water	gallons/100 pounds of BOD processed
* cheesemaking	23,930	220
** setting	1,000	9
** cooking	6,296	58
** cooling	8,435	78
CIP	2,320	22
hand cleaning vats	5,000	46
total	46,980	433

*includes whey and 3 washes

** clean water discharged to drain: heat exchanger= setting, vat condensate water = cooking, vat circulating water to drain = cooling.

COD and casein loss:

Analyses were made for COD and for casein (pH 4.6, insoluble nitrogen x 6.38) in the skimmilk, dressing, starter, whey, wash waters and finished product. The mean values for total solids, COD strength and pounds of COD are summarized as follows:

Sample	%total solids	mg/l COD	lbs COD
Skimmilk	9.70	113,000	16,000
Skimmilk-casein	6.9	71,000	10,090
Dressing	20.0	315,000	4,770
Starter addition	10.0	123,000	760
Whey	7.0	68,000	6,720
First wash	0.9	8,800	882
Second wash	0.5	4,700	471
Third wash	0.2	950	95

Coefficients of losses in cheese making operations were as follows:

Unit process	*Pounds COD/100 pounds COD processsed	
	based on curd	based on final
whey	39.8	34
first wash	5.3	4.1
second wash	2.8	2.1
third wash	0.6	0.4

* This is also equivalent to pounds of BOD per 100 pounds of BOD processed or % loss of COD.

Fines loss was significant in this operation and two approaches were used to measure this loss. One was the removal of the fines by centrifugation (Table 29) and the second was the measurement of the casein loss. The second was more accurate than the first, since centrifugatic removed only from 30 to 86% of the casein due to the small size of some particles.

Table 29. Effect of Fines Removal on BOD of Cottage Cheese Whey[a]

BOD_5, mg/l		
Before	After Fines Removal	% BOD Attributed to Fines
35,000	23,000	34
29,500	17,500	41
31,000	18,500	40
35,000	18,200	48
43,000	24,000	44

[a]Include a Portion of the First Rinse.

The loss of casein in the whey and washwaters was different in the 3000 and 1600 gallon vats, as shown in the following:

Unit process	percentage casein loss	
	small vat	large vat
whey	3.1	3.5
first wash	2.1	1.8
second wash	1.6	0.6
third wash	0.4	0.3
total	7.2	6.2

About one-half of the casein loss was associated with the washing procedure and the loss in the small tanks was greater than in the larger vats. There was considerable difference between trials in the loss which could be attributed to the characteristics of the curd and also to the time the mechancial agitators were in use. The highest loss observed was 12.1% for one vat. Other vats made on the same night had losses below 6%. The lowest loss was 4.4%. One single trial was made to determine the effect of hydrolysis by either rennin or microbial cultures

on casein loss. The results indicated that up to 5% of the total casein loss could be attributed to hydrolysis.

The BOD/COD ratio was 0.45. Overall the BOD loss associated with the cheesemaking process ranged from 3300 pounds to 5500 pounds, depending on the amount of cheese made and the amount of casein loss.

COD and BOD losses and coefficients for all operations associated with cottage cheese processing and packaging are summarized as follows:

Unit process	lbs COD	COD coefficient	lbs BOD	BOD coefficient
* Setting	30	0.14	14	.14
Cutting, cooking and draining	6450	30.5	2900	30.9
Washing	1557	7.0	700	7.0
Creaming	20	0.1	9	0.1
Packaging	48	0.22	21	0.22

Hand wash	70	.32	32	0.32
CIP	154	0.7	69	0.7
total	8329	39.4	3745	39.4

The whey and wash waters made up over 97% of the total loss of organic matter in the cheese making process. Of the other losses, about 50% were due to leaks or spills.

FLUID MILK PRODUCTS:

All of the milk and cream for all products processed in the plant passed through the receiving room, raw milk storage and milk processing area. Total milk intake was used as a basis for coefficients in receiving and processing and packaged fluid milk products as a basis for coefficients in packaging and storage operations.

Wastewater use in fluid milk operations:

The water use associated with the milk operation included that being discharged through the floor drains in the receiving, processing, packaging and storage areas and a major portion of the water going out drain #2 from the hub drains of the HTST

units. Mean water use by unit processes was as follows:

Unit Process	gallons / day	gallons/100lb BOD processed
Receiving	(25,000)	(16)
Milk Processing	(104,520)	(60)
Separating/ clarifying	57,440	33
homogenization	5,000	3
HTST start-up & shut-down	22,500	13
HTST heating water	17,280	10
hose stations	1,300	1
Packaging	(107,900)	(97)
case washer	38,000	30

fillers	6,000	5
hose stations	1,500	1
Storage	12,400	11
CIP of tanks and lines	(14,000)	(15)
TOTAL	(251,420)	188

Major water use was for the case washer, clean-up of the HTST units, and CIP separators. The HTST start-up and shut-down was variable, depending upon the use of the rinse recovery system. This system was not used about one day in three, because of production scheduling problems.

The water used in the clean-up of the HTST was mostly clean-water for final rinse. The amount of water used for rinsing and discharged to drain for the three HTST units ranged from about 6,500 to 156,000 gallons / day.

Product losses:

Determination of product losses from unit processes for the milk department was most difficult, since there was no direct

drain access. Determination was made when no other plant production was in operation, such as receiving on week ends when no processing was being done or when either cottage cheese or ice cream processing was not being done. Generally these studies were conducted for only portions of the total days operation and values obtained on hourly data projected for the full days operations

Estimation of BOD and COD for unit processes for fluid products is summarized below:

Unit Operation	lb COD/ day	lb BOD/ day	lb BOD/100 lb of BOD processes
Receiving	(700)	(370)	(0.23)
Pasteurization	(1764)	(937)	(0.58)
start-up & shut-down	1206	639	0.40
leaky HTST#3	150	80	0.03
cream HTST over-flow	109	58	0.04
homogenization	20	11	0.01
separation	199	106	0.07
HTST overflows	80	43	0.03

Storage before packaging	(960)	(509)	(0.31)
Defective air blow	160	85	.05
CIP (raw and past.)	800	424	0.26
Packaging	(1509)	(799)	(0.50)
Storage of packaged product	(301)	(160)	(0.1)
* Miscellaneous leaks and spills	(592)	(314)	(0.20)
TOTAL	5826	3089	1.9

* COD estimated from analysis of drain #2-COD from unit processes discharging from drain #1.

About 60% of the product losses in the processing of fluid milk products is from the milk floor drains and the remainder is from drain #2.

The values for milk receiving were from days where the tankers were unloaded promptly. The effect of time of standing before unloading of tankers is shown in Figure 13.

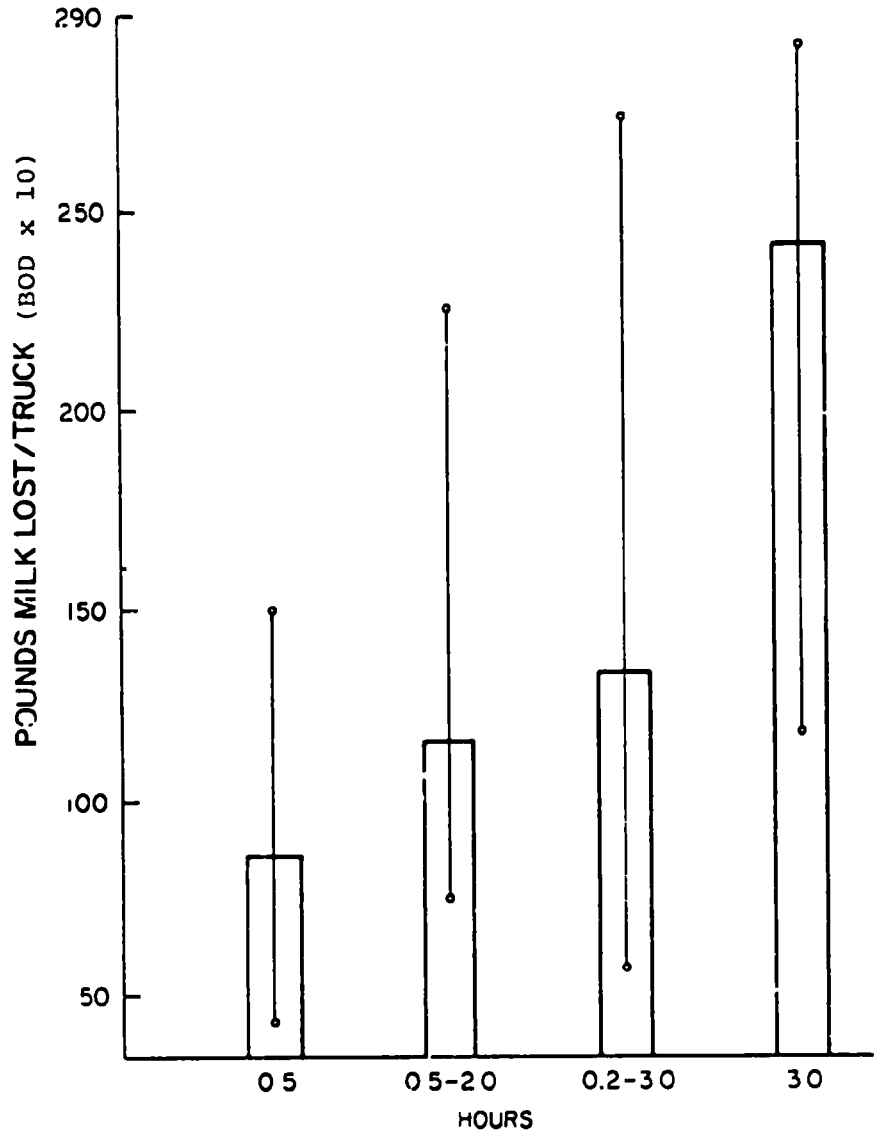


Figure 13. Effect of Tankers Standing Before Unloading on Milk Loss.

Although there was considerable variation, a linear relationship was observed bewteen time of standing and the amount of BOD loss during washing. The average loss of BOD per tanker was 70 pounds for those unloaded promptly and up to 350 pounds for those that stood for 3 hours before unloading.

The data presented in this section of the report provided a basic understanding of the plant operations and a basis for determination of major areas to which to give attention during subsequent periods of the study. The coefficents could be compared to those reported in the literature for design coefficients and provide a basis for estimating the preventable wastewater discharges.

SECTION 9

DEVELOPMENT AND IMPLEMENTATION OF WASTE MANAGEMENT CONTROL PROGRAM

The management control phase of the study was conducted in three separate stages:

Stage I Management used basic data obtained in the plant survey and undertook a control program with no outside assistance in the planning or execution.

Stage II Management appointed a waste control committee to supervise the program and The Ohio State University personnel provided input in planning and execution of the program.

Stage III A single resource control manager was placed in charge of the control program, reporting directly to the plant manager with no other responsibilities. The managment control handbook developed during Stage II was utilized by the resource control manager.

Prior to the initiation of the management control phase of the program, the following steps were taken:

1. A meeting was held to acquaint Kroger management with the findings of the plant survey. The economic impact of the losses was reviewed.

2. A PDP-11 computer was installed to monitor water use, water discharge to the sewers and the production of fluid milk products. The system printed a daily summary and could print hourly reports as required.

3. Goals were established for the management control program based on data and an estimation of what should be achievable in the reduction of water being discharged to the sewer and reduction of BOD/COD.

ECONOMIC IMPACT OF KROGER PLANT WASTEWATER:

The cost of wastewater discharge from the Kroger Indianapolis plant was computed on the basis of the baseline period data and was computed in respect to cost per day, per four week period and per year. Different levels of management were found to relate differently to the various time frames.

Total water use for the plant per year was 176,800,000 gallons as projected from the base period data. The municipal treatment works costs for treatment of the dairy plant wastes were:

water	$0.42/1000 gallons
volume discharge to sewer	0.42/1000 gallons
service charge	0.03/1000 gallons
BOD (over 250 mg/l)	0.025/pound
SS (over 200 mg/l	0.045/pound

The value of raw milk was computed at $11.20 per hundred pounds.

Waste and sewer volume charges were:

	Ave/	$ Value	
	per day	per period	per year
water	252	7,056	91,728
water volume to sewer	252	7,056	91,728
Sewer service charge	18	504	6,552

TOTAL	522	14,616	190,008

The projected annual BOD discharged to the sewer was 3,385,200 pounds. The cost of BOD was:

Pounds per year	3,385,200
Pounds BOD/year exempted	547,938
Pounds per year chargable	2,837,262
Surcharge (2,837,262 x 0.026)	$73,768/year

This breaks down to a daily cost of $202 or a period cost of $5674.

The percentage contribution of various areas to BOD loss was:

milk	18.0%	$13,275
ice cream	36.0	26,557
cottage cheese	34.0	25,080

CIP, Hub drains	12.0	8,851

The BOD contribution of the CIP and hub drains must be divided among the milk, ice and cottage cheese operations. About two-thirds of the load may be charged to the milk department.

The effect of low, median and high BOD loads on the BOD surcharge is depicted in Figure 14, which is a reproduction of one of the visual aids used in the management meeting.

For suspended solids the charges project for one year would be:

pounds SS/ year	1,054,063
pounds SS/year exempted	368,628
pound SS/YEAR CAREABLE	685,435
Surcharge (685,435x 0.045)	$30,844

This breaks down to a dairy surcharge of $84.74 and a period surcharge of $2372.

The total cost of the sewer related bill is:

daily	$ 308.50

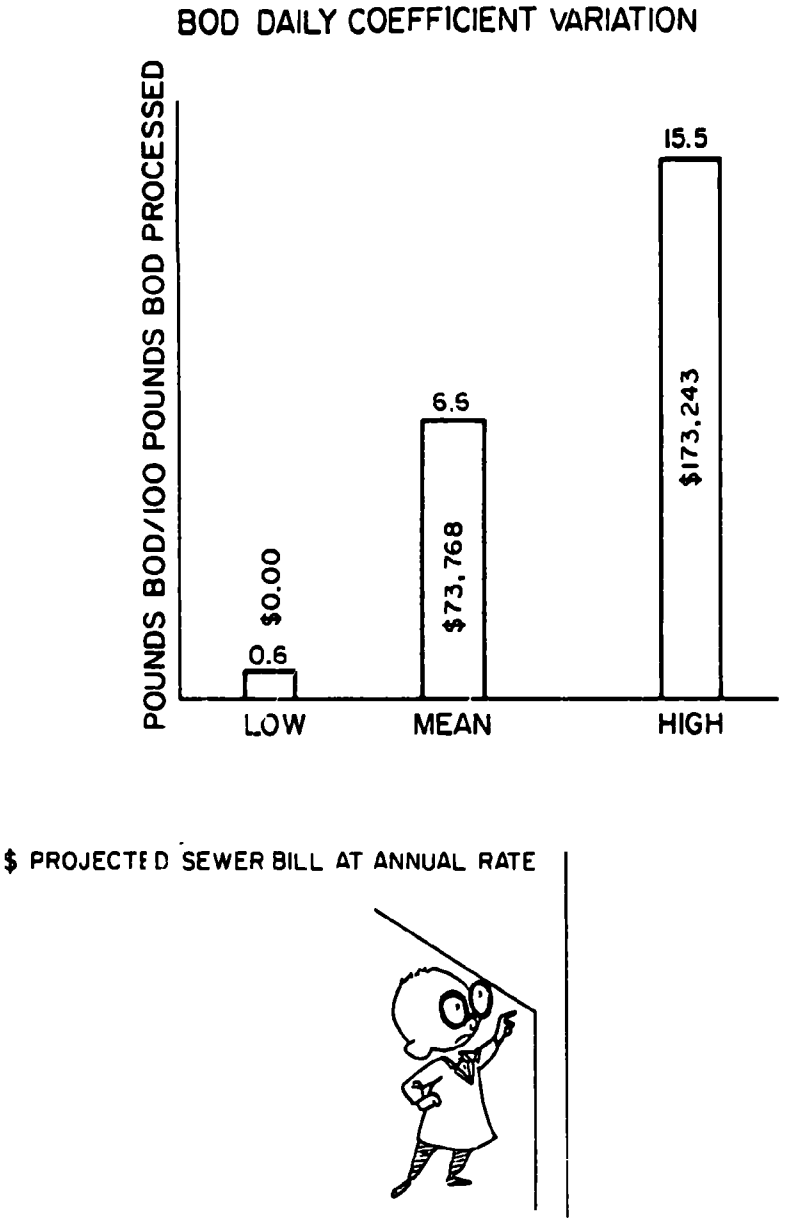


Figure 14. Projected Annual BOD Surcharges at Various Waste Loads.

4 week period	$22,639
yearly	$294,620

The percentage of cost for volume, BOD and SS was 65, 25, and 10%, respectively. However, these costs do not fully indicate the total cost associated with product losses. In addition to the sewer bill, product losses, packaging materials losses, labor associated with loss product and energy associated with product losses must also be taken into consideration. The overall breakdown of these losses for the total plant were:

	$ Annual Cost	% of Cost
* Sewer bill	292,620	19.8
Product losses:		
raw milk	155,000	10.5
product losses	759,959	51.5
** Labor	203,560	13.8

** Energy	7,307	0.5
Packaging	58,458	4.0
Total	$1,476,904	

*includes water, sewer volume charge and surcharges for BOD and SS.

**based only on lost product.

Product losses were estimated on the basis of the mean losses from ice cream , milk cultured products and finished cottage cheese. Whey was deducted and no value was assigned to it. The sewer bill included the cost of water discharged to sewer. Labor and energy are based on cost of lost product only.

The above cost figures are estimates, suspected to be on the conservative side.

Overall the preventable wastewater and BOD in this plant was found to range from 40-80%. The losses as measured at the sewer were consistently greater than determined from production records. The mean pounds of BOD loss/100 pounds of BOD processed (including all ingredients) was 2.72 and the loss measured from wastewater analysis was 6.2 or 2.28 times higher than shown by

management records. A comparison of losses based on production figures and those based on sewer analysis are compared in Table 30 for January to September 1977.

Whey, which is the most visible waste from a dairy plant, contributed about 35% of the total BOD and on an annual projection the plant would discharge 1,231,588 pounds of BOD from whey. The volume and surcharge cost would be $52,000 per year or $4000 per period and $200 per processing day. The cost per pound of finished cottage cheese would be $0.008 and the cost per pound of fluid whey would be $0.0015.

Table 30. BOD Losses Based on Market Report Values for Dairy Product Losses Only

Month 1977	# BOD Lost	#BOD Lost/100# BOD Processed*	% of Loss Measured in Effluent
January	77,230	1.20	32
February	69,926	1.87	30
March	42,971	1.08	21
April	42,176	1.13	23
May	71,180	1.88	38
June	51,999	1.33	23
July	208,112	0.54	8
August	221,112	1.75	28
September	238,000	1.22	22

*Based on skim and fat losses from Production Reports

Computer Monitoring of Selected Plant Operations:

Computer Concepts of Knoxville, Tennessee, installed a PDP-11 computer with Computer Concepts I/O's to monitor selected production and water flows in the Kroger Plant. The system was not programmable by the project personnel.

The system gave a daily summary and could also be set to give hourly or half-hourly reports that permitted monitoring of events in the plant. Reports could be called for at anytime within intervals sufficient to complete the report (2.5 minutes).

A typical day's Summary report is reproduced below (values in gallons):

KROGER - EPA DAILY REPORT 27-Sept-77 00:00:00 page 1

WATER/SEWER SUMMARY

WATER SUPPLIED

HM1	7312
HM2	427793
HM3	93549

HM4	87312
TOTAL	615971

WATER USED

CIP1	4785
CIP2	8236
CIP3	4837
CIP4	33894
CIP5	899
CIP6	537
CIP7	4327
BATCH WEIGH	4441
LANCE	0
TOTAL	61946

SEWER DISCHARGE

LINE1	0
LINE2	187060
LINE3	592430

UNIT #1 SUMMARY

RAW MILK USED	62621
WATER USED	11394
RINSE MADE	0
SLURRY USED	0

CREAM PRODUCED	5431
CHEESE SKIM	27143
SKIM MILK 0.45%	10249
LOW FAT 0.55%	4621
HI NU 2.00%	116540
HOMO 3.25%	12306
TO BLEND VAT	0

ATST #2 SUMMARY

RAW MILK USED	24344
WATER USED	11720
RINSE MADE	0
SLURRY USED	0
CREAM PRODUCED	472
CREAM USED	119
CHEESE SKIM	0
STARTER	0
YOGURT 1%	265
YOGURT 3.25%	929
CHEESE DRESSING 9%	1654
VEG. FAT SOUR CREAM 10%	0
SOUR CREAM 13%	0
DRINKS	0
WEIGHT WATCHERS	0
BUTTERMILK 1%	4223

CHOCOLATE MILK 1%	5525
CHOCOLATE DRINK (H20 & VEG FAT)	0
EGG NOG 2%	0
EGG NOG 6%	0
HALF & HALF 10.5%	1078
WHIPPING CREAM 35%	329
SKIM MILK 0.45%	0
LOW FAT 0.55%	1479
HI NU 2.00%	10817
HOMO 3.25%	909

RTST #3 SUMMARY

RAW MILK USED	90074
WATER USED	6008
RINSE MADE	0
CREAM PRODUCED	4674
HI NU 2.00%	17344
HOMO 3.25%	72507

RTST #5 SUMMARY

WATER USED	38169
RINSE MADE	21171
ICE CREAM MIX	28544

TOTAL RTST SUMMARY

RAW MILK USED	177033
WATER USED	67290
RINSE MADE	21171
SLURRY USED	0
CREAM PRODUCED	10627
CREAM USED	119
CHEESE SKIM	27143
STARTER	0
YOGURT 1%	265
YOGURT 3.24%	928
CHEESE DRESSING 9%	1954
VEG FAT SOUR CREAM 10%	0
SOUR CREAM 18%	0
DRINKS	0
WEIGHT WATCHERS	0
BUTTERMILK 1%	4223
CHOCOLATE MILK 1%	5525
CHOCOLATE DRINK (H2O & VEG FAT)	0
EGG NOG 2%	0
EGG NOG 6%	0
HALF & HALF 10.5%	1078
WHIPPING CREAM 35%	329
SKIM MILK 0.75%	10245
LOW FAT 0.55%	6100
MILK 2.00%	37865
MILK 3.25%	85722

ICE CREAM MIX	2534
TO BLEND VAT	0
TOTAL MILK RECEIVED	**********
MILK RECOVERED FROM FILLER	2534.40

MANAGEMENT CONTROL GOALS:

The following goals were set for reduction of water utilization and BOD (ingredients) through the implementation of a manager control program.

Water utilization:

Current water use at Indianapolis at the end of the base period was approximately 400 gallons per 100 pounds of BOD processed. The best combination plant in the country utilizes 100 gallons of water per 100 pounds of BOD processed. The target for the Kroger Dairy in Indianapolis was to reduce the water usage to 200 gallons per 100 pounds of BOD processed for a projected savings of $65,000 per year.

BOD Target:

The BOD discharge per 100 pounds of BOD processed was 6.2 pounds. The best combination plant in the country operates at 1.5 pounds of BOD per 100 pounds of BOD processed. The target at Kroger Indianapolis plant was to reduce the BOD to 3.5 pounds of BOD per 100 pounds of BOD processed. This target included the discharge of whey. The minimum estimated savings would have been $250,000 per year.

STAGE 1

Stage 1 management control was directed by the plant manager without any assistance from The Ohio State University project personnel. After presenting the material in terms of waste loads and economic impact and potential savings to the manager, the manager was then left in charge of development of the control program. In this stage, there was no specific assignment of any individual personnel and the manager really indicated an increased awareness of need and passed on through channels the need for water and waste reduction.

There was no statistically significant decrease in either water utilization, BOD/COD discharge or suspended solids discharge over the three-month period. The mean water, BOD and suspended solids values for the months of October, November and December were as follows:

MONTH	Wastewater gallons/day	BOD POUNDS /DAY
October	621,000	11,375
November	625,000	11,100
December	610,000	12,225

The computer daily readout was not utilized by the personnel. One of their major objectives was to use this as a production review procedure but because of air incorporation in processing to varying degrees, the quantities indicated on the computer review were not accurate. The information that could be gleaned from this was not used, but it should be indicated that no interpretations were provided.

There were several lessons learned in this stage of investigation, none of which was unexpected. These were:

1. A control program is not easy to install in a operating dairy plant. It must meet a specific production schedule.

2. Without specific responsibilities assigned, essentially no control will be achieved.

3. Raw data generated either by an inplant monitoring computer or from waste analysis data have very little meaning at any level of management.

4. Interest alone on the part of plant management and personnel is insufficient to achieve a control program.

STAGE II

There was a change in management at the Kroger dairy in January of 1978, just proceeding the initiation of Stage II of the management control program. This necessitated bringing the new manager up to date on previous studies and the results of the Stage I control program. Following this, a new management control program was initiated, which built on the previous experiences.

Program Development:

The program was designed to cover a six month period of time. In January, a committee was formed which consisted of Mr. John Morrison (Plant Manager), Mr. Norman Clark (Production Superintendent), Mrs. Art Rush (Chief Engineer), Mr. Joseph Salimbene (Quality Control Manager) and W. James Harper from the CSU project staff to discuss prior findings and to plan an overall program.

The philosophy and general procedures used in the Stage II program are detailed in a separate document "Waste Management Control Handbook for the Dairy Industry" prepared under this grant. This document is available from EPA.

The management program involved a combination of an educational program, waste control supervision and implementation of improved procedures and evaluation.

Educational Program; The education program was conducted by W. J. Harper of The Ohio State University project group following the general format and subject matter presented in the management control handbook.

Initially all management personnel, which included about 25 people, were introduced to the significance of wastes at the dairy and given an overview of waste control procedures. Follow-up meetings were held with management personnel to provide more background in respect to all aspects of dairy food plant wastes and waste control. This included half day meetings on details of plant equipment operations and maintenance procedures.

Meetings were held at shift changes with all employees emphasizing the environmental impact of dairy food plant wastes and outlining general control procedures. A follow-up general meeting was held to indicate specific procedures. In addition, meetings were held with interested employees in all departments over a several month period of time to discuss specific needs for operators in different departments of the plant. About 10 percent of the plant operators developed a strong interest in the program and presented valuable suggestions for waste control prodedures.

Program Supervision: At the beginning of the program, two Waste Control Co-supervisors were named to head up the control program that was given the name "RESOURCE CONTROL PROGRAM". They were: Mr. Joe Salimbene, Quality Control Manager who worked the first shift and Mr. Eric Perkins, second shift Ice Cream Foreman.

A committee was made up of the Co-supervisors, Production Superintendent, Chief Engineer and Plant Manager to hear reports on progress, make suggestions for improvement and facilitate implementation.

In addition, W. J. Harper provided back-up and direct assistance through weekly visits to the plant over a four month period of time between mid February and mid June. These visits permitted observations to be made of progress, reinforce educational programs and make studies of needed changes in the program. Special studies were made to define problem areas and to improve the control program. A detailed report was made to the plant manager of each plant visit to keep the manager fully informed of progress and areas in need of attention.

Evaluation of Needs for Control Program

Observations made by the supervisory staff in the very early phases of the program indicated the following needs:

a. Additional definition of preventable waste loads

b. Study of causes for preventable wastes

c. Investigation of whether production loss or sewer analysis reports were correct

d. Development of a system of loss reporting

e. Development of proper records and forms to facilitate control

f. Conversion of raw data from the waste analyses and the in-plant computer to make the results more meaningful to management

g. More complete implementation of the preventative maintenance program that was on the books, but not actually in practice and to modify the program to include maintenance that specifically related to waste problems.

h. Determination of methods to motivate middle-management to take a more active interest in the control program.

i. The fostering of communication between operators and management

j. Increasing the rate of response from management to problems associated with waste and well known to plant workers

k. Development of an ongoing and continuing educational program for operators in the use and maintenance of equipment

Evaluation of Preventable Waste Load: Further study was made to determine on a product basis the percentage of preventable waste predominately from the point of view of product losses with some attention to water.

Based upon the low cost for municipal treatment of whey, a decision was made to continue to discharge whey to the municipal treatment system. Other studies were in progress to provide a long term soution to this problem.

Excluding whey, the preventable wastes load from the cottage cheese operation ranged from 35 to 85 percent with an average of 60 percent. In the ice cream department operation, from 50 to 80 percent of the waste going out the #1 drain from the ice cream processing, freezing and packaging floor drains was assessed to be preventable. The average was 71 percent. For the novelty operation, with machines in their current condition, it was determined that 75 percent of current losses could be prevented. Essentially, 85 percent of all wastes going through the floor drains in the milk receiving, processing, packaging and

storage area was ascertained to be preventable.

The preventable BOD/COD coefficients, were 3.0, 5.2, 1.7 and 1.0 for the preventable wastes in cottage cheese, novelties, ice cream and fluid milk products. In addition, there was indication that a further reduction of 0.3 pounds of BOD per 100 pounds of BOD processed could be saved in the milk operation provided that the rinse system was used.

Major preventable water losses included:

1. Unnecessary discharge of water to the drain during cleaning of HTST units. On the average up to 40,000 gallons of water per day could be saved in this manner

2. Not leaving hoses running unattended would reduce the water usage by approximately 5,000 gallons per day.

3. Reduction of flow rates could reduce the water use from the novelty machines to one-third of current level without impairing operations.

Production versus Drain Losses: Because of continued concern on the part of management as to the reasons that losses measured in the wastewater were higher than those based upon production records, several detailed studies were made to

investigate this further. The ice cream department was used as the basis for study, since total pounds of preventable losses were estimated to be highest in this area.

Complete reconciliation of the differences was not possible. There were a number of factors influencing this difference:, which included production reports not actually reflecting the amount of specific product produced; the utilization of standard values, rather than actual values of package weights and composition; counters on packaging machines that counted packages, but did not exclude those packages lost after counting; and unreported losses. An example is presented for unreported losses for one day when production figures showed a 0.7% gain and wastewater analysis showed a 4.2% loss. For this particular day there was a series of unrecorded losses as follows:

1. 50 gallons of cream were lost when a line was not attached to the cream receiving vat and cream was pumped directly onto the floor.

2. Approximately 25 gallons of ice cream went to the drain as a result of package failure on the half-gallon ice cream packaging machine.

3. Because of production overscheduling of sherbet, which can not be rerun, 100 gallons of sherbet mix was diverted to the drain.

4. The loss of sticking in the novelty operations was 46,000 by count, which equaled about 46,000 ounces of novelties discharged to the drain.

5. Approximately 35 gallons of ice cream was left in the flavor vats and was rinsed to drain prior to the CIP operaton.

The total BOD loss for the above was 1,039 pounds.

In additon there was a difference of 0.3% between the standard weights and the actual mean package weights in the ice cream department. Calculations made it possible to account for approximately 73% of the discrepancy between the production gain and the wastewater loss. Studies on other days showed that 55-82% of the discrepancy could be accounted for by following details of production and using actual rather than standard values and by accounting for unreported losses.

These results confirmed previous observations that wastewater analysis was more predictive of true plant losses than production record.

The study also indicated the need to develop better record keeping procedures, to utilize actual package weights , to

use actual values of products processed and to record packages that are lost after filling.

A portion of the problem could be attributed to a lack of sensitivity on the part of both supervisory managment and operating personnel to events that had become common place in the operation of the plant and were accepted as normal practices. Failure to report all losses of any consequence contributed to the lack of knowledge by management of what losses were. This was especially true during the second and third shift, when all senior management was off duty. Evaluation of CCD coefficients for these two shifts showed much higher losses that for the first day shift.

Major losses could be attributed to three main causes:

(a) Errors in judgment, such as not hooking up filling lines.

(b) Equipment that was not operating properly, frequently related to needed maintenance.

(c) Problems in production scheduling that resulted in spoiled product, dumped product or inability to operate plant as designed and leading to significant losses.

Loss Reporting: Unreported losses were considered to be a significant problem. A form was developed that was made available to all foremen for reporting losses. Initially, this was labeled as a "SPILL REPORT". A week after initiation there had been no reports filed, even though there were observed major losses due to overflow, package failure, etc. Discussion revealed that nobody wanted to fill out an account of a spill. Therefore the form name was changed to "LOSS REPORT" (See Appendix B). During the following week a number of loss reports were filed. Loss reports were routed to the General Foreman, Production Superintendent, Accountant and Laboratory.

Records: A large number of different record forms were developed and tried. All forms developed are presented in the Management Handbook. Many were not used routinely. Those record forms which were useful in this particular plant are included in Appendix B. These included forms for:

1. Loss Report
2. Maintenance Request
3. Plant Resource Control Inspection Form
4. Computer Summary
5. Non-dairy Ingredient Use Report
6. Milk Ingredient Use and Loss Report
7. Ice Cream Ingredient Use Report
8. Cottage Cheese Ingredient Use Report

9. CCD Loss Report

10. Waste Summary Report

11. Waste Cost Analysis Report

Calculations: During initial stages, it became immediately apparent that the plant personnel did not make the same interpretion that the CSU project personnel made from the same computer and wastewater data. This emphasized the value of having personnel experienced in wastewater control and also showed the need for developing calculations that would transform the raw data into a form that management could easily understand and take action on. Example calculations are presented in Appendix C.

The data that could be generated in one day required from two to three hours of hand calculation to convert it into a form that was usable by management. In the latter stages of the project, a microcomputer was used to develop simple programs that performed these same calculations in from 10 to 20 minutes.

Preventive Maintenance Program: Detailed study indicated that the maintenance program as established was not being strictly followed because of the amount of emergency maintenance work that needed to be done. In addition, there were a number of maintenance areas that were not included in the standard preventive maintenance program that

were a cause of substantial preventable wastes. These were identified as:

1. Weekly checking of all high and low level settings on storage tanks.

2. Daily checking of settings and controls of CIP separators

3. Weekly evaluation of automated air blow systems.

4. Daily inspection of pump seals for wear.

5. Bimonthly evaluation of setting of CIP separator "shoot".

6. Monthly check on setting and timing of HTST recovery system.

7. Regular inspection and replacement of worn parts on CIP fittings and air actuated valves. Rotating inspection of some units each week to provide one complete servicing every three months.

8. Replacement on a regular continuing basis of worn parts on packaging machines, with special attention to the gallon plastic milk filler.

Communications: Recognizing a need for communications, a special effort was made to make sure that plant operators had an opportunity to present their views on the control program and that management was responsive to suggestions and that prompt action was taken on perceived needs. Where action was not

possible because of justifiable delays, this information needed to be passed on to operators. Active interest on the part of all managment personnel in the program was recognized as essential to the success of the program.

Loss Acounting:

Based on a determination that wastewater analysis provided the best means of loss accounting, the following procedure was developed:

1. Determine COD for all ingredients used in the department or the total plant, depending on the type of report desired.

2. Make a daily accounting of all ingredients used.

3. Determine COD produced for the day.

   a. Calculate the COD for each ingredient based on prior analysis of COD for each ingredient

      example: 1000 pounds of cream x 0.55 lbs COD/pound of cream= 550 pounds of COD in the cream.

   b. Sum the pounds of COD to get the total.

   c. Measure the COD in the waste water and covert to pounds of COD.

   d. Calculate loss in terms of (COD out/COD used) X 100 =%loss

   e. Compare the loss value to the design value to determine the preventable waste level. Determine the significance of loss: % loss measured-% design loss = % preventable

f. Convert to $ loss:

pounds COD used x% loss X$value/pound

COD = $ loss.

An example of an analysis of ingredients of materials used in ice cream in terms of pounds COD/pound of material and calculated $ values/pound of COD is presented in Table 31. Table 32 presents a summary for the ice cream department in terms of pounds of COD processed, compared to measured effluent loss, and pounds reported loss of mix and butterfat. Percentage COD loss and reported butterfat loss are compared. The data are for the last two weeks of April and the last two weeks of May. For the period represented, the average daily ingredient loss at a COD value of $0.41 per pound was $1435, for an annual equivalent of $373,100 of lost ingredients. It should be noted that this was about one-half of that of the base period.

Further cost accounting was to identify all contributing factors to preventable wastes and to assign $ values to these. Figure 15 diagrams the contributions to preventable wastes. A computer model was used to determine the contribution of each of these areas of loss in the plant and to determine the cost of each contributing factor and the percentage contribution of each.

Weekly summary sheets were made to indicate total COD processed, total water and COD coefficients and the value of

Table 31. COD Cost Accounting for Ice Cream Department

INGREDIENT	lbs COD/lb Material	lb COD	$/lb COD
Cream (42%)	1.10	28,242	0.48
Milk (35%)	0.173	7,113	0.52
Whey Powder	0.88	4,135	0.15
Sugar (7%)	0.56	42,538	0.21
Chocolate Solids	1.32	4,606	1.82
Stabilizer Slurry	0.58	420	1.22
Egg Yolk Solids	1.0	100	0.55
TOTAL		87,154	
Average Cost			0.41

Pounds COD discharged = 3,500

% loss = $\frac{3,500}{87,154} \times 100$ = 4.02

Daily loss = 3,500 x 0.41 = $1,435

Yearly loss = $1,435 X 260 = $373,100

Table 32. Summary of Chemical Oxygen Demand Entering the Ice Cream and Frozen Novelty Drain Catchment Area, the Losses of Chemical Oxygen Demand and the Percentages of COD Lost in the Effluent.

Input COD lb	Effluent Loss COD (lb)	Chemical Oxygen Demand: Reported Loss: Butterfat	Chemical Oxygen Demand: Reported Loss: MIX	% Loss	% Report B of Loss
92,050	3,000	+226	3,077	3.26	1.05
10[illegible],305	3,000	+574	+312	2.96	4.0
94,185	3,385	-154	-423	3.59	0.9
91,430	2,713	+1561	-423	2.97	+13
101,550	4,290	+53	+797	4.21	+0.7
108,055	3,260	-132	-340	3 02	0.9
94,348	4,635	-477	-771	4.91	2.3
108,850	4,490	+1027(+6.9)	+102	4.12	+6.5
98,055	5.445	12.8(7.45)	-2002	5.55	7.6
112,680	3,580	555(3.17)	-2039	3.18	3.17
110,324	4,600	+273	-1211	4.17	+7.1
88,042	5,460	193(4.4)	764(4 1)	6.20	2.25
106,300	2,962	-89	7510	2.79	.72
91,456	1,381	-85	+730	1.51	.91
128,694	1,969	72	208	1.53	1.2
101.400	3,910			3.86	+-/-7

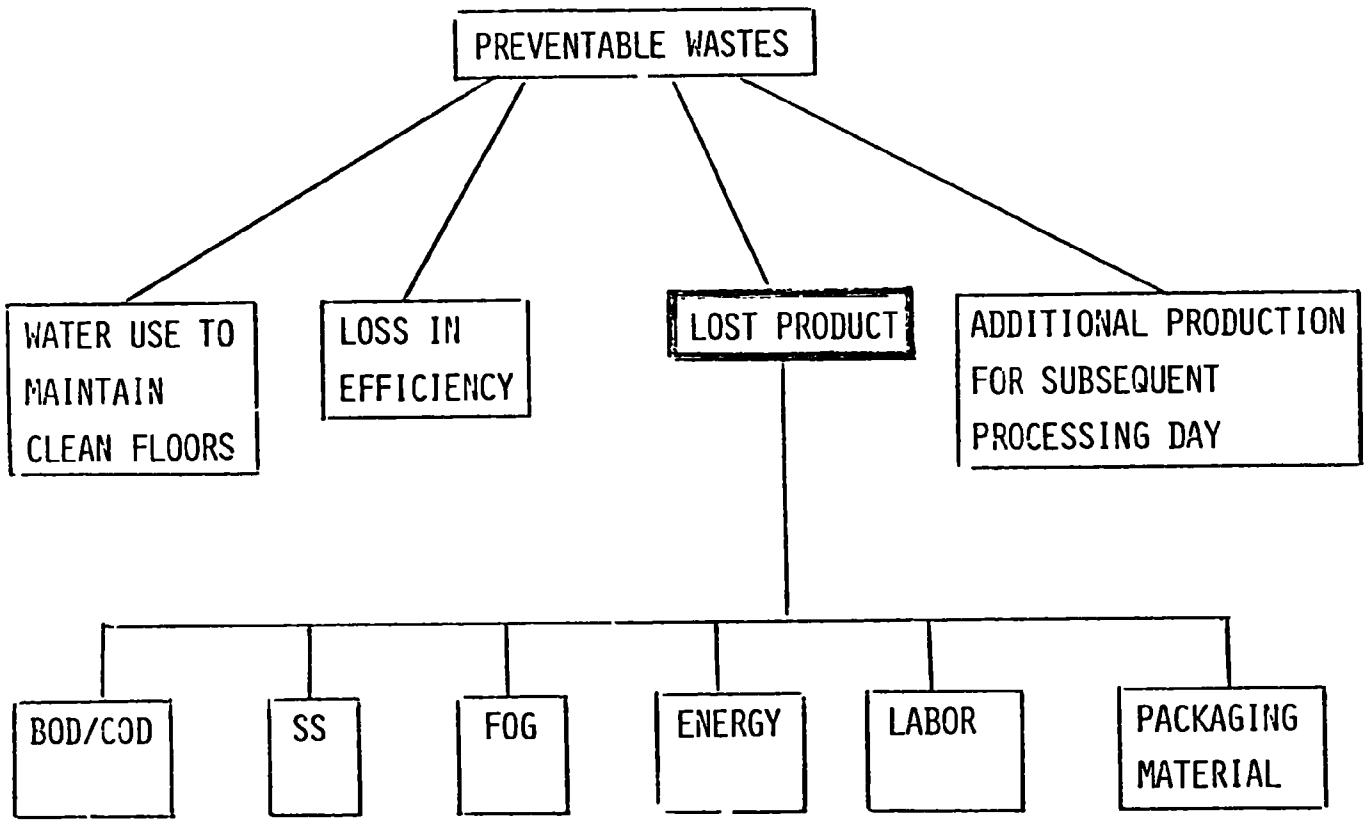


Figure 15. Contributions to Preventable Wastes.

sewer charge in milk equivalents. (The necessary calculations are shown in the Appendix). A typical report is shown in Table 33.

Interpretation of In-Plant Computer Output:

The computer provided valuable information on a daily basis, primarily in respect to water and wastewater relationships. Because of previously mentioned air problems, production figures were not reliable. The air problem would require constant attention and resetting of pressure differences on the separator by the operating personnel. The settings had to be done by hand and was generally considered to be too difficult. Other responsibilities precluded the operator having time to give this area the close attention required.

Whereas Ohio State Project personnel could glance at the computer reports and obtain instantaneous interpretive information, this was not generally done by the plant personnel. A number of calculations had to be done to convert the raw data into a form of value to plant management. Investigation was made of incorporating the mathematical conversion into the computer program. Because of dependence on outside computer programmers, the cost was prohibitive. Consequently this was not done.

Computer interpretation provided a means of estimating the following:

Table 33. Weekly Summary - Kroger, Indianapolis

	BOD PROCESSED in 100's lb	Gallons/ 100 lb BOD	lb BOD	lb BOD/ 100 lb BOD
4/24 Monday	1,622	284	8,591	5.3
4/25 Tuesday	1,457	323	8,616	5.9
4/26 Wednesday	1,875	337	9,922	5.3
4/27 Thursday	1,848	260	8,055	4.4
4/28 Friday-4/29 Saturday	2,448	220	10,050	4.1
Weekly Average		285	9,046	5.0
Base Data		400		6.2
%Improvement		29		19

	Daily	Period	Year
Sewer Bill	$538	$10,760	$139,880
$Value Product Loss ($ value o BOD = 0.30)	$2,713	$54,260	$705,380

1. Determination of proper operation of the wastewater flow monitors.

2. Determination of whether or not the rinse recovery system on the HTST units was being used.

3. The efficiency of water use in the HTST systems.

4. The efficiency of the CIP sytems.

5. Problems associated with filling operations, revealed by the amount of milk diverted to the rinse tank from the milk filling area.

6. Determination of coefficients for water use and wastewater discharge from the different departments.

7. Estimation from the ice cream pasteurizer, where rinse was recorded and not saved, of the losses in start-up and shut-down operations.

A typical computer summary and HTST performance report are presented in Figures 16 and 17 respectively.

Alterations in the computer system would make this a more meaningful management control tool. These would include:

1. Elimination of milk production input data.
2. Addition of water meter inputs from:
    a. cooling tower
    b. soft water supplies to compressors and

Figure 16. RESOURCES CONTROL PROGRAM

COMPUTER SUMMARY

TOTAL GALLONS OF WATER SUPPLIED	505,500		
TOTAL GALLONS OF WASTE WATER DISCHARGED	475,470	$ 212,000	
GALLONS WATER DISCHARGE FROM ICE CREAM	180,000	% OF TOTAL DISCHARGED	37.9
TOTAL GALLONS WATER CONSUMED IN PLANT CORRECTED FOR WHEY	30,000		
WATER USED FOR CIP (GALLONS)	25,511	% OF TOTAL DISCHARGED	5.4
HTST WATER USED - ALL UNITS	107,541	% OF TOTAL DISCHARGED	22.6
HTST WATER USED - MILK	52,969	% OF TOTAL DISCHARGED	11.1
HTST WATER USED - ICE CREAM	54,575	% OF TOTAL DISCHARGED	11.5
GALLONS WASTE WATER X 100 lb BOD INTO ICE CREAM	693		
RINSES MADE	7,416		
RINSES SAVED	3,000		
RINSES DISCHARGED TO DRAIN	4,416		
MILK RECOVERED FROM FILLER	562		
TOTAL MILK PROCESSED (POUNDS)	1,690,192		
GALLONS OF WASTEWATER (1000) / MILK PROCESSED	281		

Figure 17. RESOURCES CONTROL PROGRAM

HTST PERFORMANCE REPORT

Date: 4/10/78

HTST #1: Volume of water discharged to drain (gal):

	Volume	Time to Drain	Vol Rinse Made
12:00 am - 6.00 am	5,690	5.7 min	0
6:00 am - 6:00 am	0	0	0
6:00 pm - 12:00 am			
Total for Day	5,690	5.7 min	0

Volume of Rinses Made: 0
No. of Start-ups & Shut-downs: 2

HTST #2: Volume of water discharged to drain (gal):

12:00 am - 6:00 am	9,724	1.62 hr	0
6:00 am - 6:00 pm	10,205	1.7 hr	0
6:00 pm - 12:00 am	34,646	9.1 hr	1148
Total for Day	54,575	12.4 hr	1148

Volume of Rinses Made: 0
No. of Start-ups & Shut-downs: 5

HTST #3: Volume of water discharged to drain (gal):

12:00 am - 6:00 am	712	7 min	0
6:00 am - 6:00 pm	2,895	29 min	0
6:00 pm - 12:00 am			100
Total for Day	3,607	36 min	100

Volume of Rinses Made: 0
No. of Start-ups & Shut-downs: 3

HTST #4:
Volume of water discharged to drain (gal):

12.00 am - 6:00 am	24,960	4.16 hr	635
6:00 am - 6:00 pm	2,534	25 min	107
6:00 pm -12:00 am	8,627	1.4 hr	5376
Total for Day	36,121	5.9[illegible] hr	6118

No. of Start-ups & Shut-downs 4

Total gallons to drain: 107,355 ([illegible]1.41)

Total needed. 20,000 20,000

Cost $74.41/day $1,488/period $19,346/year

boiler feed

c. case washer

d. CIP separators

e. the 4 vitafreeze novelty machines

3. Addition of inputs from fillers currently being recorded on a recording chart.
4. Addition of inputs from package counters on vitafreeze units
5. Incorporation of software to provide for input of analytical data and compilation of a complete managment report in terms of $ value of losses.

Because of advances in micro and minicomputers, it may be more economical to replace the current unit with a system that the plant personnel can program. Simple programs in basic were developed to do this with the data from the computer and by the addition of COD data from wastewater analysis and input of ingredient usaje, a complete waste report was generated. (See Appendix D)

Determination of Major Areas of Losses and Causes*

Table 34 shows for each department the major processes contributing to either water or COD (BOD) loss the estimated amount of the loss and the causes of this loss. This information resulted in management action and was also utilized in

Table 34. Processes Contributing to Major Losses in Kroger Dairy

Process	Daily Amount	Cause
Water Related Losses (gallons):		
HTST Cleaning	29,000	No controls on time to drain
HTST Hot Waster	24,000	Condensate discharged to drain
HTST Start-up	2,000	Production scheduling problem
CIP Separators	36,000	Hand controls on separator water lines.
Milk Case Washer	88,000	Hand control of water lines
Vita-freeze	70,000	Hand controls on water lines
Product Loss Related Areas (BOD Loss - lb):		
Milk Receiving	320	Cleaning of tank trucks
HTST #3	80	Leaks
Milk Processing Lines	80	Improper operation of air blow
Cream Pasteurizer	58	Improper setting of pump speed
CIP Separators	30	Improper setting of pressures
Remy plastic gallon filler	164	Poor operating condition and leaks
Vita-freeze	540	Machines need overhaul, stick feeding faults, missing clips, improper defrosting temperature, packaging machine jamming
Flavor Vats	200	Product left in processing vats, cannot be fully drained
Ice Cream Clean-up	200	Product left in lines and freezer
Fines	80	Curd break-up in cooling and washing steps
C C skim storage tanks	20	Leaks

determination of possible process and equipment changes to reduce losses in the last phase of the study.

Management Changes During Study:

In response to the finding of the investigation, a number of changes were made during the waste management control phase to improve management control.

These were:

1. Creation of a new position of General Foreman of the Second Shift to provide more management supervision during what was indentified as a high loss period of time.

2. Relocation of several foremen to improve management efficiency.

3. Creation of a new position of Operations Coordinator of stick novelties operations, by appointing an experienced novelties operator to this position to oversee all four machines and to assist training of operators on a continuing basis. (This was the area of highest loss in the plant and also where the greatest labor turnover occurred.)

Progress of Management Control Program:

Figures 18 through 25 show the changes in coefficients for water and BOD for the total plant, ice cream operations, stick novelty operations, fluid milk products and BOD coefficients for total plant less whey BOD.

Over the period shown, there was a marked decrease in both the volume of wastewater discharged and the BOD discharged per 100 pounds of milk equivalent. Overall the lowest level achieved was for the month of May. For ice cream, the lowest level of coefficients was achieved in the first part of June. In most cases the goals established were met. The greatest reduction was achieved in the stick novelty area, where the greatest emphasis was placed.

When A. J. Harper stopped making weekly visits, the losses in the plant increased. However, they never went back to the same level as for the base comparison period. The results were not to be unexpected, since the OSU personnel was actually serving in the capacity of a Waste Control Supervisor. Of interest was the fact that during April and May, the days that he was present, the plant showed a significantly lower loss than the mean values. This amounted to a coefficient reduction of about 50 gallons for water and 0.5 pounds for BOD per 100 pounds of BOD processed.

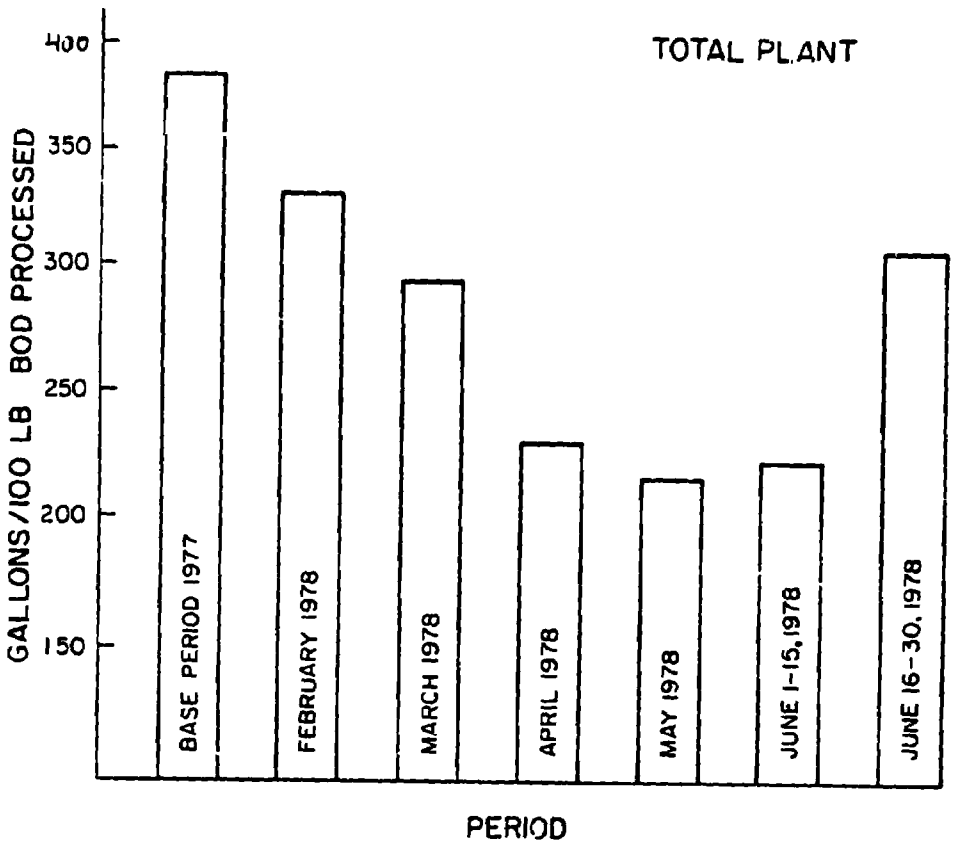


Figure 18. Effect of Management Control Program on Wastewater Volume Coefficient for Total Plant.

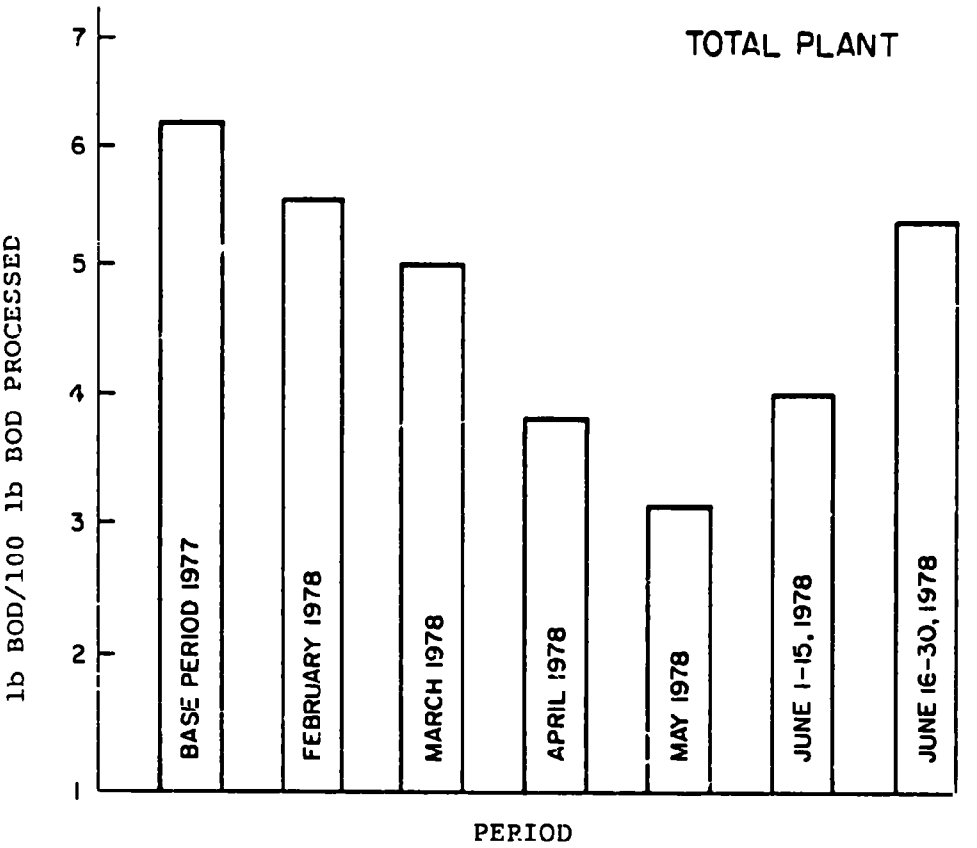


Figure 19. Effect of Management Control Program on BOD Coefficient for Total Plant.

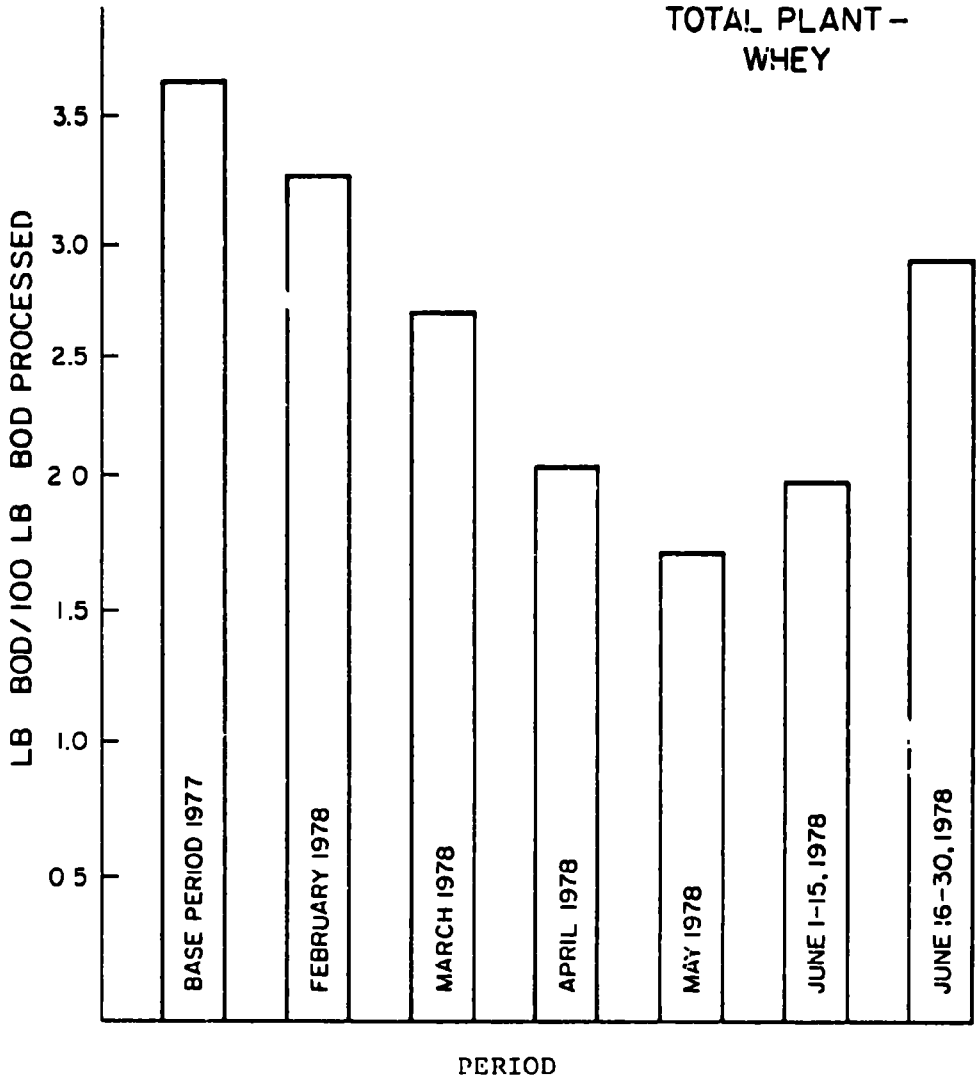


Figure 20. Effect of Management Control on BOD Coefficient for Total Plant Less Whey.

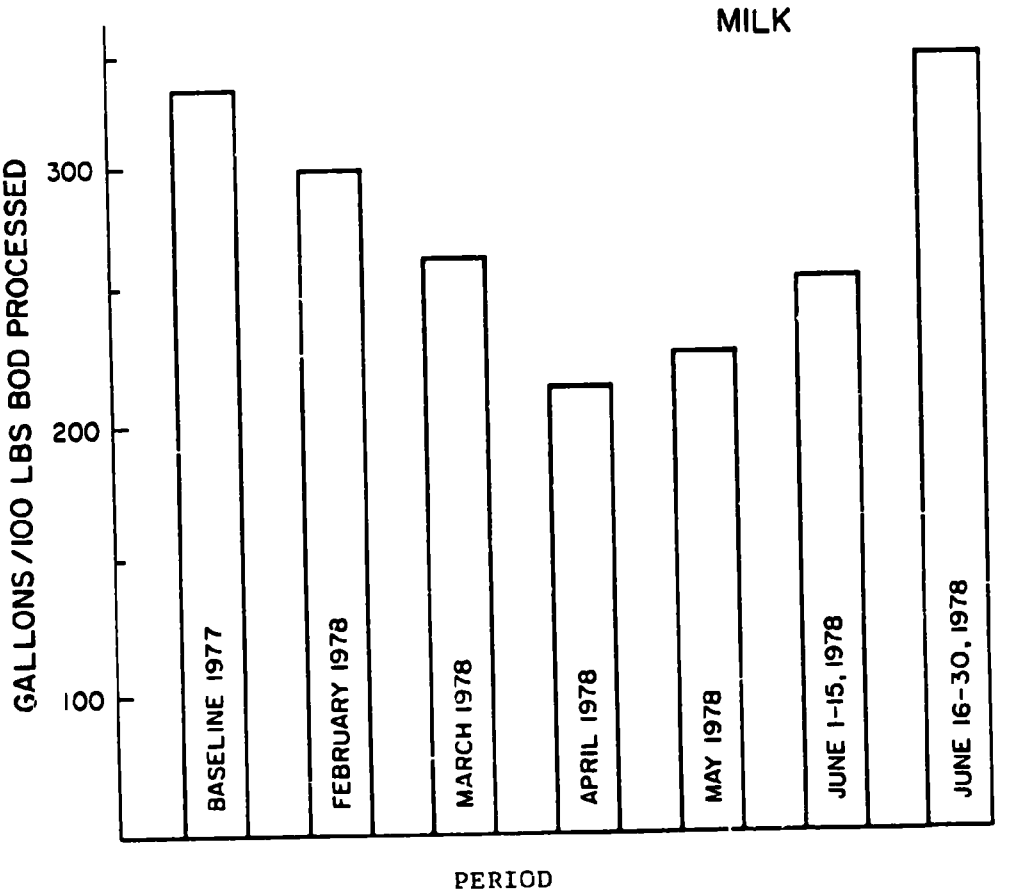


Figure 21. Effect of Management Control Program on Wastewater Volume Coefficient for Milk Department.

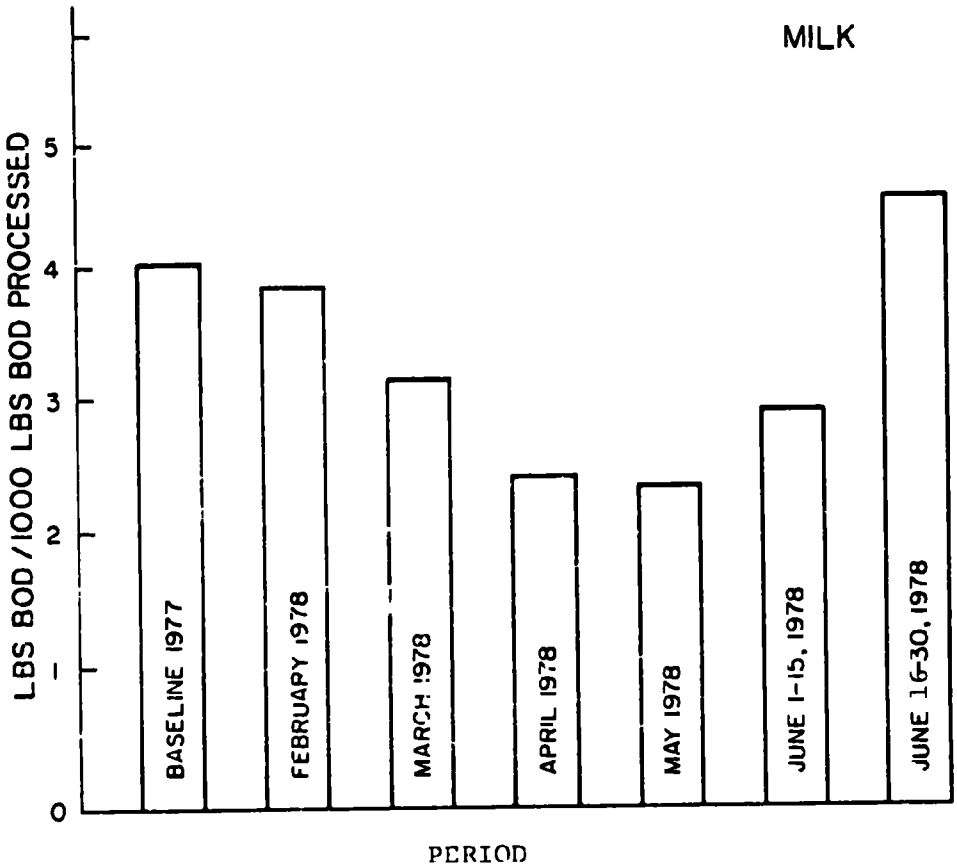


Figure 22. Effect of Management Control Program on BOD Coefficient for Milk Department.

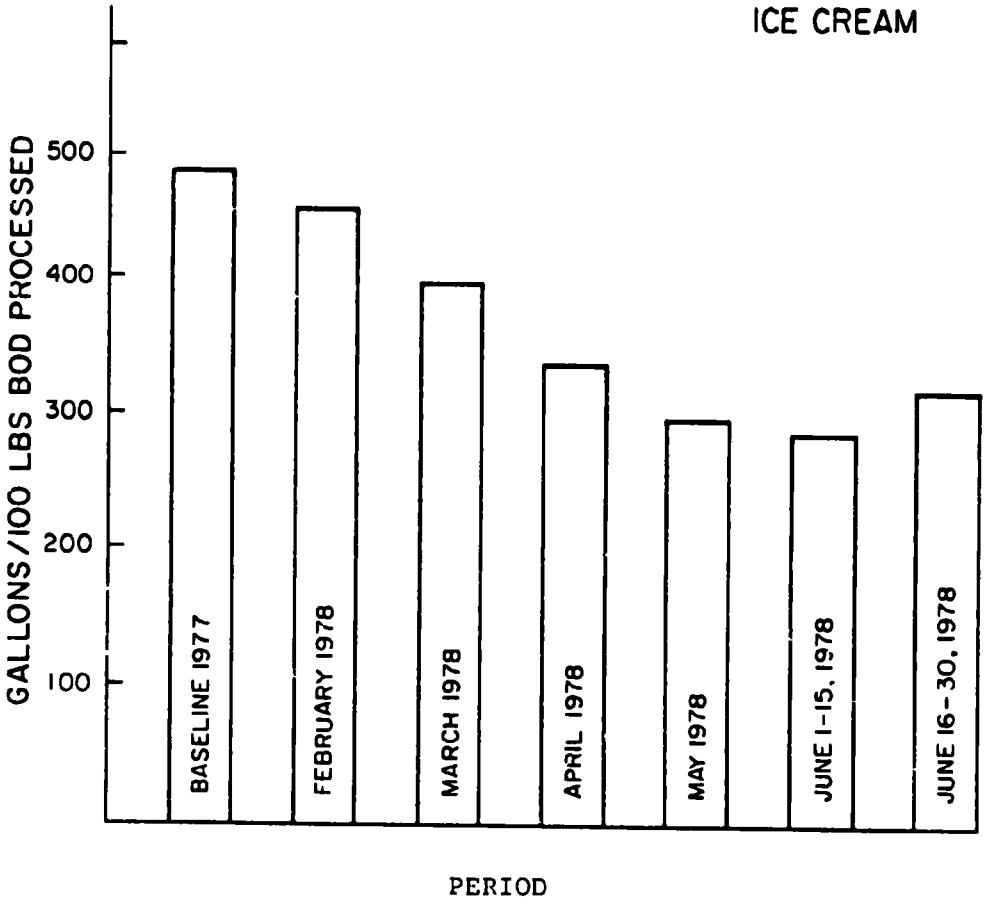


Figure 23. Effect of Management Control Program on Wastewater Volume Coefficient for Ice Cream Operations.

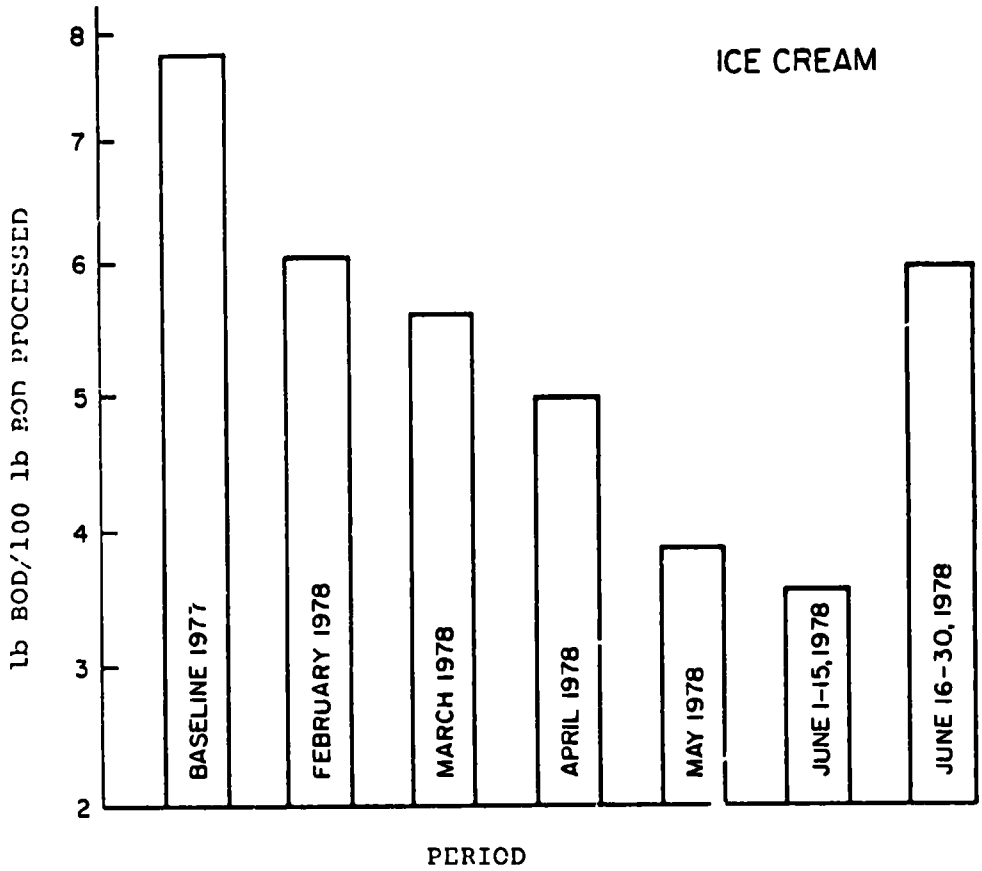


Figure 24. Effect of Management Control Program on BOD Coefficient for Ice Cream Operations.

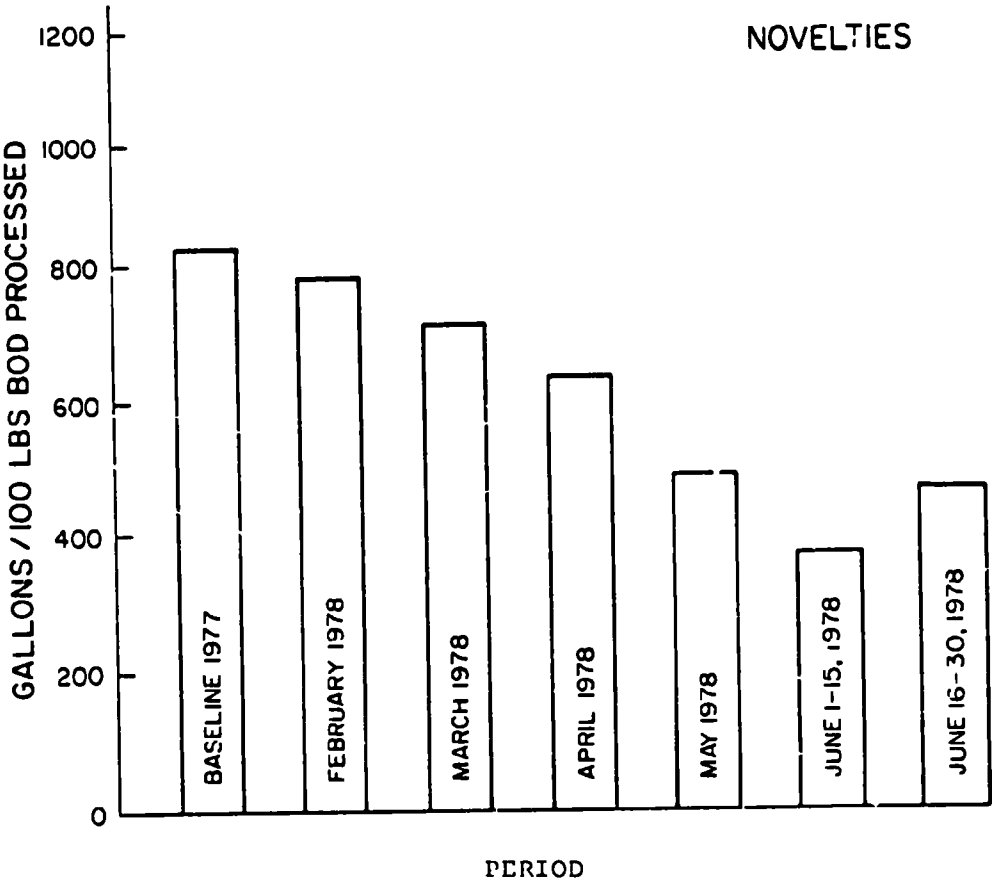


Figure 25. Effect of Management Control Program on Wastewater Volume Coefficient for Novelty Operations.

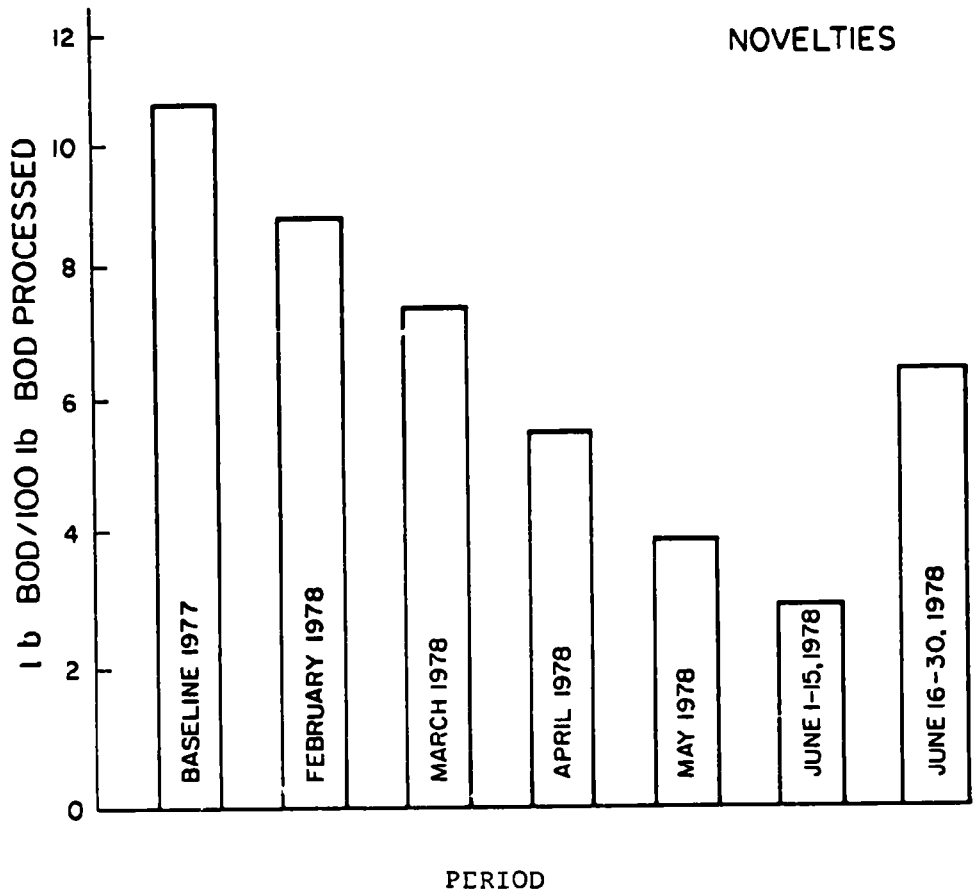


Figure 26. Effect of Management Control Program on BOD Coefficient for Novelty Operations.

The results led to the conclusion that waste reduction of about 50% in both water and product losses could be achieved, but that constant attention was required. The job was more time demanding than recognized and could not be achieved by making the responsibility an additional one to existing personnel, regardless of the interest such individuals obviously had toward the project.

STAGE III:

Based on the findings during the second stage management control program, an individual was hired as Resource Control Manager. The only responsibility of this individual was to devote attention to the control of water losses, ingredient losses and energy losses. He reported directly to the manager and was independent of all current departments. He operated on a flexible schedule, giving attention to all three shifts.

The success of this approach can not be fully assessed at this time, since insufficient time has elapsed since the hiring of the individual to fully assess the impact. Initial indications are that the degree of control will surpass that achieved in Stage II.

SECTION 10

PROCESS AND EQUIPMENT CHANGES TO REDUCE WASTE LOADS

The purpose of this section is to describe the investigation of process and/or equipment changes that could result in material savings in water and product losses. Some of these changes would eliminate operator discretion through the installation of controls and thus reduce preventable waste loads; whereas others would reduce unavoidable waste loads by altering the design coefficient.

The Kroger dairy had a number of waste saving features in operation at the time this study was initiated. These included:

1. Cooling tower with evaporative condensor and a recyle system.

2. Solenoids on air compressors and refrigeration compressors with recycle of water to cooling tower supply tank.

Product Loss Related:

1. Rinse recovery system for start-up and shut-down of the three milk HTST units.

2. Recovery system for damaged milk containers.

3. Ice re-run system.

The modifications included for consideration in this study were both those that were water related and those that were product loss related. Each potential modification was considered in relation to the following:

(a) Determination of the technical feasibility of the change.

(b) Significance of the changes in reducing water and/or product losses.

(c) Estimation of costs of making the change and determination of cost/benefit of the change.

DETERMINATION OF POSSIBLE CHANGES

Two approaches were used initially to assess possible unit processes for study: (a) delineation of coefficients for unit

operations under design and actual conditions and (b) utilization of these coefficients to model waste loads and interpret these in terms of costs. The computer model described in Appendix D was used for this purpose and also to assess the change in waste loads and costs that could be expected from any proposed waste savings change.

Coefficients for Design and Actual Operations

To utilize the model, it was necessary to have coefficents for incorporation into the model. For this purpose, the coefficients were given in units of gallons of water or pounds of waste characteristics per 1000 pounds of product processed, because of difficulty of generating consecutive processes with either BOD or COD processed. A second basic computer program was utilized to generate coeff cients in common units (100 pounds BOD or COD).

The coefficients utilized for the LP modeling for design purpose (unavoidable loss related to process and equipment design) for milk, ice cream, stick novelties and cottage cheese are in Tables 35, 36, 37 and 38. The coefficients for the actual plant situation before any changes were made are in Tables 39, 40, 41 and 42.

Loss Associated Costs:

Table 35. Actual Coefficients for Fluid Milk Processing in Kroger, Indianapolis Plant*

Process	Code	Water Use (BUYWA)	Effluent (SANSEW)	BOD_5	Product Loss (milk loss)
		(gal/1000 lb)	(gal/1000 lb)	(lb/1000 lb)	(lb/1000 lb)
Receiving	RC	16	16	0.23	2.3
Separation	PR	17.5	17.5	0.75	7.5
Clarification	CL	17.5	17.5	0.075	0.75
Raw Storage	RS	15	15	0.44	4.4
HTST	HT	80	67	0.58	5.8
Pasteurized Storage	SP	15	15	0.25	2.5
Filling	FF	98	98	0.5	5.0
Conveying	CV	4	4	0.1	1.0
Storage	SF	10	2	0.1	1.0
Miscellaneous (Spills, overflows, etc.)	SP	12	12	0.3	3.0
TOTAL		285	264	3.32	33.2

*Units/1000 lb Milk Processed.

Table 35 - Design Coefficients for Fluid Milk Processing

Process	Code	Water Use (BUYWA)	Effluent (SANSEW)	BOD_5	Product Loss (milk loss)	Fat Loss
		(gal/1000 lb)	(gal/1000 lb)	(lb/1 00 lb)	(lb/1000 lb)	(lb/1000 lb)
Receiving	RC	16	16	0. 5	1.5	0.05
Separation	PR	2	2	0.025	0.25	0.008
Clarification	CL	2	2	0.025	0.25	0.01
Raw Storage	RS	20	20	0.15	1.5	0.05
HTST	HT	80	40	0.3	3.0	0.11
Pasteurized Storage	SP	20	20	0.15	1.5	0.005
Filling	FF	15	15	0.1	1.0	0.035
Conveying	CV	1	1	0.05	0.5	0.012
Storage	SF	10	2	0.05	0.5	0.012
Miscellaneous	--	10	10	--	--	--
TOTAL		176	128	1.0	10	0.29

Table 37 - Design Coefficients for Cottage Cheese Processing

Process	Code	Product	Water Use (BUYWA)	Effluent (SANSEW)	BOD_5	Product Loss (CC Loss)
			(gal/1000 lb)	(gal/1000 lb)	(lb/1000 lb)	(lb/1000 lb)
Skim Transfer	TCCSMUS	Skim	1.2	1.2	0.08	1.0
Cream Transfer	CCCMUS	Cream	15.	15.	0.30	4.0
HTST	CCHT	Skimmilk	16.	16.	0.22	3.0
Starter Preparation	CCST	Starter	10.	10.	0.30	4.0
Set, Cut & Cook	CCMF	Skimmilk	24.	24.	0.1	1.39
Drain	CCDR	Curd	10.	107.	27.6	10.
First Wash	CCW1	Curd	247.	117.	7.0	8
Second Wash	CCW2	Curd	247.	117.	3.0	6
Third Wash	CCW3	Curd	0.	0.	.0	0
Blending	CCBL	Curd	75.	75.	1.0	5.0
Filling	CCFF	Cottage Cheese	40.	40.	0.2	1.2
Storage	CCSF	Cottage Cheese	2.5	2.5	0.1	0.5
Distribution	CCSH	Cottage Cheese	5.0	5.0	0.1	0.5
Dressing Preparation	CCDS	Dressing	2.0	2.0	0.2	1.0

Whey not recovered, assume 0.1% fines loss.

Table 38 Actual Coefficients for Cottage Cheese Processing in Kroger, Indianapolis Plant.

Process	Code	Product	Water Use (Water or Potwater)	Effluent (Sewer TR)	BOD_5 (BOD)	Product Loss (Loss TRCC)
			(gal/1000 lb)	(gal/1000 lb)	(lb/1000 lb)	(lb/1000 lb)
Skim Transfer	TCCSMUS	Skim	3.0	3.0	0.2	2.7
Cream Transer	CCCMUS	Cream	(Not in Design) 15	15.	3.0	10
HTST	CCHT	Skimmilk	16	16.	0.22	(Loss TR FM) 3.0
Starter Preparation	CCST	Starter	10	10.	0.36	(Loss TR FM) 5.0
Set, Cut & Cook	CCMF	Skimmilk	24	24.	0.1	1.39
Drain	CCDR	Curd	(No H_2O in Design) 10	107	33.1	36
First Wash	CCW1	Curd	116	116.	8.7	16
Second Wash	CCW2	Curd	116	116.	4.1	8
Third Wash	CCW3	Curd	58	58.	0.6	2
Blending	CCBL	Curd	50	50.	1.5	3.6
Filling	CCFF	Cottage Cheese	40	40.	0.5	1.5
Storage	CCSF	Cottage Cheese	2.5	2.5	0.1	0.5
Distribution	CCSH	Cottage Cheese	5.0	5.0	0.1	0.5
Dressing Preparation	CCDS	Dressing	2.0	2.0	0.2	1.0

*Whey not recovered; assume 0.1% fines loss.

Table 39. Design Coefficients for Ice Cream Processing in the Kroger, Indianapolis Plant.*

Process	Code	Water Use	Wastewater	BOD_5	Product Loss
		Ice Cream Processed			
		(gal/1000 lb)	(gal/1000 lb)	(lb/1000 lb)	(lb/1000 lb)
Receiving	(RMRC)	16	16	.15	1.5
Storage	(RMST)	4.5	4.5	.15	1.5
Standardizing	(RMSP)	2	2	.025	.25
Blending	(CBL)	28	28	.25	2.64
HTST	(KCHT)	80	80	.75	7.9
Pasteurized Storage	(ICDP)	20	20	0.15	1.6
Flavoring, Fruit and Nuts	(INCIN)	10	10	0.02	1.5
Freezing	(ICAF)	30	30	0.35	4.0
Filling	(ICFF)	20	20	0.35	4.0
Conveying	(ICCV)	10	10	0.04	0.4
Hardening	(ICZZ)	--	--	0.04	0.4
Storage	(KCDF)	3	3	0.04	0.4
Distribution	(ICSH)	5	5	0.04	0.4
TOTALS		228.5	228.5	2.36	26.5

BOD H Factor = 2.64

BOD corrected to 100 lb BOD processed. Computer values for mix and ice cream are multiplied by 2.54.

Table 40 Actual Coefficients for Ice Cream Processing in the Kroger, Indianapolis Plant.*

Process	Code	Product	Water Use	Wastewater	BOD_5	Product Loss
			(gal/1000lb)	(gal/1000 lb)	(lb/1000 lb)	(lb/1000 lb)
Receiving	(RMRC)	Milk	16	16	0.19	1.95
Storage of Milk	(RMST)	Milk	4.5	4.5	0.27	2.75
Standardizing	(RMSP)	Milk	4.5	4.5	0.075	0.75
Blending	(ICBL)	IC Mix	75	75	0.25	1.0
HTST	(ICHT)	IC Mix	265	265	2.2	10.0
Pasteurized Storage	(ICSP)	IC Mix	40	40	1.0	4.0
Flavoring, Fruit and Nuts	(ICIN)	IC Mix	26	26	1.0	3.0
Freezing	(ICAF)	IC	180	180	1.25	5.0
Filling	(ICFF)	IC	132	132	1.9	7.5
Conveying	(ICCV)	IC	53	53	--	4.0
Hardening	(ICZZ)	IC	--	--	0.1	0.4
Storage	(ICSF)	IC	3	3	0.1	0.4
Distribution	(ICSH)	IC	5	5	0.1	0.4
TOTALS			804	804	8.44	41.2

BOD H factor = 2.54

*Data in gallons or pounds/1000 pounds of product produced.

Table 41. Design Coefficients for Stick Novelty Processing in the Kroger Indianapolis Dairy

Process	CODE	Water Use (gal)	Wastewater (gal)	BOD (lb)
		Units per 1000 Pounds of Product		
Blending	IPOPBL	0.07	-	1.0
Pasteurization	CPOPHT	80	80	1.3
Mix Storage	IPOPST	5	5	2
Freezing	IOPOVF	800	800	2
Packaging	IPOPBG	3	3	2
Store Frozen	IPOPSF	2	2	.5

Table 42. Actual Coefficient for Stick Novelty Processing at the Kroger Indianapolis Dairy*

PROCESS	CODE	Water Use (Gal)	Waste Water (Gal)	BOD_5(lb)
Blending	IPOPBL	0.07	--	1.6
Pasteurizing	IPOPHT	240	240	1.3
Storage	IUPOST	30	30	2.0
Freezing	IPOPVF	2400	2400	10
Packaging	IOPOBG	30	30	10
Frozen Storage	IPOPSF	5	5	1

* Per 100 lb of product.

The costs associated with losses under design and actual conditions are presented in Tables 43 to 50.

The major cost associated with losses was product loss, followed by the sewer bill, labor, packaging losses and energy. Energy was a minor overall cost, even though analysis reveals that overall about 50% of all product losses followed the pasteurization and cooling of the product. In the ice cream department, 75% of the product lost followed pasteurization cooling, storage and freezing.

Labor, which was more intensive for the ice cream and novelty operations was a greater percentage than for other areas in the plant.

A general rule of thumb was that the total plant loss was about 2 times the product loss and about 5 times the sewer bill. The latter would vary markedly from community to community depending on sewer charges. The surcharges in the Indianapolis market were lower than in most major cities.

Based on observations made during this investigation, and earlier recommendations in the literature of process and equipment modifications that could reduce wastes, all possibilities were listed for subsequent evaluation. Those

Table 43. Waste Associated Costs of Fluid Milk Operations Under Design Conditions

OPERATION	QUANTITY*	COST**	COST/DAY	PERCENT OF COST
RM Loss	1,800	$ .112	$ 201.60	9.4
Product Loss	14,400	.112	1612.80	75.6
Pkg Loss	14,400	.004	57.60	2.7
BOD Loss	1,880	.026	48.88	2.3
Sus Solids	676	.045	30.42	1.4
Buy Water	135,000	.00042	56.70	2.7
San Sewer	128,250	.00045	57.71	2.7
Energy	14,400	.0015	21.60	1.0
Labor	14,400	.0032	46.08	2.2
TOTAL			2133.39	

Total Yearly Cost = $554,680

Cost/lb Product $1.7094017E - 11

Coefficient for BOD (lbs BOD/100 lbs BOD processed) = 2.0

Coefficient for Suspended Solids (lbs/100 lbs BOD Processed) = .75

Coefficient for Water Use (Gallons/100 lbs BOD processed) = 150

*Pounds or gallons per day.

**Dollars per gallon or pound.

Table 44. Waste Associated Costs of Fluid Milk Operations Under Actual Conditions (Includes Buttermilk and Sour Cream).

OPERATIONS	QUANTITY*	COST**	COST/DAY	PERCENT OF COST
Rm Loss	1,800	$.112	$ 201.60	4.9
Product Loss	28,200	.112	3158.40	76.5
Pkg Loss	28,200	.004	112.80	2.7
BOD Loss	3,525	.026	91.65	2.2
Sus Solid	1,410	.045	63.45	1.5
Buy Water	432,688	.00042	181.73	4.4
San Sewer	411,054	.00045	184.97	4.5
Energy	28,200	.0015	42.30	1.0
Labor	28,200	.0032	90.24	2.2
TOTAL			4127.14	

Total Yearly Cost = $1,073,056

Cost/Lb Product $1.7E-11

Coefficient for BOD (Lbs BOD/100 lbs BOD Processed) = 3.9

Coefficient for Suspended Solids (lbs/100 lbs BOD Processed) = 1.6

Coefficient for water use (Gallons/100 lbs BOD Processed) = 480.8

*Pounds or gallons per day.

**Dollars per pound or gallon.

Table 45. Waste Associated Costs of Cottage Cheese Operations Under Design Conditions

OPERATION	QUANTITY*	COST**	COST/DAY	PERCENT OF COST
Rm Loss	1,037	$ .112	$116.14	16.9
Fm Loss	399	.08	31.92	4.6
Ds Loss	26	.16	4.16	0.6
Product Loss	710	.44	312.40	45.3
Pkg Loss	710	.003	2.13	0.3
BOD Loss	4,117	.026	107.04	15.5
Sus Solid	1,647	.045	74.12	10.3
Buy Water	38,576	.00042	16.20	2.4
San Sewer	51,176	.00045	23.03	3.3
Energy	710	.00262	1.86	0.3
TOTAL			689.00	

Total Yearly Cost = $179,140.00.

Cost/lb Product $7.7E- 11

Coefficient for BOD (lbs BOD/100 lbs BOD Processed) = 36.1

Coefficient for Suspended Solids (lbs/100 BOD Processed) = 14.4

Coefficient for Water Use (Gallons/100 lbs BOD Processed) = 338.4

*Pounds or gallons per day.

**Dollars per pound or gallon.

Table 46. Waste Associated Costs of Cottage Cheese Design Under Actual Conditions.

OPERATION	QUANTITY*	COST**	COST/DAY	PERCENT OF COST
RM Loss	1,037	$.112	$116.14	8.4
FM Loss	399	.08	31.92	2.3
DS Loss	40	.16	6.40	0.5
Product Loss	2,089	.44	919.16	66.3
Pkg Loss	2,089	.003	6.27	0.4
BOD Loss	4,470	.026	116.22	8.4
Sus Solids	1,656	.045	74.52	5.4
Buy Water	38,576	.00042	16.20	1.2
San Sewer	53,176	.00045	23.93	1.7
Energy	2,089	.00262	5.47	0.4
Labor	2,089	.0332	69.35	5.0
TOTAL			1385.58	

Total Yearly Cost = $360,250.00

Cost/Lb Product $7.7E-11

Coefficient for BOD (lbs BOD/100 lbs BOD Processed = 39.2

Coefficient for Suspended Solids (lbs/100 lbs BOD Processed) = 14.5

Coefficient for Water Use (Gallons/100 lbs BOD Processed) = 338.4

*Pounds or gallons per day.

**Dollars per pound or gallon.

Table 47. Waste Associated Costs of Ice Cream Operations Under Design Conditions

OPERATION	QUANTITY*	COST**	COST/DAY	PERCENT OF COST
RM Loss	601	$ .112	$ 67.31	11.1
Product Loss	1,952	.195	380.64	62.7
Pkg Loss	1,952	.00495	9.66	1.6
BOD Loss	795	.026	20.67	3.4
Sus Solid	211	.045	9.50	1.6
Buy Water	83,680	.00042	35.14	5.8
San Sewer	78,546	.00045	35.34	5.8
Energy	1,952	.0049	9.56	1.6
Labor	1,952	.02	39.04	6.4
TOTAL			606.86	

Total Yearly Cost = $157,783.00

Cost/lb Product 2.0

Coefficient for BOD (lbs BOD/100 lbs BOD Processed) = 2.6

Coefficient for Suspended Solids (lbs/100 lbs BOD Processed) = .7

Coefficient for Water Use (Gallons/100 lbs BOD Processed) = 274.1

*Pounds or gallons per day.

**Dollars per pound or gallon

Table 48. Waste Associated Costs of Ice Cream Operations Under Actual Conditions

OPERATIONS	QUANTITY*	COST**	COST/DAY	PERCENT OF COST
RM Loss	653	.112	$73.14	5.1
Product Loss	4,699	.195	916.30	63.4
Pkg Loss	4,699	.00495	23.26	1.6
BOD Loss	1,718	.026	44.67	3.1
Sus Solid	670	.045	30.15	2.1
Buy Water	72,300	.00042	30.37	2.1
San Sewer	68,685	.003	30.91	2.1
Energy	4,699	.003	14.10	1.0
Labor	4,699	.06	281.94	19.5
TOTAL			1444.84	

Total Yearly Cost = $375,658.00

Cost/lb Product 2.0

Coefficient for BOD (lbs BOD/100 lbs BOD Processed) = 5.6

Coefficient for Suspended Solids (lbs/100 lbs BOD Processed) = 2.1

Coefficient for Water Use (Gallons/100 lbs BOD Processed) = 236.8

*Pounds or gallons per day.

**Dollars per pound or gallon.

Table 49. Waste Associated Losses for Noveltv Operations Under Design Conditions

OPERATION	QUANTITY*	COST**	COST/DAY	PERCENT OF COST
Product Loss	2,260	$.45	$1017.00	75.0
Pkg Loss	2,260	.042	94.92	7.0
BOD Loss	452	.026	11.75	0.9
Sus Solid	122	.045	5.49	0.4
Buy Water	54,600	.00042	22.93	1.7
San Sewer	51,308	.00045	23.09	1.7
Energy	2, 260	.02	45.20	3.3
Labor	2,260	.06	135.60	10.0
TOTAL			1355.98	

Total Yearly Cost = $352,555.00

Cost/lb Product 1.3 - 9

Coefficient for BOD (lbs BOD/100 lbs BOD Processed) = 2.0

Coefficient for suspended Solids (lbs/100 lbs BOD Processed) = 0.53

Coefficient for Water Use (Gallons/100 lbs BOD Processed) = 227.7

*Pounds or gallons per day

**Dollars per pound or gallon.

Table 50. Waste Associated Costs for Novelty Operation Under Actual Conditions

OPERATION	QUANTITY*	COST**	COST/DAY	PERCENT OF COST
Product Loss	5,235	$ .4637	$ 2427.47	74.7
Pkg Loss	4,235	.042	177.87	5.5
BOD Loss	1,920	.026	49.92	1.5
Sus Solid	762	.045	34.29	1.1
Buy Water	189,170	.00042	79.45	2.4
San Sewer	180,000	.00045	81.00	2.5
Energy	4,235	.02	84.70	2.6
Labor	5,235	.06	314.10	9.7
TOTAL			3248.80	

Total Yearly Cost = $844,688.00

Cost/lb Product 2.7 - 10

Coefficient for BOD (lbs BOD/100 lbs BOD Processed) = 8.5

Coefficient for Suspended Solids (lbs/100 lbs BOD processed) = 3.1

Coefficient for Water Use (Gallons/100 lbs BOD Processed) = 796.9

*Pounds or gallons per day.

**Dollars per pound or gallon.

modifications that were considered are discussed briefly in the following by product areas.

Milk:

1. Raw milk receiving recovery system by using 2-20 gallons burst rinses and transferring to the raw milk silo tanks.

2. Raw milk receiving recovery system by using a series of burst rinses and transferring raw milk rinses to a refrigerated storage tank.

3. Raw milk line rinse system.

4. CIP separator controls to control pressure operation and prevent air incorporation into product.

5. Remodeling of the cream pasteurizer to prevent air incorporation and freeze on.

6. Saving clean water from HTST vac-heat systems.

7. Put automatic controls of water supply for CIP separators.

8. Repair or replace HTST #3 that continually leaks.

9. Rebuild Kemy filler.

10. Install drip shield.

11. Investigate animal feed for filler drips.

12. Installation of high pressure hose stations.

13. Clarifier sludge recovery.

14. Collection tank for product-water residues.

15. Fluid milk fillers drip shields.

16. CIP initial rinse recovery.

17. Remodeling of air blow system.

18. Construction of a recycle system for milk case washer.

19. Installation of shut-off control on case washer.

20. Pasteurized tank and line rinse recovery system.

21. CIP reuse of final rinses.

Frozen Desserts:

1. Drip collectors in ice cream packaging machine.

2. A rinse recovery system for material left in flavor vats, lines and ice cream freezers.

3. Collection for use as animal feed of frozen dessert materials than can not be re-run, such as stick novelties and sherbet. (Requires frozen storage in drums).

4. Rebuilding of Vita-freeze machines.

5. Automatic controls on water feed lines for Vita-freeze machines.

6. Rebuilding of flavor vats to permit more complete product removal before cleaning.

7. CIP re-use of rinses.

Cottage Cheese:

1. Replacement of small cheese vats to reduce fines

loss.

2. Elimination of final wash of cottage cheese.

3. Repair of damaged lines at skimmilk storage tanks.

4. Process revision to reduce fines.

5. Fines recovery by screening.

6. Fines recovery by centrifugation.

7. Whey utilization:

   a. animal feed
   b. hydrolysis and fermentation for bakers yeast production
   c. shipment to another processing plant for processing
   d. ultrafiltration and/or reverse osmosis
   e. modification of process procedures to permit in-plant utilization
   f. drying

SELECTION OF ALTERNATIVES:

All alternatives were studied in detail to determine their feasibility. The LP program was utilized to evaluate each possibility. Table 51 presents the results of projected cost-benefit in indicating the time required for pay back. An arbitrary decision was made to further investigate those changes that could provide pay back in two years or less. These changes are summarized in Table 51 in respect to daily reduction in water and/or BOD. The whey alternatives are not tabulated, but will be discussed separately.

All of the changes in Table 51 were selected for implementation, except for whey fines recovery and pasteurized rinse recovery systems. Technical evaluation of the fines recovery system indicated that the efficiency of either a centrifugal or rotary screen method was insufficient to afford cost recovery. A new screen method has been installed in a new Kroger plant in Newark, Ohio. The cost of this procedure is less than $10,000 and the recovery is about 50%. Following further evaluation, this technique will be considered for use in the Indianapolis dairy plant. The pasteurized lines recovery system would generate more dilute rinse than could be utilized in ice cream production. Because of current Health Department regulations, installation of this system will have to wait for Health Department approval.

Table 51. Projected Savings from Process and/or Equipment Modifications

Description of Change	Reduction/Day Waste Water (gal.)	Reduction/Day BOD (lb.)	$ Savings/Year Product	$ Savings/Year Sewer Charges*	$ Savings/Year Other**	$ Savings/Year Cost***
Water Reduction						
Vita-Freeze (C)	70,000	-	-	15,834	-	5,000
HTST Hot Water	24,000	-	-	5,211	-	3,500
Separator Controls (C)	20,160	-	-	4,500	-	1,800
Case Washer	47,400	-	-	10,721	-	6,000
Sub-Total	161,560			36,266		16,300
BOD Reduction						
Raw Milk Rec. A	1,200	320	130,816	5,637	-	5,500
Raw Milk Rec. B	1,200	320	130,816	5,637	-	30,000
HTST Replacement (C)	-	80	23,296	936	383	55,000
Air Blow Revisions	-	43	12,521	503	107	-
Cream Pasteurizer	30	58	17,500	585	117	5,000
Past Line Rinse Rec.	-	100	29,120	1,170	234	20,000
Remy Filler Rec.	100	164	47,756	1,918	383	5,000
Vita-Freeze (C)	70,000	540	260,000	22,152	5,538	75,000
Ice Cream CIP	2,000	400	156,000	5,132	1,539	20,000
CC Wash Revision (C)	12,000	32	33,130	4,084	800	-
Fines Rec.	-	80	50,000	936	200	50,000
Curd Saving	-	14	9,000	163	-	-
Replace CC Skim & Cream Lines	-	17	3,449	198	-	5,000
Sub-Total	85,330	1848	724,458	42,912	9,362	265,000
Total	246,890	1848	724,458	79,182	9,362	281,300

Total Saving Projected*** $813,000

Total Cost Projected*** $281,300

*Sewer = cost of water discharges to sewer and hydraulic sewer charge + BOD + SS surcharges.

**Other = caculable labor + energy costs of lost product.

***Total cost based on most expensive approach where two alternatives exist.

****(C) = change completed by December 31, 1978.

Whey Alternatives: Two of the alternatives were given detailed study: (a) lactose hydrolysis and fermentation for the production of baker's yeast and (b) process modification to permit direct incorporation of fluid whey into products in the plant.

The use of whey as a substitute for baker's yeast production was evaluated at the Kroger research laboratories on a laboratory basis and found to indicate that the process would be economically feasible. A pilot plant has been constructed, where intensive study is in progress to evaluate the technological and economic feasibilities of the process. The results of these studies will not be completed for one year.

The use of whey for in-plant use was investigated for all products that used water as a part of the process. These included (a) whey slurries, (b) buttermilk slurries, (c) sherbet, (d) ice pops and (f) fruit flavored drinks. Ice cream, sherbet, ice pops and fruit flavored drinks were made in which acid whey was used as a direct substitute for water. The results of organoleptic evaluations are shown in Table 52.

The results showed that ice cream and sherbet could be made that were equally acceptable to an untrained consumer panel.

Table 52. Consumer Acceptance of the Use of Fluid Acid Whey as a Substitute for Water in Selected Dairy Products.

PRODUCT	WHEY APPLICATION	ORGANOLEPTIC RESULTS
Ice Cream	Replacement of water solids in 20% slurry	Statistically significantly preference for whey slurry in water
Ice Cream	Replacement of water in buttermilk slurry	No significant difference from control
Ice Cream	Replacement of water in both whey and buttermilk, in slurry	Statistically significant difference but no significant difference in preference
Sherbet	Replacement of water	No signficant difference in preference, but statistically significantly different
Ice Pop (orange)	Replacement of water	Inferior product, salty
Ice Pop (orange)	Replacement of 25% of water	Slight preference for whey product
Fruit Flavored Drink (orange)	Replacement of 25% of water	Inferior product

Ice pops could substitute 25% acid whey for water without loss of consumer acceptance.

About 6,000 gallons (60% to 70%) of the whey discharged to the drain could be used in the plant without serious effect on quality. However, legal restrictions on the use of acid whey in frozen desserts imposed by standards of identity by the Food and Drug Administration would have to be changed before this approach could be utilized.

Any decision about the final utilization of whey was deferred until the results of the pilot plant study of yeast production could be fully assessed and in the meantime whey would continue to be discharged to the municipal treatment plant. In this instance, the whey load made up less than 0.38% of the BOD load of the treatment plant and would have no effect on operational efficiency.

EVALUATION OF RESULTS OF PROCESS AND EQUIPMENT MODIFICATIONS

The period of time for evaluation after completion of the changes was quite short, so that the data presented for a two-week period are less comprehensive than earlier data.

A baseline study was made during December before changes

were made. By the end of January, a number of changes had been completed, including: (a) Vita-freeze rebuilding, (b) installation of separator controls, (c) saving of HTST hot water, (d) replacement of HTST #3, (d) raw milk recovery system A, and (e) partial improvement of air blow systems.

Analyses made at the end of January indicated the results shown in Table 53. Overall, the predicted effect would have been a water reduction of 161,000 gallons and a BOD reduction of 1,840 pounds for all changes. The actual reduction was 87,000 gallons of water and 780 pounds of BOD. By the middle of February all changes were complete except the cream pasteurizer and the case washer. The total reduction in water use was 110,000 gallons and the total reduction of BOD load was 1550 pounds. The case washer revision should achieve an additional 50,000 gallons reduction in the wastewater. Based on these results, the projections made by the LP computer program would appear to be reliable.

Based on the unit operations that were to be used in the new Kroger dairy in Ohio, the LP model was used to predict the wastewater loads for this plant prior to construction. The prediction was 200,000 gallons of wastewater and 7,000 pounds of BOD per day. Actual values, based on municipal analyses, indicated 220,000 gallons and 5,700 pounds of BOD were being discharged 5 months after the plant was opened.

Table 53. Effect of Process and Equipment Changes on Waste Loads.

	Water* Gallons	BOD* lbs
July - Sept, 1977	450	6.8
December 1978 Base	320	5.0
After Changes in January	233	4.5
After Changes in February	200	3.9

*Per 100 lb of BOD processed.

APPENDIX A. GLOSSARY

bacteria: Primitive plants, generally free of pigment, which reproduce by dividing in one, two or three planes. They occur as single cells, chains, filaments, well-oriented groups of amorphous masses. Most bacteria do not require light, but a limited number are photosynthetic and draw upon light for energy. Most bacteria are heterotrophic (utilize organic matter for energy and for food growth materials), but few are autotrophic and derive their bodily needs from inorganic materials.

BAT: Best available treatment. Level of treatment established by EPA .

BCT: Best conventional treatment. Level of treatment which is to be obtained for conventional pollutants.

BOD (Biochemical Oxygen Demand): An indirect measure of the concentration of biologically degradable material present in organic wastes. It is the amount of free oxygen utilized by aerobic organisms when allowed to attach the organic matter in an aerobically maintained environment at specified temperature

(20 C) for a specific time period (5 days). It is expressed in milligrams of oxygen utilized per liter of liquid waste volume (mg/l) or in milligrams of oxygen per kilogram of solids present (mg/kg = ppm = parts per million).

BOD5: Five day biochemical oxygen demand. The most common time period for the measurement of a BOD.

BODu: The ultimate biochemical oxygen demand. The highest value for the amount of oxygen needed to oxidize an organic waste.

Biological Oxidation: The process whereby, through the activity of living organisms in an aerobic environment, organic matter is converted to more biologically stable (less putrifiable) matter.

Biological Treatment: Organic waste treatment in which bacterial and/or biochemical action is intensified under controlled conditions.

Buttermilk Slurry: A high solids mixtured of churned buttermilk powder in water or skimmilk to be used as a source of milk solids in ice cream manufacture.

C/N, Carbon-Nitrate Ratio: The weight ratio of carbon to nitrogen.

Chemical Oxidation: Oxidation of organic substances without benefit of living organisms. Examples are by thermal combustion or by oxidizing agents such as chlorine.

Chlorine Contact: A detention basin where chlorine is diffused through the treated effluent which is held a required time to provide the necessary disinfection.

Churned Buttermilk: By-product resulting from the churning of cream into butter. It is largely defatted cream and its typical composition is 91% water, 4.5% lactose, 3.4% nitrogenous matter, 0.7% ash and 0.4% fat. Churned or "true" buttermilk is distinguished from cultured buttermilk, which is a fermentation product of skim milk. The latter is sold in the retail market and referred to simply as "buttermilk."

CIP: A term used to describe cleaned-in-place. The system for circulation cleaning of food plant equipment including the spray cleaning of tank trucks and processing tanks and vats.

CIP-Separator: A centrifugal machine that separates, standarizes and clarifies milk. It automatically desludges on a preset

program, generally one second every 45 minutes. The machine can be cleaned in place without being dissasembled.

COD (Chemical Oxygen Demand): An indirect measure of the biochemical load exerted on the oxygen assets of a body of water when organic wastes are introduced into the water. It is determined by the amount of potassium dichromate consumed in a boiling mixture of chromic and sulfuric acids. The amount of oxidizable organic matter is proportional to the potassium dichromate consumed. Where the wastes contain only readily available organic bacterial food and no toxic matter, the COD values can be correlated with BOD values obtained from the same wastes.

Condensed: The term "condensed" as used in this report, applies to any liquid product which has been concentrated through removal of some of the water it normally contains, resulting in a product which is still in the liquid or semi-liquid state. When applied to milk, the term "condensed" is used interchangeably with "evaporate" to designate milk which has been concentrated. Commercially, however, the term "evaporated milk" is commonly used to define unsweetened concentrated milk.

Consumptive use: Portion of the gross water applied that is consumed or depleted - i.e., evaporated into the atmosphere or incorporated into the product itself.

Contamination: A general term signifying the introduction into water of microorganisms, chemical, organic or inorganic wastes, or sewage, which renders the water unfit for its intended use.

Cost: That which must be given in order to acquire, produce or effect something.

Cultured Products: Fermentation-type dairy products manufactured by inoculating different forms of milk with a bacterial culture. This designation includes yoghurt, cultured buttermilk, sour cream, and cultured cream cheese, among other products.

Cream: The product resulting from the separation of whole milk into skimmilk and the high fat product cream. It contains about 40% fat and has a BOD of 0.32 pounds per pound and a COD of about 0.55 per pound.

Design Waste Load: That waste load that is unavoidable and relates to the design of the plant and equipment. This includes material left on equipment surfaces, in pipe lines and deliberately wasted, such as in the start-up of an HTST unit.

Dissolved Oxygen: The oxygen dissolved in sewage, water, or other liquid usually expressed as milligrams per liter or as

percent of saturation.

Efficiency: In engineering analyses, it is most commonly applied as a measure of the input which results in output of useful work. Efficiency in percent is obtained by dividing the output by the input and multiplying by 100. (Input = Output + loss).

Effluent: That which flows out from a space. The waste discharge(s) from the plant.

Endogenous: An auto oxidation of cellular material that takes place in the absence of assimilable organic material to furnish energy required for the replacement of worn-out components of protoplasm.

EPA: The Environmental Protection Agency. The Federal agency is sometimes referred to as such, but individual states may have an EPA. It is preferable to use U.S. Environmental Protection Agency (US EPA) when referring to the federal agency.

Externality or External (dis)economy: An economic influence of one activity or another activity, with no cost to the activity causing the externality. Pollution is an external diseconomy when someone not connected to the pollution causing activity must suffer personal or economic loss as a result of the pollution, or must pay the cost of eliminating it with no recourse to those

causing it.

Fat: As used in this study, fat will be used synonymously with butterfat, a part of fats, oil and grease (FOG).

Filtration: The process of passing a liquid through a porous medium for the removal of suspended or colloidal material contained in the influent liquid by a physical straining action.

Flavor Tanks: Small processing vats of 50 to 200 gallons for making-up different flavors of ice cream, sherbet and novelties.

FOG: Fats, Oils and Greases. See hexane solubles.

Food to Microorganism Ratio: An aeration tank loading parameter. Food may be expressed in pounds of COD or BOD_5 added per day to the aeration tank, and microorganisms may be expressed as mixed liquor suspended solids (MLSS) or mixed liquor volatile suspended solids (MLVSS) in the aeration tank.

Gross Water Applied: Total quantity of water necessary to process a unit of raw material or to process a unit of output.

Hexane Solubles: The concentration of TOC recoverd from a sample of wastewater using the hexane distillation procedure.

HTST: High temperature short time pasteurization. A plate heat exchanger for the pasteurization of fluid dairy products. For milk all particles of milk are heated to a minimum of 161°F for a minimum of 15 seconds.

Hydraulic Loading: The flow (volume per unit time) applied to the surface area of the clarification of biological reactor units or the wastewater flow from a process plant.

ICR: Industrial Cost Recovery. System of charges levied to recover from an industrial user of the wastewater treatment facilities the federal grant amount, issued under Public Law 92-500, as amended, allocable to the construction of facilities for treatment of wastes from the industrial user. These charges are separate from and not a part of the wastewater treatment bill whose constituent element includes the user charge system and the billing and collection charge.

Ice Cream: Applied in a general sense, this term refers to any milk-based product sold as frozen food. Food regulatory agencies

define ice cream in terms of composition, to distinguish the product from other frozen dessert-type products containing less milk-fat or none at all, such as sherbert, water ices and Mellorine.

Infiltration Rate: The rate at which water can enter the soil. Units are usually inches of water per day.

Influent: Wastewater or other liquid - raw, or partially treated - flowing into a reservoir, basin, treatment process or treatment plant.

Milk Equivalent: Quantity of milk (in pounds) to produce one pound of product. The milk equivalents used where those given by the U.S. Department of Agriculture, Statistical Bulletin No. 362 "Conversion Factors and Weights and Measures for Agricultural Commodities and their Products."

Municipal Bill: Local bill which represents the cost of water and the cost of wastewater treatment if the user discharges into the public owned treatment works. The cost of wastewater treatment may be based on the metered water supplied to the user and may contain a surcharge for excessive amounts of a pollutant.

NPDES: National Pollution Discharge Elimination System.

regulates the discharge of wastewaters to the navigable waters of the United States pursuant to Section 402 of Public Law 95-217, The Clean Water Act of 1977.

Optimization: Process of selecting the mix of activities, and the levels of these activities, which are optimum under the desired conditions - in this study, that mix which gives the maximum net revenue or least cost to the dairy plant.

pH: The symbol for the logaritnm of the reciprocal of the hydrogen ion concentration, expressed in mols per liter of a solution, and used to indicate an acid or alkaline condition. (pH 7 indicates neutral; less than 7 is acid, greater than 7 is basic.)

Pollution: The presence in a body of water (or soil or air) of substances of such character and in such quantity that the natural quality of the body of water (or soil or air) is degraded so it impairs the water's usefulness or renders it offensive to the senses of sight, taste, or smell. Contamination may accompany pollution. In general, a public health hazard is created, but in some cases only economy of estnetics are involved, as when waste salt brines contaminate surface waters or when foul odors pollute the air.

Population equivalent: The calculated human population which

would normally contribute the same amount of BOD per day. A common base is 0.2 lb (90.7 g) of 5-day BOD per capita per day. A dairy producing 200 lb (90.7 kg) of BOD per day will have a population equivalent (PE) of 1,000.

Preventable Waste: Waste which can be avoided by proper operation. Generally refers to leaks, spills, spoiled products and from improperly operated equipment.

Process: A continuous and regular action or succession of actions, taking place or carried on in a definite manner.

Process Effluent (discharge): The volume of wastewater emerging from a particular use in the plant.

Putrefaction: A process of decomposition in which, as a consequence of the breakdown of organics, end-products with offensive odors are formed.

Raw Milk: Milk as received from the farm or of standardized composition that has not been pasteurized or separated.

Raw Waste Load: Numerical value of any waste parameter that defines the characteristics of a plant effluent as it leaves the plant, before it is treated in any way.

Recycle: Use of water over and over again for the identical application whence it came.

Sanitary Sewer System: A sewer intended to carry wastewater from homes, businesses and industries. Storm water runoff sometimes is collected and transported in a separate system of pipes.

Settleable Solids: Those suspended solids contained in sewage or wastewater that will separate by settling when the carrier liquid is held in quiescent condition for a specified time interval.

Sewage: Water after it has been fouled by various uses. From the standpoint of source, it may be a combination of the liquid or water-carried wastes from residences, business buildings, and institutions, together with those from industrial and agricultural establishments, and with such ground water, surface water, and storm water as may be present.

Sewerage System: The term "sewerage system" means any system, whether community, individual, publicly or privately owned, for the collection and disposal of sewage or industrial wastes of a liquid nature, or both including various devices for the treatment of such sewage or industrial wastes.

Sewer Use Ordinance: A legislative enactment of a municipality governing sewer discharge.

Skim Milk: In common usage, skim milk (also designated non-fat, defatted, or "fat-free" milk) from which fat has been separated as completely as commercially practicable. The maximum fat content is normally established by law and is typically 0.1% in the United States. There is also a common but not universal requirement that non-fat milk contain a minimum quantity of milk solids other than fat, typically 3.25%. In many states the meaning of the term skim milk is broadened to include milk that contains less fat than the legal minimum for whole milk, such as the low-fat sold in the retail market. The term skim milk used in this study refers to non-fat milk.

Sludge: The accumulated settled solids deposited from sewage or other wastes, raw or treated, in tanks or basins, and containing more or less water to form a semi-liquid mass.

SS: Suspended solids. Particles of solid matter in suspension in the effluent which can normally be removed by settling or filtration.

Standard Manufacturing Process (SMP): An operation or a series of operations which is essential to a process and/or which produce a waste load that is substantially different from that of an alternate method of performing the same process. The concept was developed in order to have a flexible "building block" means

for characterizing the waste from any plant within an industry.

Standard Raw Waste Load (SRWL): That waste load that is unavoidable and associated with the design of the process (See Design Waste Load). Generally refers to a unit operation.

Storm Sewer System: A sewer intended to carry storm water runoff and other waters to the nearest surface waters.

Surcharge: A charge levied by a municipality for wastewaters of strengths greater than those defined as normal.

System: A group, set or aggregate of processing forming a connected or complex whole.

Total Product: Quantity of total production of all product produced and packaged for distribution.

Total Solids: The residue remaining when the water is evaporated away from a sample of water, sewage, other liquids, or semi-solid masses of material and the residue is then dried at a specified temperature (usually 103°C).

TSS: Total Suspended Solids.

Total Water Utilization Costs: All costs of obtaining, handling

and disposing of water from intake to outlet.

Unavoidable Waste: That waste which cannot be prevented.

User Charge: System of charges levied on users for the cost of operation and maintenance including replacement reserve requirements on new and old wastewater collection and treatment facilities.

Vita-Line or Vita-Freeze: A machine for the freezing of stick novelties. The novelty mix is metered into a series of metal molds (usually 18-24 molds wide) that pass through a calcium chloride brine tank for freezing. A stick is inserted into the partially frozen product and then hot water is sprayed on the bottom of the mold to release the novelty. The molds are then rinsed and washed for re-use.

Waste: Potentially polluting material which is discharged or disposed of from a plant directly to the environment or to a treatment facility which eliminates its undesirable polluting effect.

Waste Coefficients: Used to express a given waste parameter in terms of units of product processed or product manufactured. In this report, coefficients are generally reported in terms of 100

pounds of BOD or COD processed. The coefficients also give a direct value for % loss.

Waste Discharged: The amount (usually expressed as weight) of some residual substance, if any, which is suspended or dissolved in the plant effluent after treatment.

Waste Load: Numerical value of any waste parameter (such as BOD5, FOG, etc.) that serves to define the characteristics of a plant effluent.

Wastewater: Waste-containing water discharged from a plant. Used synonymously with "effluent" in this study.

Water Utilization (use): The totality of water and steam flows - including intake water and wastewater treatment - for all water uses within a production unit, from one or more points of intake through one or more points of discharge of the final effluent.

Whey: By-product in the manufacture of cheese which remains after separating the cheese curd from the rest of the milk used in the process. Whey resulting from the manufacture of natural cheese is termed "sweet whey" and its composition is somewhat different than "acid whey" resulting from the manufacture of cottage cheese.

Whey Slurry A high solids (generally about 20% of sweet whey powder in water or skimmilk) for use as a milk solids source in ice cream manufacture.

Whole Milk: In its broad sense, the term whole milk refers to milk of composition such as produced by the cow. This composition depends on many factors and is seasonal with fat content typically ranging between 3.5% and 4.0%. The term whole milk is also used to designate market milk whose fat content has been standardized to conform to a regulatory definition, typically 3.5%.

APPENDIX B. RECORD FORMS FOR WATER AND WASTE CONTROL

RECORD FORM	USE	PAGE
1. Waste Management Control Inspection Form	Plant survey for problem areas	
2. Maintenance Request	Reporting maintenance problems	
3. Product Loss Report	All overflows, spills, major leaks, etc.	
4. Daily Ingredient Loss Report	Reporting loss control	
5. Raw Material Use Ice Cream & Novelties	Reporting, calculations	
6. Daily Milk Loss Report	Loss control	

7. Raw Materials Use Cottage Cheese	Reporting, calculations
8. Ingredient Use for Fluid Products	Reporting, calculations
9. Daily Ice Cream Loss Report	Loss control
10. Milk Operations Report	Management control
11. Total COD and Loss Report	Loss control
12. Weekly Waste Summary	Management control

1. WASTE MANAGEMENT CONTROL INSPECTION FORM

Milk, Ice Cream and Cottage Cheese

Plant:_____ Location:_____

Date:___Time In___Time Out___Evaluated By_____

	Compliance Yes/No	Comments/ Recommendations
RECEIVING ROOM:		
Tankers - unloaded promptly	_	_____
No leaks from unloading pumps	_	_____
Pipe connections free from leaks	_	_____
Tankers completely drained before washing	_	_____
Unloading hose properly drained	_	_____
Air-blow system in proper operation	_	_____
CIP system operating properly, no leaks	_	_____
Burst rinses recovered to raw silos	_	_____
RAW MILK STORAGE:		
Outlet valves free from leaks	_	_____
Connections free from leaks	_	_____
Air actuated valves free from leaks	_	_____
Sampler not leaking	_	_____
Unloading pumps free from leaks	_	_____

MILK PROCESSING AREA:

HTST #1:

Plate sections free from leaks _ _____

TP, BP seals not leaking _ _____

Homo seals not leaking _ _____

Separator operating properly, no overflow and shooting properly timed _ _____

Connections free from leaks _ _____

No overflow of balance tank _ _____

Valves free from leaks _ _____

No excessive water usage _ _____

HTST #2:

Plate Sections free from leaks _ _____

TP, BP seals not leaking _ _____

Homo seals not leaking _ _____

Separator operating properly, no overflow; and shooting properly times _ _____

Connections free from leaks _ _____

No overflow of balance tank _ _____

Valves free from leaks _ _____

No excessive water usage _ _____

HTST #3:

Plate Sections free from leaks _ _____

TP, BP seals not leaking _ _____

Homo not leaking _ _____

Separator operating properly, no overflow; and shooting properly timed _ _____

Connections free from leaks _ _____

No overflow of balance tank _ _____

Valves free from leaks _ _____

No excessive use of water _ _____

CREAM PROCESSOR:

Plate sections free from leaks _ _____

Pump seals free from leaks _ _____

No freeze-up of plates _ _____

Connections free of leaks _ _____

No overflow of balance tank _ _____

Valves free from leaks _ _____

PASTEURIZED MILK STORAGE TANKS:

Outlet valves free from leaks _ _____

Pumps free from leaks _ _____

Connections free from leaks _ _____

Dry ingredient spillage handled as solid waste _ _____

MILK FILLING AREA:

Milk filler #1:

Filler valves free from leaks _ _____

No foam overflow _ _____

Line connections free from leaks _ _____

Sealer/capper operating properly _ _____

Drip shields in use _ _____

Containers for damaged cartons in use _ _____

Proper use of product recovery system _ _____

Milk filler # 2:

Filler valves free from leaks _ _____

No foam overflow _ _____

Line connections free from leaks _ _____

Sealer/capper free from leaks _ _____

Drip shields in use _ _____

Containers for damaged cartons in use _ _____

Proper use of product recovery system _ _____

Milk filler #3:

Filler valves free from leaks _ _____

No foam overflow _ _____

Line connections free from leaks _ _____

Sealer/capper operating properly _ _____

Drip shields in use _ _____

Containers for damaged cartons in use _ _____

Proper use of product recovery system _ _____

Milk filler #4:

Filler valves free from leaks _ _____

No foam overflow _ _____

Line connections free from leaks _ _____

Sealer/capper operating properly _ _____

Drip shields in use _ _____

Containers for damaged products in use _ _____

Proper use of product recovery system _ _____

Milk filler #5:

Filler valves free from leaks _ _____

No foam overflow _ _____

Sealer/capper operating properly _ _____

Drip shields in use _ _____

Containers for damaged cartons in use _ _____

Proper use of product recovery system _ _____

Milk filler #6:

Filler valves free from leaks _ _____

No foam overflow _ _____

Sealer/capper operating properly _ _____

Drip shield in use _ _____

Container for damaged product in use _ _____

Proper use of product recovery system _ _____

Stainless Steel Milk Coolers:

Case wts or operating properly _ _____

No excessive water usage for case washer _ _____

Case loaders operating properly, causing no spillage _ _____

Case stackers operating properly, causing no spillage _ _____

Conveyors operating properly, causing no spillage _ _____

No leaks in cooler _ _____

No loss of product in lost out _ _____

Dumpster not leaking _ _____

ICE CREAM PROCESSING AREA:

Make-up tanks:

Valves free from leaks _ _____

Pumps free from leaks _ _____

Fittings free from leaks _ _____

No overflow of tanks _ _____

Blend Tank:

Valves free from leaks _ _____

Pumps free from leaks _ _____

Line connections free from leaks _ _____

Ice Cream VAT:

Plate sections free from leaks _ _____

Vat, etc free from leaks _ _____

Bond seals not leaking _ _____

Connections free from leaks _ _____

No overflow of balance tank _ _____

Pasteurized Ice Cream Mix Storage Tanks:

Outlet valves free from leaks _ _____

Pumps free from leaks _ _____

Connections free from leaks _ _____

Connecting lines free from leaks _ _____

No overflow of tanks _ _____

Air blowdown of lines operating properly _ _____

Mix flavoring tanks:

Valves free from leaks _ _____

No overflow of tanks _ _____

Connecting lines free of leaks_ _____

Ice Cream Freezers:

No leaks in valves or connecting lines _ _____

No leaks in seals _ _____

Supply pumps free from leaks _ _____

Machines operating properly _ _____

Ice Cream Packaging Machines:

No leaks in valves or lines _ _____

Machines operating properly _ _____

Ice cream collected during shut downs _ _____

Ice cream on floor handled as solid waste _ _____

Proper disposal of damaged cartons _ _____

Dumpster not leaking product _ _____

NOVELTY OPERATIONS:

Vita Line #1:

No overflow, foaming at filling area _ _____

Sticks feeding properly _ _____

No loss of novelties from holders _ _____

Pumps free from leaks _ _____

Supply lines free from leaks _ _____

Float valve operating properly_ _____

No excessive use of water _ _____

Vita Line #2:

No overflow, foaming at filling area _ _____

Sticks feeding properly _ _____

No loss of novelties from holders _ _____

Pumps free from leaks _ _____

Valves free from leaks _ _____

Supply lines free from leaks _ _____

Float valve operating properly_ _____

No excessive use of water _ _____

Vita Line #3:

No overflow, foaming at filling area _ _____

Sticks feeding properly _ _____

No loss of novelties from holders _ _____

Pumps free from leaks _ _____

Valves free from leaks _ _____

Supply lines free from leaks _ _____

Float valve operating properly_ _____

No excessive use of water _ _____

Vita Line #4:

No overflow, foaming at filling area _ _____

Sticks feeding properly _ _____

No loss of novelties from holders _ _____

Pumps free from leaks _ _____

Valves free from leaks _ _____

Supply lines free from leaks _ _____

Float valve free from leaks _ _____

No excessive use of water _ _____

Novelty Packaging Machines:

Machine #1 operating properly, no losses _ _____

Machine #2 operating properly, no losses _ _____

Machine #3 operating properly, no losses _ _____

Machine #4 operating properly, no losses _ _____

COTTAGE CHEESE PROCESSING:

Processing:

Starter vat and fittings free from leaks _ _____

Cream dressing tanks, valve and fittings free from leaks _ _____

Lines and valves supplying cheese vats free from leaks _ _____

Cheese vat properly filled _ _____

Cheese vat valves free from leaks _ _____

Whey excluded from drain _ _____

Spilled curd handled as solid waste _ _____

Packaging:

Lines and valves free from leaks _ _____

Filler valves free from leaks _ _____

Spilled product on floor handled as solid waste _ _____

2. RESOURCES CONTROL PROGRAM

Maintenance Request

Note: This form is to facilitate maintenance and is to be filled out by the foreman and can be initiated by the operator or foreman.

DATE: _____

NO.. (To be filled in by Engineering Dept.) _____

INITIATED BY: _____ FOREMAN: _____

AREA: _____

EQUIPMENT: _____

WHEN PROBLEM FIRST OBSERVED: _____

_____

PROBLEM: _____

_____

_____

_____

SUGGESTED SOLUTION: _____

_____

_____

_____

ROUTING: (initial and forward to Chief Engineer)

Production Supervisor _____

Engineering Foreman _____

Chief Engineer _____

MAINTENANCE ORDER NO.: _____

3. RESOURCES CONTROL PROGRAM

PRODUCT LOSS REPORT

NOTE: REPORT ANY MATERIAL, SUCH AS OVERFLOWS, DUMPED PRODUCT, MAJOR LEAKS, SPILLS, PACKAGED PRODUCT LOST, ETC.

DATE: _____ TIME: _____

LOCATION: _____

PRODUCT LOST: _____

ESTIMATED VOLUME LOSS: _____

DESCRIPTION OF PROBLEM (OVERFLOW, LEAKAGE, ETC): _____

_____

_____

_____

CAUSE OF PROBLEM: _____

_____

_____

RECOMMENDATIONS FOR CORRECTION: _____

_____

_____

_____

4. RESOURCES CONTROL PROGRAM

DAILY INGREDIENT LOSS REPORT

INGREDIENT	TOTAL USED	TOTAL NOT ACCOUNTED FOR IN PRODUCT	% LOSS	% LOSS
Sucrose-milk				
Sucrose-ice cream				
Sucrose-novelty				
Corn syrup				
Whey powder				
Chocolate				
Condensed skim				
Non Fat Dry Milk				
Citric Acid				

5. RAW MATERIAL USE

ICE CREAM & NOVELTIES

CREAM	_____	lbs.	_____	fat
MILK	_____	lbs.	_____	fat
TOTAL B/FAT	_____	lbs.		
STD. B/FAT	_____	lbs.	_____	Difference
S.M. POWDER	_____	lbs.		
SUCROSE	_____	lbs.		
CORN SYRUP	_____	lbs.		
FRUCTOSE	_____	lbs.		
WHEY POWDER	_____	lbs.		
RINSE RECOVERY	_____	lbs.	MILK _____	lbs.
			FAT _____	%
CHOCOLATE	_____	lbs.		
SALT	_____	lbs.		
CITRIC ACID	_____	lbs.		
6% STAB. SLURRY	_____	lbs.		
STARCH	_____	lbs.		
EGG YOLK SOLIDS	_____	lbs.		

COMMENTS:

5. DAILY MILK LOSS REPORT

DATE: _____

1. TOTAL POUNDS OF MILK RECEIVED _____

2. TOTAL POUNDS OF FAT RECEIVED _____

3. TOTAL POUNDS OF SKIM MILK RECEIVED _____

4. TOTAL POUNDS OF MILK PROCESSED _____

5. YIELD LOSS IN PROCESSING (POUNDS) _____ $_____

6. FAT LOSS IN PROCESSING (POUNDS) _____ $_____

7. SKIM MILK LOSS IN PROCESSING (POUNDS) _____ $_____

8. TOTAL POUNDS OF MILK PACKAGED _____ $_____

9. YIELD LOSS IN PACKAGING (POUNDS) _____ $_____

10. FAT LOSS IN PACKAGING (POUNDS) _____ $_____

11. SKIM MILK LOSS IN PACKAGING (POUNDS) _____ $_____

12. TOTAL NUMBER OF MILK CARTONS USED _____ $_____

13. TOTAL NUMBER OF MILK CARTONS LOST _____ $_____

14. TOTAL POUNDS OF MILK RECOVERED FROM PACKAGED PRODUCTS RECOVERY _____ $_____

15. TOTAL AMOUNT OF REPORTED SPILLAGE _____ $_____

16. TOTAL ESTIMATED LOSS (5+9+15-14) _____ $_____

17. TOTAL ESTIMATED FAT LOSS _____ $_____

18. TOTAL ESTIMATED SKIM MILK LOSS _____ $_____

19. ESTIMATED LOSS OF BOD FROM MILK OPERATIONS _____ $_____

20. MILK EQUIVALENT OF BOD LOSS _____ $_____

21. DIFFERENCE IN LOSS IN 16 AND 20 _____ $_____

7. RAW MATERIAL USE: COTTAGE CHEESE

Date:_____

Skimmilk to cheese vats	_____	% fat_____
Starter to cheese vats	_____	
Cheese Dressing	_____	% fat_____
Curd yield	_____ lbs	
Whey volume	_____	
Casein in skims + starter	_____	
Casein in first wash	_____	
Casein in second wash	_____	
Casein in third wash	_____	
TOTAL in Casein loss	_____	
% Casein loss	_____	

C. INGREDIENT USE FOR LIQUID PRODUCTS

Date: _____

	Gallons	Pounds
Total milk received	_____	_____
Total milk processed	_____	_____
Skim to CC	_____	_____
Cream to CC	_____	_____
Milk to IC	_____	_____
Skim to IC	_____	_____
Cream to IC	_____	_____
# Sugar		_____
# Liquid corn		_____
# Fructose		_____
# Chocolate		_____
Orange Juice		_____

9. RESOURCES CONTROL PROGRAM

DAILY ICE CREAM LOSS REPORT

1. TOTAL GALLONS OF MIX MADE _____ TOTAL POUNDS _____

2. TOTAL POUNDS OF FAT UTILIZED _____

3. TOTAL POUNDS OF MILK SOLID NOT FAT UTILIZED _____

4. TOTAL POUNDS OF SUGAR UTILIZED _____

5. TOTAL NUMBER OF PACKAGES USED _____

6. TOTAL NUMBER OF PACKAGES FILLED _____

7. TOTAL NUMBER OF PACKAGES LOST _____ $_____

8. TOTAL GALLONS OF ICE CREAM PACKAGED _____
Total Pounds _____

9. TOTAL POUNDS OF ICE CREAM LOST _____ $_____

10. POUNDS OF BCD FROM ICE CREAM LINE _____
Surcharge $_____

11. POUNDS OF BCD CORRECTED FOR QUALITY OPERATION _____
Surcharge $_____

12. ESTIMATED ICE CREAM LOSS FROM BCD VALUE IN 11 _____
$_____

13. DIFFERENCE BETWEEN 9 AND 12 _____

Date: _____

[illegible] MILK SPREADSHEET

DATE: _____

Total Milk to Account for: _____

Total Milk Accounted for: _____

Milk to Ice Cream: _____

Cream to Ice Cream: _____

Skim Milk to Cottage Cheese: _____

Dressing to Cottage Cheese: _____

Total Cream Produced: _____

Total Skim Milk to Account for: _____

Total Skim Milk Accounted for: _____

Total Fat to Account for: _____

Total Fat Accounted for: _____

Total Chocolate powder used: _____

Total [illegible] used: _____

Total Sugar used: _____

Total Corn Syrup used: _____

Total Fructose used: _____

Receiving Loss %: _____

Manufacturing Milk Loss %: _____

Manufacturing Skim Loss %: _____

Manufacturing Fat Loss %: _____

II. COD AND LOSS REPORT

A.	Total pounds COD processed	_____ lbs
B.	COD in Wastewater	_____ lbs
C.	COD loss (B/A x 100)	_____ %
D.	Value of COD (B x 1)	$ _____
E.	Loss/Day (C x D)	$ _____
F.	Loss/Period (E x 21)	$ _____
G.	Loss/Year (E x 250)	$ _____

12. WEEKLY SUMMARY OF WATER AND WASTE COEFFICIENTS

WEEK _____

DAY	1000 GAL WATER/ 1000# MILK	PROD 1000# MILK	PROD/ 1000# MILK	$	DAILY MILK EQUIVALENT LOSS
MILK PROC.			SEWER		
MONDAY.					
TUES.					
WED.					
THURS.					
FRIDAY					
SAT.					
SUNDAY					
WEEKLY AVG.					

$ VALUE OF SEWER BILL AND PRODUCT LOSS FOR WEEK_____:

PROJECTED YEARLY $ VALUE_____.

APPENDIX C. COMPUTATIONS AND CALCULATIONS

I. CALCULATION OF BOD PROCESSED

The simplest approach is to use milk equivalent values to convert all products back to 3.5% milk. In this case, the pounds BOD processed = [(pounds of product) x (milk equivalent)] x 0.1 pound of BOD/pound of 3.5% milk.

Milk equivalents:

Skimmilk	0.72
2% Milk	0.82
3.25% Milk	0.97
3.50% Milk	1.00
Cottage cheese	5.30
Ice cream	2.70
Condensed milk	2.40
Dry whole milk	7.40
Dry skimmilk	11.00
Dried whey	18.00
Cheddar cheese	9.90
Butter	———

A more accurate approach for a multiple product plant is to calculate BOD from composition.

The following is an example of the calculations needed for a milk, ice cream and cottage cheese plant.

Milk:

(a) for 3.5% milk,
pounds of BOD5 = pounds of milk x 0.10
where BOD5 = 1,000,000 mg/l

(b) for mixed fluid products,
pounds of BOD5 = pounds of product x [(% fat x 0.9) + (% protein x 0.103 + % carbohydrate x 0.05)]
where # of BOD5/# of product = 0.9, 1.03, and 0.7 for fat, protein and carbohydrate, respectively.

Ice Cream.

(a) for 10% fat ice cream,
pounds of BOD5 = pounds of ice cream x 0.320
where BOD5 = 320,000 mg/l

(b) for frozen desserts of mixed composition,
pounds of BOD5 = pounds of product x [(% fat x 0.09 + (% protein x 0.103) + (% carbohydrate x 0.07)]

Cottage Cheese:

Cottage cheese is a blend of curd and cream dressing.

pounds of BOD5 processed = [(% curd/100) x # of BOD5 in skimmilk processed] + [(% dressing/100) x # of BOD5 in dressing]

pounds of BOD5 processed into curd = pounds of curd x (100/% yield of curd/100) x .072

where skimmilk = 72,000 mg/l BOD5; generally this would be pounds of curd x 0.0752

pounds of BOD5 from dressing = pounds of dressing x (% fat x 0.09) + (% protein x 0.103) + (% carbohydrates x 0.065)

II. WASTE CALCULATIONS.

BOD

A. Pounds of BOD based on sewer data

1. Need:
   a. Volume of water in gallons
   b. Conversion factor for changing gallons to pounds (8.34 #/gal)
   c. BOD in mg/l
   d. Conversion for mg/l to fraction 3 (1,000,000)

2. Calculation:
   gallons x 8.34 x mg BOD/1,000,000 = #'s of BOD

3. Example:

   a. Given 100,000 gallons at a BOD strength of 2000 mg/l
   b. # BOD = (100,000 x 8.34)x(2000/1,000,000) = 1668 #

B. Pounds of BOD based on market report

1. Need:

   a. Pounds of skim milk

b. BOD value for skim milk
[(72,000 mg/l)/1,000,000] = 0.072
c. Pounds of fat
d. BOD value for fat
[(900,000 mg/l)/1,000,000] = 0.90

2. Calculation:

(pounds of skim milk)x(0.072) + (pounds of fat)x(0.9) = # of BOD

3. Example:

a. Given 90,000 of skim lost; 4,000 of fat lost
b. # BOD = (90,000)x(0.072) + (4,000)x(0.9) = 10,000 lbs of BOD lost

C. Pounds of BOD Based on Compositional Data

1. Needs:

a. Pounds of protein
b. Protein factor for BOD/pound (1.03)
c. Pounds of fat
d. Fat factor for BOD/pound (0.90)
e. Pounds of carbohydrate
f. Carbohydrate factor for BOD/pound (0.70)

2. Calculations:

(pounds of protein)x(1.03) + (pounds of fat)x(0.9) + (pounds of carbohydrate)x(0.7) = pounds of BOD

3. Example:

a. Given 100,000 pounds of milk with 3% protein, 4% fat and 5% lactose.
NOTE: pound of fat = (# of product) x (0.04)
b. # BOD = (100,000)x(0.03)x(1.03) + (100,000)x(0.04)x(0.9) + (100,000)x(0.05)x(0.7) = 10,190 #'s of BOD

III. SURCHARGE CALCULATIONS

BOD5 Load

Known: (a) Flow (gallons)
(b) Concentration (mg/l)

BOD5 Load (lbs) = [8.34x(Flow)]x[(Concentration)/1,000,000]

where: Monthly Flow = 2,000,000 gal
Average Concentration = 3,000 mg/l

BOD5 Load (lbs) = [8.34x(2,000.000)]x[(3,000)]/ 1,000,000]

BOD5 Load = 50040 lbs

Surcharge Bill Known: (a) BOD5 Load (lbs)
(b) Flow (gallons)
(c) Normal BOD5 Concentration (mg/l)
(d) BOD5 Surcharge Cost ($/1000 lb)

where: (a) 50040 lbs
(b) 2,000,000 gal
(c) 300 mg/l
(d) $80/1000 lbs BOD5 excess of normal

BOD5 Surcharge = BOD5 Surcharge Cost x(Excess BOD5 Load)

where excess BOD5 Load = (BOD5 Load - Normal BOD5 Load)

Normal BOD5 Load (lbs) = [8.34X(2,000,000)x(300)]/ 1,000,000

Normal BOD5 = 5004 lbs

Excess BOD load = 45036

BOD5 Surcharge = {[$80x(45036 lbs)]/1000 lbs}

BOD5 Surcharge = $3,602.88

Milk has a BOD5 of 100,000 mg/l (ppm). Thus, 1 lb milk = 0.1 lb BOD5.

A dairy employee who saves 10 gallons of milk a day may save his plant (85 lbs milk x $.12* + $0.05** x 8.5 lbs BOD5) x 250 days/ year = $2687.50.

A dairy employee who does not use 1,000 gallons of water (less than 16 minutes of a water hose running) a day may save his plant 1,000 gallons x 250 days/year x $0.30/1000 gal = $150. The value is not too much, but it is 250,000 gallons of water - enough for a family of 4 for about 2 years.

*Value of product
**Cost of waste treatment

IV. YIELD CALCULATIONS FROM COD

Example for Ice Cream

Materials	lbs of product	lb COD/lb product	lbs COD processed	$/lb COD
Cream				
Milk				
Buttermilk powder				
Whey powder				
Condensed skim				
Egg yolk solids				
Starch				
Sucrose				
Corn syrup				
Fructose				
Chocolate				
Citric acid				
TOTAL				

COD is based on product analysis/lbs COD + lbs product x 1 COD/lb product

Yield calculations:

A. lbs of COD processed _____

B. lbs COD down the drain _____

C. lbs COD/100 lbs processed [A/(B/100)] _____

D. % loss + C x 100 _____

E. Yield = 100 - D _____

APPENDIX D1

COMPUTER MODELING OF DAIRY PLANT WASTEWATER

A linear analysis (LP) model was developed by Carawan (1977) for a combination milk, ice cream and cottage cheese plant and adapted to this study. Initially an attempt was made to use the Carawan model by adding processes and altering input coefficients. However, when the needed additional unit process inputs were included, the model became too complex and costly to operate when looking at changes or effects in a single department. Mistakes were too easy to make and too difficult to de-bug. Therefore, four separate programs were developed:

1. Fluid milk products, including cultured products

2. Cottage cheese

3. Ice cream and stickless novelties

4. Stick novelties

The model was used to (a) determine the contributions of various factors to waste associated costs under actual and design

conditions and (b) to evaluate the cost effectiveness of proposed changes in processes or equipment to reduce water and/or product losses.

FEATURES OF MODELING

The LP model was designed to represent the Kroger dairy in Indianapolis. The objective function was minimized to select least cost of all water and waste related costs which included values for all products. An option built into the model was the ability for the plant to purchase major products that could not be optimumly processed due to costs of water or waste related parameters. The model could be used to determine effect of actual or proposed restrictions on any parameter on the plant operation, or effect of changes in unit processes.

The model:

The model contains all of the necessary processes to treat and or dispose of all waste streams generated in all unit processes. An array of alternatives is provided for each function to allow plant configuration and to adapt changes in operating conditions, product mix and or effluent discharge alterations.

The model was run using International Business Machines

ROWS	ACTIVITIES: Product Inputs X_a	Product Inputs X_b	Production Processes X_c	Production Processes X_d	Production Processes X_e	Production Processes X_f	Product X_g	Water Supply X_h	Sewer Discharge X_i	Waste Parameter X_j	Product Loss X_k	Product Recovery X_l	Use of Recovered Product X_m	Collection X_n	Animal Feed Sales X_o	Truck Disposal X_p		RHS Constraints
a. Input availability	-1	-1	1										-1				=	b_a
b. Product mix requirement	a_{ba}	$-a_{bb}$	a_{bc}										$-a_{bm}$				≥	b_b
c. Transfer, X_c to X_d			$-a_{cc}$	1													≤	b_c
d. Transfer, from X_d				$-a_{dd}$	1	1											≤	b_d
e. Transfer, to X_g					$-a_{ee}$	$-a_{ef}$	1										≤	b_e
f. Minimum production							.001										≥	b_f
g. Water use			a_{gc}	a_{gd}	a_{ge}	a_{gf}		-1000									=	b_g
h. Sewer discharge			$-a_{hc}$	$-a_{hd}$	$-a_{he}$	$-a_{hf}$			1000								=	b_h
i. Waste discharge			$-a_{ic}$	$-a_{id}$	$-a_{ie}$	$-a_{if}$				1000							=	b_i
j. Product loss			$-a_{jc}$	$-a_{jd}$	$-a_{je}$	$-a_{jf}$					1000						=	b_j
k. Maximum waste concentration									-CF	.1199							≤	b_k
l. Product recovery			$-a_{lc}$	$-a_{ld}$	$-a_{le}$	$-a_{lf}$						1					≤	b_l
m. Non-sanitary recovery			$-a_{mc}$	$-a_{md}$	$-a_{me}$	$-a_{mf}$								1			≤	b_m
n. Transfer, to X_m												-1	1				≤	b_n
o. Transfer of collected materials														-1	1	1	=	b_o
OBJECTIVE FUNCTION	c_a Costs of inputs	c_b				c_f cost of alternative process		c_h cost of water		c_j Cost for waste discharge		c_l Cost of recovery system		c_n Cost of collection system	$-c_o$ Value of sales	c_p Cost for disposal	=	f(minimize)

CF = Wastewater parameter restriction factor = Concentration (mg/l)/1,000,000

Table 55. Representative Segment of Case Study Plant Model. (from Carawan 1977)

Corporation (IBM 370/165) computer using the Mathematical Programming System (MPS)/360(A-CO-14X) version 2. The use of LP and the MPS/360 package is described in IBM manuals. The date of input format is completely described in the IBM manuals and will not be included in this report. Specific adaptions of the MPS/360 package are detailed by McCallister (1973).

The model is available on computer cards in The Data Matrix. The Data Matrix for the model used in this study is in Appendix L showing description of rows and columns.

Information needed for the model included definition of activities, activity coefficients, costs coefficients with the objective function, internal restrictions for the activities an external restrictions for the model. A representative section of the model is presented in Table 55. A complete overview of one of the models (novelties) is presented as the computer pictures output at the end of this appendix.

Objective function. The objective of the model, as presented, was to select the least cost of all water and waste related activities including raw product' costs. These are shown in Table 55 as the OBJECTIVE FUNCTION (1) and the costs coefficient (C-j's). Cost minimization was chosen for the solutions; i.e. any solution identifies the minimum I=1 (or Sum) C-j for the activities presented to satisfy both the internal and

external model restraints.

The objective function shown in Table 55 includes the cost inputs (C-a and C-b), the increased cost of the process alternative (C-i), the cost of water (C-h), the cost for waste discharge (C-j), the increased cost of the recovery system (C-l), the increased cost of the collection system (C-n), the cost of animal feed sales (C-o), and the cost of transport.

Restrictions. The restrictions are shown in Table 55 as the right hand sides (RHS) which are indentified for each row with a quality or any quality and a value is given as the L-i's. Internal restrictions inherent in the manufacturing processes have vis vi = 0; while external restrictions have L-i equal to some value. A less than (L) restriction was used to make supply greater than demand except for certain selectant transfers like buttermilk, mix of blend activities, water use, sewer discharge, BOD_5, suspended solids, and TDS transfers which needed to be equalities for the model to function.

Activities. The activities (ACTIVITIES) for the section of the model are shown in Table 55 and are fully described in Appendix B.

The process activities include the supply or production inputs of raw materials (X-a, X-b), recovered materials used for

product (X-m), the process sequence involving first a blend or mix process (X-c) followed by two production processes (X-d and X-e) and an alternative process for X-c(X-f) which combine to give product (X-g). For each of the production processes, the activity coefficients (X-ij values) specify the use or contribution of that activity to water, waste, wastewater, product loss, product recovery and transfer of the product to the next sequential activity. Other activities shown in Table 55 are water supply (X-h), sewer discharge (X-i), waste parameter discharge (X-j), product loss (X-k), sanitary products recovery (X-l), use of sanitarily recovered products (X-m), collection of water - product mixtures (X-n) for disposal as animal feed (X-o), or transportation (X-p).

Rows: Illustration of rows as given in Table 55 to equate the linear relationship of the activity to the activity coefficients and the right hand sides (Rhs's). This illustration shows that the rows include input availability a), product mix (b), product transfers (c, d, e, n and o), product reduction requirement (f), water supply use (g), sewer discharge contribution (h), waste discharge (i), product loss (j) maximum waste restriction (k), product recovery (l), and non-sanitary recovery (m). The inequality restricts the activity of each row subject to the equality or inequality restraint place on that row.

Coefficients for the model:

Cost Coefficients: cost coefficients (C-j) for product inputs, sales, purchases and disposal activities were estimated for design purposes using data from the Kroger dairy. Coefficients for actual situations were obtained from the studies at the Kroger dairy.

Activity coefficients: the developement of the activity coefficients (a-ij's) proceeded as follows. A consistently signed convention was followed in that a negative sign was a sign to the activity coefficients for any activity supplying something to another activity; i.e. water supply as an activity coefficient of 1,000 for the water supply activity in row (d) in Table 55. The unit activity coefficients were determined by examining the units of activities and making unit consistency for the rows. The activities had units of pounds (16).

Acceptable water and sewer activities which are given in gallons (gal). Activity coefficients were expressed in pounds per pound except the water use, sewer discharge, product loss, BOD discharge, suspended solids discharge and FOC discharge. Water use and sewer discharge activity coefficients were expressed as gallons per thousand pounds of activity. Product loss, BOD discharge, suspended solids and FOC discharge activity

coefficients were expressed pounds per thousands pounds of activity.

A special case was used for the product transfer coefficients or product was lost in the activity. In these cases, the transfer coefficient from that activity was developed by subtracting the absolute value of the lost activity coefficient (pounds per thousand pounds) divided by a thousand pounds from one. For example, in Table 31, production activity X-e has a loss coefficient (A-je) which is divided by 5,000 and subtracted from one equals one minus A-je over one thousand (1 - A-je over 1,000). This expression equals the coefficient for the product from X-e to X-g of A-ee.

Model Limitations:

The model is first limited by the analysis method chosen. Even though LP is a very powerful tool for management to consider alternative approaches to water and waste reduction, the inherent limitations of LP must be considered. First, the use of LP requires a linear equation for each particular combination of activities. In actual practice, all activities in a dairy plant may not always have a linear relationships.

Next the formation of objective function costs (C-j values) often required assumptions to be made about projected

costs and depreciation. For the purpose of this study, costs were pro-rated over a 1.5 year depreciation.

A major limitation is a lack of specific information for a given plant situation of coefficients to be applied to the model. However, the utilization of best estimates available have been shown to be of value in other application.

Another limitation of the model is a difficulty in incorporating individually a number of small activities. Examples include CIP systems, COP systems, and water station uses. If information were specifically available these activites could be individually incorporated in the model, but would require considerable model expansion. They are currently incorporated as a portion of the coefficient of each activity using the function.

Dairy plant management in general may not be in a position to directly utilize the model without outside assistance. However, once the model has been formulated, any dairy manager may be able to obtain useful information. Not only waste related, but other aspects that impinge upon management decisions.

Table 56. Raw Products Codes

Code	Raw Products
BO	Butteroil
BP	Buttermilk powder
CA	Chocolate based additive
CM	Cream
CS	Condensed skim
FC	Fruitade concentrate
FN	Fruits and nuts
IG	Ingredients other than those specified
LC	Corn syrup
LS	Cane sugar, liquid
LU	Lubricants
RE	Ice cream remelt
RH	Recovered product, high solids
RM	Raw milk
RT	Returns
WH	Whey
WO	Water for other uses
WP	Product water

Table 57. Operations, Activities and Process Codes.

Code	Operation, Activity or Process
AF	Continuous Freezers
BG	Bag
BL	Blend
CL	Buy
CO	Clarify
CU	Cool Culture
CV	Convey
CX	COP, Clean out of place in vat
DC	Discharge
DR	Drain cottage cheese whey
FF	Fill
FN	Fruit and nuts feeder, IC
HA	Heat
HL	HTST, long holding tube
HO	Homogenize
HS	Hose Stations
HT	High temperature, short, time
PR	Separate
ST	Starter preparation
RC	Receiving
RT	Product returns
SF	Store, packaged product
SH	Ship
SL	Sell
SP	Pasteurized, store processed
ST	Store, raw
SV	Save
TR	Transport, pump
US	Use
VC	Vat cooling
VF	Cita free
WA	Wash cottage
W1	First was, cottage cheese
W2	Second wash, cottage cheese
W3	Third wash, cottage cheese
ZZ	Freeze

Table 58. Processed Product Codes.

Code	Processed Products
AF	Animal food
BM	Buttermilk
BOD	BOD_5
CC	Cottage cheese, dressed
CD	Curd, cottage cheese
CH	Chocolate
CR	Cream
DR	Drinks
DS	Dressing
FA	Fruitade
FB	Fudge bar
FL	Fat loss
FM	Fluid milk products
FN	Fines
FP	Fluid products
HO	Homogenized
IB	ice milk bar
IC	Ice cream
IP	Ice pop
IM	Ice milk
IR	Frozen products
lf	Low fat
ls	Loss
OJ	Orange juice
RH	Recovered product, high solids
SC	Sour cream
SK	Skim
SR	Starter
SS	Suspended Solids
SO	Storm sewer
SW	Sewer, sanitary
TP	Total products
WH	Whey
WW	Wash water

Table 59. Description of Vectors for Basic Solution (Columns)

Code	Activity	Unit of Activity
BUYWAT	Potable water buying and supplying for use	lb
RMRC	Raw milk receiving	lb
RMPR	Raw milk separating	lb
RMUS	Raw milk use	lb
SMUS	Skim milk use	lb
CMUS	Cream use	lb
WHUS	Whey use	lb
CSUS	Condensed skim use	lb
LCUS	Liquid corn syrup use	lb
LSUS	Liquid cane sugar use	lb
FCUS	Fruitade concentrate use	lb
SBUS	Stabilizer use	lb
OCUS	Orange juice concentrate use	lb
IGUS	Ingredients use	lb
CAUS	Chocolate based additive use	lb
BPUS	Buttermilk powder use	lb
BOUS	Butteroil use	lb
REUS	Ice cream remelt use	lb
TOTPRODS	Total products processed	lb
SURCHB	Paying for BOD_5 in effluent	lb
FOG	Accumulation of fats, oils and greases lost during processing	lb
STORMSEW	Discharge of effluents to storm sewer	gal
SANSEWER	Discharge of products and process water to sanitary sewer	gal
CCCMUS	Use of cream for preparation of cottage cheese dressing	lb
CCST	Preparation for use of cottage cheese starter	lbs
CCHT	Pasteurization of skim for cottage cheese by HTST	lb
CCCU	Process processing skim milk into cottage cheese curd	lb
CCWA	Process of draining the whey, washing the cottage cheese curd and fines loss	lb
CCVC	Cooling of cottage cheese curd	lb
CCBL	Blending of cottage cheese curd and dressing	lb
CC	Creamed cottage cheese	lb
CCDS	Blending of cottage cheese dressing	lb
CCFF	Filling of creamed cottage cheese	lb
CCDR	Cottage cheese drain	
CCW1	Cottage cheese wash 1	
CCW2	Cottage cheese wash 2	
CCW3	Cottage cheese wash 3	

Table 59. continued

Code	Activity	Unit of Activity
SCHO	Homogenization of sour cream mix	lb
SCVC	Vat cooling of sour cream mix	lb
SCCU	Culturing of sour cream mix	lb
SCST	Storage of sour cream	lb
SCTR	Pumping of sour cream to fillers	lb
SCFF	Filling of sour cream	lb
SCCV	Conveying sour cream including casing	lb
SCSF	Storage of sour cream in cooler	lb
FABL	Blending of concentrate, sugar and water to make fruitade	lb
FAVC	Vat cooling of fruitade	lb
FAFF	Filling of fruitade	lb
FASF	Storage in cooler of fruitade	lb
FACV	Conveying filled containers of fruitade through casers and stackers	lb
FAWPUS	Use of product water for dilution of fruitade concentrate	lb
FALSUS	Use of liquid sugar in fruitade	lb
FPFCUS	Use of fruitade concentrate in fluid milk processing	lb
FAFCUS	Use of fruitade concentrate in fruitade processing	lb
OJBL	Blending of orange juice concentrate and water in vat	lb
OJVC	Cooling of orange juice in vat	lb
OJFF	Filling of orange juice	lb
OJCV	Conveying filled containers through casers and stackers	lb
OJSF	Storage of orange juice	lb
OJWPUS	Potable water used for dilution of orange juice concentrate	lb
OJOCUS	Orange concentrate use for orange juice	lb
ICWPUS	Use of water for dilution of ice cream ingredients	lb
ICCMUS	Use of cream in ice cream	lb
ICSMUS	Use of skim milk in ice cream	lb
ICRMUS	Use of raw milk in ice cream	lb
ICWMUS	Use of neutralized whey in ice cream	lb
ICLSUS	Use of liquid cane in ice cream	lb
ICLCUS	Use of liquid corn syrup in ice cream	lb
ICCSUS	Use of condensed skim milk in ice cream	lb
ICSBUS	Use of stabilizer in ice cream	lb
ICBPUS	Use of buttermilk powder in ice cream	lb

Table 59. continued

Code	Activity	Unit of Activity
CCSF	Storage of filled cottage cheese containers	lb
DSSMUS	Skim milk use for cottage cheese dressing	lb
BMSMUS	Skim milk use in buttermilk	lb
BMCMUS	Cream use in buttermilk	lb
BMBL	Blending of buttermilk ingredients	lb
BMST	Production of buttermilk starter	lb
BMVP	Vat pasteurization of milk for buttermilk	lb
BMCU	Culturing skim and starter to make buttermilk	lb
BMVC	Vat cooling of buttermilk	lb
BMTR	Transfer of buttermilk from vat to fillers	lb
BMFF	Filling of buttermilk	lb
BMCV	Conveying, casing and stacking of buttermilk containers	lb
BMSF	Storage of cased buttermilk in cooler	lb
FMILK	Fluid milk products	lb
BUYFM	Buying of cartoned fluid milk products	lb
FMSMUS	Skim milk use for fluid milk products	lb
FMCMUS	Cream use for fluid milk products	lb
FMBL	Blend for fluid milk products	lb
FMHT	HTST pasteurization of fluid milk products	lb
FMSP	Pasteurized storage of fluid milk products	lb
FMFF	Filling of fluid milk products	lb
FMCAUS	Chocolate additive use for fluid milk products	lb
FMCSUS	Condensed skim use for fluid milk products	lb
FMLCUS	Liquid corn syrup use for fluid milk products	lb
FMCV	Conveying, casing and stacking of filled fluid milk products	lb
FMSF	Storage of fluid milk products	lb
SCCMUS	Cream use for sour cream	lb
SCSMUS	Skim milk use for sour cream	lb
SCCSUS	Condensed skim use for sour cream	lb
SCSBUS	Stabilizer use for sour cream	lb
SCBL	Blending of sour cream ingredients	lb
SCVP	Vat pasteurization of sour cream mix	lb

Table 59. continued

Code	Activity	Unit of Activity
ICBOUS	Use of butteroil in ice cream	lb
RHUS	Use of recovered product-high solids for ice cream	lb
REUS	Use of ice cream remelt for ice cream	lb
ICBL	Blending of ice cream ingr nts in a vat	lb
ICHT	HTST processing of ice cream mix	lb
ICSP	Vat storage of ice cream for aging and flavoring	lb
ICAF	Partial freezing of ice cream in continuous freezers	lb
ICTRF	Transfer of frozen ice cream	lb
ICFN	Fruit, nuts and flavor addition to ice cream	lb
ICFF	Filling of ice cream	lb
ICZZ	Hardening of filled packages of ice cream in plate unit	lb
ICSF	Storage of ice cream in -20F frozen storage	lb
ICBY	Buying of ice cream	lb
IC	Ice cream	lb
OTHER	Ancillary activities for plant including offices, garage, refrigeration systems, air supply system, etc.	lb
IPSU	Ice pop sugar use	lb
IPBL	Ice pop blend	lb
IPHT	Ice pop heating	lb
IPVF	Ice pop freezing	lb
IPBG	Ice Pop bagging	lb

Table 60. Description of Vectors (Rows) for CASESTUD

TYPE	ROW NAME	DESCRIPTION	UNIT
L	MAXFOG	FOG transfer	lb
L	MAXBOD	BOD transfer	lb
L	GOODRTTR	Good return transfer	lb
L	COLLTR	Transfer from COLLECT	lb
L	RECRHTR	Transfer from HISOLID	lb
L	BADRTTR	Bad return transfer	lb
L	DRIPTRIC	Drip collection transfer from ice cream	lb
L	RHTRFM	Fluid filler recovery transfer	lb
L	DRIPTRFM	Fluid filler drip transfer	lb
L	RMRCBTR	Clarifier sludge recovery transfer	lb
L	WHEYTR	Whey transfer	lb
L	REMELT	Remelt transfer	lb
L	FMHTASTR	HTST recovery transfer	lb
N	OBJ	Objective function	$
G	LOSSTRIC	Ice cream loss transfer	lb
L	BLTRIC	Ice cream transfer from blend	lb
L	HTTRIC	Ice cream transfer from HTST	lb
L	SPTRIC	Ice cream transfer from surge	lb
L	TRMTRIC	Ice cream transfer from pumping	lb
L	FNTRIC	Ice cream transfer from feeder	lb
L	AFTRIC	Ice cream transfer from freezer	lb
L	TRFTRIC	Ice cream transfer from pumping	lb
L	FFTRIC	Filled ice cream transfer	lb
L	STORIC	Ice cream transfer to storage	lb
L	FNTR	Fruit and nut transfer	lb
L	MAXWHSIC	Whey solids restriction for ice cream	lb
L	MAXIC	Product restriction for ice cream	1000 lb
G	MINIC	Product restriction for ice cream	1000 lb
L	MAXBPIC	Buttermilk powder restriction for ice cream	lb
E	WEIGHTIC	Ice cream b' nd transfer	lb
E	ICTR	Ice cream transfer	lb
L	MAXLACIC	Lactose restriction for ice cream	lb
L	MAXCRNIC	Corn syrup solids restriction for ice cream	lb
L	MAXTSIC	Solids restriction for ice cream	lb
G	MINSUGI	Sugar restriction for ice cream	lb
G	MINSBIC	Stabilizer restriction for ice cream	lb
G	MINMSNFI	Solids restriction for ice cream	lb
G	MINMFIC	Fat restriction for ice cream	lb
L	STOREOJ	Orange juice transfer to storage	lb
L	FFTROJ	Orange juice transfer from filling	lb
L	VCTROJ	Orange juice transfer from vat cooling	lb
L	BLTROJ	Orange juice transfer from blend	lb

Table 60. continued

TYPE	ROW NAME	DESCRIPTION	UNIT
E	WTOJ	Orange juice blend transfer	lb
G	MINOC	Orange juice concentrate restriction	lb
L	MAXOC	Orange juice concentrate restriction	lb
G	MINOJ	Orange juice production restriction	1000 lb
L	MAXOJ	Orange juice production restriction	1000 lb
L	MAXFCFA	Fruit Concentrate restriction	lb
L	MAXLSFA	Sugar restriction	lb
G	MINFCFA	Fruit concentrate restriction	lb
G	MINLSFA	Sugar restriction	lb
E	WTFA	Fruitade blend transfer	lb
L	BLTRFA	Fruitade transfer from blend	lb
L	VCTRFA	Fruitade transfer from vat cooling	lb
L	STOREFA	Fruitade transfer to storage	lb
L	MAXFA	Fruitade production restriction	1000 lb
G	MINFA	Fruitade production restriction	1000 lb
E	FOGTR	FOG transfer	lb
E	BOD5	BOD_5 transfer	lb
E	SEWERTR	Sanitary sewer transfer	gal
G	LOSSTRFM	Fluid milk loss transfer	lb
G	LOSSTRRM	Raw milk loss transfer	lb
L	MAXSUGFM	Sugar restriction for fluid milk	lb
G	MINSUGFM	Sugar restriction for fluid milk	lb
L	MAXBFFM	Fat restriction for fluid milk	lb
G	MINBFFM	Fat restriction for fluid milk	lb
L	MAXMSFM	Milk solids restriction for fluid milk	lb
G	MINMSFM	Milk solids restriction for fluid milk	lb
L	MAXCAFM	Chocolate additive restriction for fluid milk	lb
G	MINCAFM	Chocolate additive restriction for fluid milk	lb
E	MIXFM	Fluid milk blend transfer	lb
L	BLTRFM	Fluid milk transfer from blend	lb
L	HTTRFM	Fluid milk transfer from HTST	lb
L	SPTRFM	Fluid milk transfer from surge	lb
L	FFTRFM	Fluid milk transfer from filling	lb
L	STORFM	Fluid milk transfer to storage	lb
L	FMTOT	Fluid milk transfer	lb
G	MINFM	Fluid milk production restriction	1000 lb
L	MAXFM	Fluid milk production restriction	1000 lb
L	MAXSBSC	Sterilizer restriction from sour cream	lb
E	MIXSC	Sour cream blend transfer	lb
L	BLTRSC	Sour cream transfer from blend	lb
L	TRTRSC	Sour cream transfer from pumping	lb

Table 60. continued

TYPE	ROW NAME	DESCRIPTION	UNIT
L	CUTRSC	Sour cream transfer from culture	lb
L	VPTRSC	Sour cream transfer from vat pasteurization	lb
L	HOTRSC	Sour cream transfer from homogenization	lb
L	FFTRSC	Sour cream transfer from filling	lb
L	STORSC	Sour cream transfer to storage	lb
G	MINSTSC	Starter restriction for sour cream	lb
E	WTSC	Blend transfer for sour cream	lb
L	MAXSNFSC	Solids restriction for sour cream	lb
G	MINSNFSC	Solids restriction for sour cream	lb
G	MINSBSC	Stabilizer restriction for sour cream	lb
G	MINFSC	Fat restriction for sour cream	lb
G	MINFSC1	Fat restriction for sour cream	lb
G	MINSC	Sour cream production restriction	1000 lb
L	MAXSC	Sour cream production restriction	1000 lb
G	MINBM	Buttermilk production restriction	1000 lb
E	MIXBM	Buttermilk blend restriction	lb
G	MINSTBM	Starter restriction for buttermilk culture	lb
L	MAXSTBM	Starter restriction for buttermilk culture	lb
G	MINFBM	Fat restriction for buttermilk culture	lb
E	BLTRBM	Buttermilk transfer from blend	lb
E	WTBM	Buttermilk blend transfer	lb
L	MAXBM	Buttermilk production restriction	1000 lb
E	FFTRBM	Buttermilk transfer from filling	lb
E	TRTRBM	Buttermilk transfer from pumping	lb
E	VCTRBM	Buttermilk transfer from vat cooling	lb
E	CUTRBM	Buttermilk transfer from culture	lb
E	STORBM	Buttermilk transfer from conveying	lb
E	RCTRRM	Raw milk transfer from receiving	lb
L	PRTRCM	Cream transfer from separation	lb
L	PRTRSM	Skim transfer from separation	lb
E	TOTPRODT	Total products transfer	lb
G	SSEWTR	Sanitary sewer transfer	lb
L	POTWATER	Potable water transfer	gal
G	LOSSTRCC	Cottage cheese loss transfer	lb
E	TPTR	Total products transfer	lb
L	STABIL	Stabilizer transfer	lb
L	SKIM	Skim transfer	lb
L	RAWMILK	Raw milk transfer	lb
L	ORANGEC	Orange concentrate transfer	lb

Table 60. continued

TYPE	ROW NAME	DESCRIPTION	UNIT
L	LCORNSUG	Corn syrup transfer	lb
L	LCANESUG	Sugar transfer	lb
L	INGRED	Ingredient transfer	lb
L	FRUITCON	Fruitade concentrate transfer	lb
L	CREAM	Cream transfer	lb
L	CONDSKM	Condensed skim transfer	lb
L	CHOCING	Chocolate ingredient transfer	lb
L	BUTTOIL	Butteroil transfer	lb
L	BUTMPOWD	Buttermilk powder transfer	lb
L	FRUITNUT	Fruit and nut transfer	lb
L	CCMAXFDS	Fat restriction for dressing	lb
G	CCMINFDS	Fat restriction for dressing	lb
G	CMINTSDS	Solids restriction for dressing	lb
L	CMAXTSDS	Solids restriction for dressing	lb
E	CCWTDS	Dressing transfer	lb
L	MAXCC	Production restriction for cottage cheese	1000 lb
G	MINCC	Production restriction for cottage cheese	1000 lb
L	CCBYTR	Buy cottage cheese transfer	lb
L	STORCC	Filled cottage cheese transfer to storage	lb
L	MAXFCC	Fat restriction for cottage cheese	lb
G	MINFCC	Fat restriction for cottage cheese	lb
E	WTCC	Equality restriction for cottage cheese	lb
G	CCMINST	Starter restriction	lb
L	CCMAXST	Starter restriction	lb
E	CCSET	Culture transfer	lb
L	YIELDCC	Curd yield transfer	lb
L	WATRCC	Curd transfer from washing	lb
L	BLTRCC	Cottage cheese transfer from blend	lb

Table 61 Example of Computer Print Out for Novelty Operations

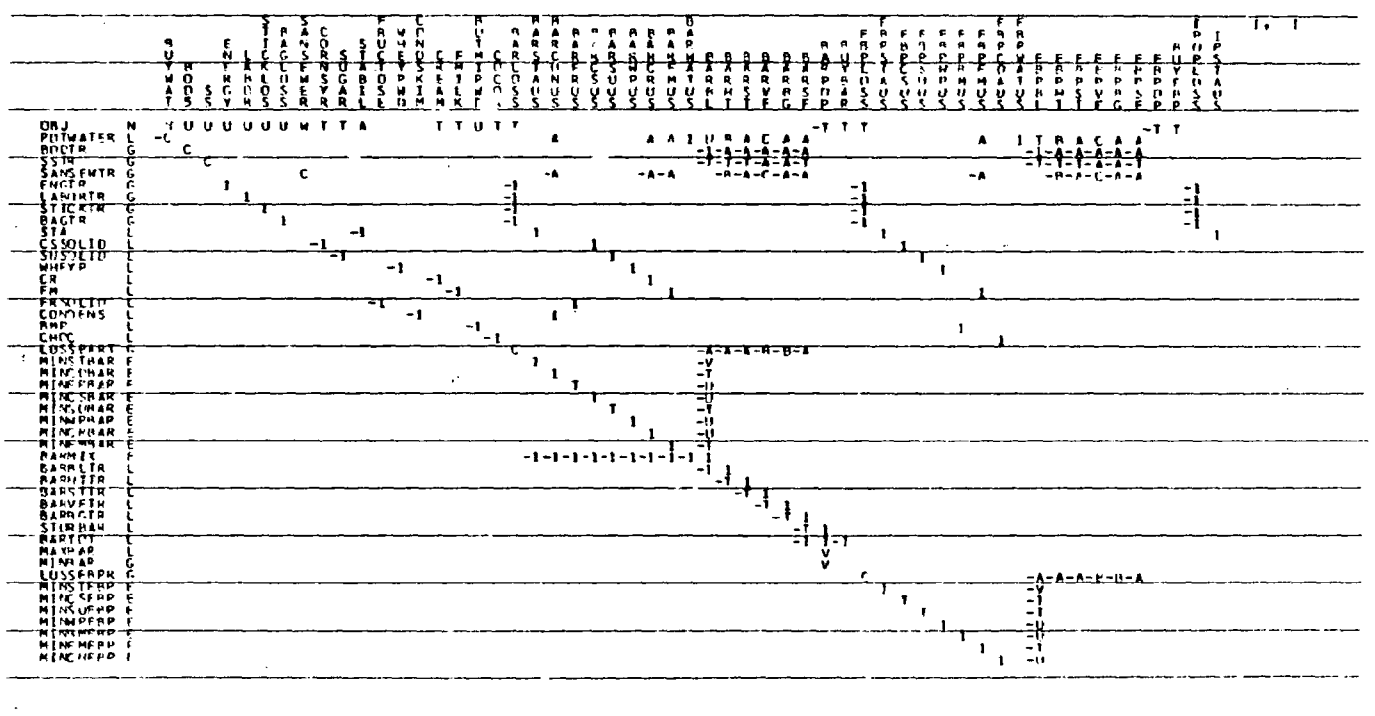


Table 61. Continued: Page 2 of 12 pages

		AVWADS	SSGY	FENERGY	LARHOOK	STICKLOS	SANSFWR	CURNOSGR	SIALIE	FUCTIONED	WHEYSWD	CONSKIMM	CEMIALK	EMILIWD	HYMICOCA	CALSUS	RARSTAUS	PAPCHNUS	KAAKFRUS	RAANCSUS	RAARKSUS	RAARKWUS	RAARKFMUS	HARWATHUS	RAAMPAL	RAARRIT	RAARSVE	RAARSGE	RAARSOF	RAKPAPR	RAUPAOR	FRPLOSS	FRPSTAUS	FRPCSUUS	FRPSWUUS	FRPWRUUS	FRPMUUS	FRPFOUS	FRPCAUS	FRPWATUS	FERPIL	FERHSTI	FERPVE	FERPGE	FERUSE	FERPUP	AYFORUS	IPCLUS	IPSTAUS
FBPMIX	E																																														
FBPMITR	L																															-1	-1	-1	-1	-1	-1	-1	-1	1								
FBPMTTR	L																																							-1	1							
FBPSTTR	L																																								-1	1						
FBPVFTR	L																																										-1	1				
FBPRGTR	L																																											-1	1			
STORFBP	L																																												-1	1		
FRPTOT	L																																													-1	1	
MAXFRP	L																																														1	-1
MINFRP	G																																														V	
LOSSTOIP	G																																														V	
MINCSIP	G																																															C
MAXCSIP	L																																															
MAXSUIP	L																																															
MINSUIP	G																																															
MINSTAUS	G																																															V
IPCMIX	E																																															-1
IPCMTTR	L																																															
IPCMTTR	L																																															
IPCMVFTR	L																																															
IPCMRGTR	L																																															
STORIPCM	L																																															
IPCMTOT	L																																															
MAXIPMP	L																																															
MINIPMP	G																																															

Table 61. Continued. Page 3 of 12 pages

| | | |

Table 61 Continued. Page 4 of 12 pages

		IPCSUS	IPSHUS	MATRUS	IPPUMP	IPPHST	IPPVFT	IPPRCL	IPPSFP	IPPDP	RUYIPP	RHSI	2. 2
FBPMIX	L												
FBPMLTR	L												
FBPMTTR	L												
FBPVFTR	L												
FBPRCTR	L												
STIMFMP	L												
FBPTMT	L												
MAXFMP	L											R	
MINFMP	C											R	
LOXSTRIP	C			-T-R-O-R-R-A									
MINCSTP	L	T		-U									
MAXCSTP	L	T		-V									
MAXSUMP	L		T	-Y									
MINSUMP	L		T	-Y									
MINSTRUS	C			-V									
IPIPMIX	L	-I-I-I-I			I								
IPIPMLTR	L			-I		I							
IPIPMTTR	L				-I	I							
IPIPSTTR	L					-I	I						
IPIPVFTR	L						-I	I					
IPIPRCTR	L							-I	I				
STIMIPMP	L								-I	I			
IPIPTMT	L									-I	I-I		
MAXIPMP	L										V	R	
MINIPMP	C										V	R	

Table 61 Continued. Page 5 of 12 pages

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SUMMARY OF MATRIX

SYMBOL	RANGE		COUNT (INCL.RHS)
Z	LESS THAN	.000001	
Y	.000001 THRU	.000009	
X	.000010	.000099	1
W	.000100	.000999	2
V	.001000	.009999	9
U	.010000	.099999	18
T	.100000	.999999	66
I	1.000000	1.000000	112
A	1.000001	10.000000	52
R	10.000001	100.000000	23
C	100.000001	1,000.000000	13
O	1,000.000001	10,000.000000	1
E	10,000.000001	100,000.000000	
F	100,000.000001	1,000,000.000000	
G	GREATER THAN	1,000,000.000000	

Table 61 Continued. Page 6 of 12 pages

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NAME DAIRYMAN

ROWS

N	OBJ
L	RCTWATER
G	RCOTR
G	SSTR
G	SANSEWTR
G	LANDTR
G	STICKTR
G	RACTR
L	STA
L	CSSOLID
L	SUSOLID
L	WRKYR
L	CR
L	FM
L	FRSOLID
L	CENTERS
L	RMP
L	CRPC
G	LOSSRANT
E	MINSTRED
E	MINCORAN
E	MINFKRAR
E	MINSCRAN
E	MINSURAR
E	MINWRRAR
E	MINCRRAP
E	MINFMRAN
E	RARMTX
L	RARHLTR
L	RARHTTR
L	RARSTTR
L	RARVETTR
L	RARRGTR
L	STORRAR
L	RARTOT
L	MAXDAR
G	MINRAN
G	LOSSFRPN
E	MINSTFRP
E	MINCSTFP
E	MINSUFRP
E	MINWFRP
E	MINRMFRP
E	MINCMFRP
E	FRPMTX
L	FRPHLTR
L	FRPHTTR
L	FRPSTTR
L	FRPVETTR
L	FRPRGTR

Table 61 Continued. Page 7 of 12 pages

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```
L  STOPERP
L  ERRTOT
L  MAXERR
G  MINERR
G  LOSSTOTP
G  MINCSTP
L  MAXCSTP
L  MAXSOTP
G  MINSOTP
G  MINSTATS
E  IPOPMTX
L  IPOPALTP
L  IPOPRATTR
L  IPOPSTTR
L  IPOPVETR
L  IPOPRGTR
L  STORTOP
L  IPOPTOT
L  MAXTPOP
G  MINTPOP
COLUMNS
    RUNDAT    OBJ            .00642   PUTWATER  - 1000.00000
    RUNTR     RUNTR       1000.00000  OBJ            .02400
    SS        SSTR        1000.00000  OBJ            .04500
    ENERGY    ENGTR          1.00000  OBJ            .02000
    LABOR     LABORTR        1.00000  OBJ            .00000
    STICKERS  STICKTR        1.00000  OBJ            .16400
    RAGLOSS   RAGTR          1.00000  OBJ            .12000
    SANSEWTR  SANSEWTR       1000.00000 OBJ          .00045
    CONSYR    OBJ             .19000  CSSOLID   -    1.00000
    SUGAR     OBJ             .18000  SUSOLID   -    1.00000
    STARTL    OBJ            1.15000  STA       -    1.00000
    FRUCTOSE  FRSOLID     -  1.00000
    WHEYPWD   WHEYP       -  1.00000
    CONDSRIM  CONDENS     -  1.00000
    CREAM     CR          -  1.00000  OBJ            .36000
    EMILK     OBJ             .11200  EM        -    1.00000
    BUTTPWD   OBJ             .04500  BMP       -    1.00000
    CHOC      OBJ             .00000  CHOC      -    1.00000
    BARLOSS   OBJ             .46600  ENGTR     -    1.00000
    BARLOSS   STICKTR     -  1.00000  RAGTR     -    1.00000
    BARLOSS   LABORTR     -  1.00000  LOSSHART      1000.00000
    BARSTATS  STA            1.00000  MINTTRAP       1.00000
    BARSTATS  BARMIX      -  1.00000
    BARCONDS  PUTWATER       2.00000  SANSEWTR  -    2.00000
    BARCONDS  CONDENS        1.00000  MINCOPAR       1.00000
    BARCONDF  BARMIX      -  1.00000
    BARFONS   FRSOLID        1.00000  MINFOPAR        .85000
    BARFONS   BARMIX      -  1.00000
    BARCSUS   CSSOLID        1.00000  MINCSPAR        .95000
    BARCSUS   BARMIX      -  1.00000
    BARSUUS   SUSOLID        1.00000  MINSUPAR        .67000
    BARSUUS   BARMIX      -  1.00000
    BARWPUS   WHEYP          1.00000  MINWPPAR       1.00000
```

Table 61 Continued. Page 8 of 12 pages

Table 61 Continued. Page 9 of 12 pages

[illegible]	[illegible]	-	1.00000			
[illegible]	[illegible]		1.00000	[illegible]		1.10000
[illegible]	[illegible]	-	1.00000			
[illegible]	[illegible]		1.00000	[illegible]	-	1.00000
[illegible]	[illegible]		.43000	[illegible]	-	1.00000
[illegible]	[illegible]	-	.60000	[illegible]	-	10.00000
[illegible]	[illegible]	-	.00000	[illegible]	-	.14000
[illegible]	[illegible]	-	.14000	[illegible]	-	.01000
[illegible]	[illegible]	-	.69000	[illegible]	-	.12000
[illegible]	[illegible]	-	.03000	[illegible]		1.00000
[illegible]	[illegible]	-	.00000			
[illegible]	[illegible]		50.00000	[illegible]	-	1.33000
[illegible]	[illegible]	-	.50000	[illegible]	-	90.00000
[illegible]	[illegible]	-	10.00000	[illegible]		1.00000
[illegible]	[illegible]	-	.00000			
[illegible]	[illegible]		5.00000	[illegible]	-	2.00000
[illegible]	[illegible]	-	.00000	[illegible]	-	5.00000
[illegible]	[illegible]	-	10.00000	[illegible]		1.00000
[illegible]	[illegible]	-	.00000			
[illegible]	[illegible]		400.00000	[illegible]	-	10.00000
[illegible]	[illegible]	-	4.20000	[illegible]	-	800.00000
[illegible]	[illegible]	-	50.00000	[illegible]		1.00000
[illegible]	[illegible]	-	.95000			
[illegible]	[illegible]		3.00000	[illegible]	-	10.00000
[illegible]	[illegible]	-	4.20000	[illegible]	-	4.00000
[illegible]	[illegible]	-	50.00000	[illegible]		1.00000
[illegible]	[illegible]	-	.95000			
[illegible]	[illegible]		2.00000	[illegible]	-	2.00000
[illegible]	[illegible]	-	.80000	[illegible]	-	2.00000
[illegible]	[illegible]	-	10.00000	[illegible]		1.00000
[illegible]	[illegible]	-	.99000	[illegible]	-	1.00000
[illegible]	[illegible]		1.00000	[illegible]		1.00000
[illegible]	[illegible]		.00100	[illegible]		.00100
[illegible]	[illegible]	-	.49000			
[illegible]	[illegible]		.68000	[illegible]	-	1.00000
[illegible]	[illegible]	-	1.00000	[illegible]	-	1.00000
[illegible]	[illegible]	-	1.00000	[illegible]	-	1.00000
[illegible]	[illegible]		1000.00000			
[illegible]	[illegible]		.00200	[illegible]		1.00000
[illegible]	[illegible]	-	1.00000			
[illegible]	[illegible]		1.00000	[illegible]	-	1.00000
[illegible]	[illegible]		.85000	[illegible]		.85000
[illegible]	[illegible]		1.00000	[illegible]	-	1.00000
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[illegible]	[illegible]		1.00000	[illegible]	-	1.00000
[illegible]	[illegible]	-	1.00000	[illegible]		1.00000
[illegible]	[illegible]	-	1.00000	[illegible]	-	.50000
[illegible]	[illegible]	-	.00000	[illegible]	-	.22000
[illegible]	[illegible]	-	.21000	[illegible]	-	.65000
[illegible]	[illegible]	-	.05000	[illegible]		.74000
[illegible]	[illegible]	-	.99000			
[illegible]	[illegible]		.92700	[illegible]		1.00000
[illegible]	[illegible]	-	15.00000	[illegible]	-	.99000
[illegible]	[illegible]	-	.47500	[illegible]	-	.40950

Table 61 Continued. Page 10 of 12 pages


```
                FREEPOOP,    MPS/1AD V2-MII
    IPOPHT      SANSEWTR  -    75.00000
    IPOPST      POTWATER        .75000   IPCPHTTR        1.00000
    IPOPST      IPOPSTTR  -     .99000   LOPSTPTP  -  15.00000
    IPOPST      BOOTR     -    1.18000   SSTP      -    .50000
    IPOPST      SANSEWTR  -     .75000
    IPOPVE      POTWATER     1,000.00000   IPCPSTTR        1.00000
    IPOPVE      [illegible]   -   10.00000   SSTR      -   4.20000
    IPOPVE      IPOPVETR  -     .87000   LOPSTPTP  -  15.00000
    IPOPVE      SANSEWTR  -   360.00000
    IPOPRC      POTWATER      5.00000   IPOPVETR        1.00000
    IPOPRC      IPOPRCTR  -    1.00000   LOPSTPTP  -  15.00000
    IPOPRC      BOOTR     -   10.00000   SSTR      -   4.20000
    IPOPRC      SANSEWTR  -   360.00000
    IPOPSE      [illegible]TOT  -     .97000   IPOPRCTR        1.00000
    IPOPSE      [illegible]OP   -     .99700   POTWATER       21.75000
    IPOPSE      [illegible]IP   -   14.00000   BOOTP     -    1.87500
    IPOPSE      [illegible]     -     .77950   SANSEWTR  -   21.75000
    IPOP        IPOPTOT       1.00000   STOWIPOP        1.00000
    IPOP        POTWATER     20.00000   BOOTP     -    .14000
    IPOP        SSTP      -     .02000   SANSEWTR  -   20.00000
    IPOP        MINIPOP       .00100   MAXIPOP         .00100
    IPOP        BBJ       -     .99000
    MINIPOP     TPJ           .55000   IPOPTOT   -    1.00000
RHS
    RHST        MAXBAR       16.10000   MINBAR         16.00000
    RHST        MAXEHP       16.10000   MINEHP         16.00000
    RHST        MINIPOP      27.00000   MAXIPOP        27.00000
ENDATA
```

Table 61 Continued. Page 11 of 12 pages

EXECUTIVE. NPS/360 V2-M11 PAGE 27 - 19/[illegible]

NUMBER	COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	..REDUCED COST.
122	[illegible]	BS	17118.55395	.	.	NONE	.
123	[illegible]	BS	1[illegible]2.52676	.	.	NONE	.
124	[illegible]	BS	1[illegible].00000	.[illegible]0-	.	NONE	.
125	[illegible]	LL	.	.[illegible]	.	NONE	.[illegible]
126	IPCPLTSS	BS	21[illegible].52966	.	.	NONE	.
127	IPSTAUS	BS	1[illegible].14631	.	.	NONE	.
128	IPCSUS	BS	1[illegible].41198	.	.	NONE	.
129	IPSUUS	BS	10[illegible].47938	.	.	NONE	.
130	WITSUUS	BS	17[illegible].13768	.	.	NONE	.
131	IPCPNL	BS	32[illegible].92625	.	.	NONE	.
132	IPUPAT	BS	336[illegible].92625	.	.	NONE	.
133	IPUPST	BS	32317.49694	.	.	NONE	.
134	IPPPVT	BS	[illegible].31212	.	.	NONE	.
135	IPUPNL	BS	27315.05155	.	.	NONE	.
136	IPCPSE	BS	27315.05155	.	.	NONE	.
137	IPCP	BS	27000.00000	.[illegible]0-	.	NONE	.
138	RUVIPUP	LL	.	.[illegible]	.	NONE	.[illegible]

Table 61 Continued. Page 12 of 12 pages

SECTION 2 - COLUMNS

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
73	[illegible]	BS	[illegible]	[illegible]	.	NONE	.
74	[illegible]	BS	[illegible]	[illegible]	.	NONE	.
75	SS	BS	[illegible]	[illegible]	.	NONE	.
76	ENERGY	BS	[illegible]	[illegible]	.	NONE	.
77	LAMP	BS	[illegible]	[illegible]	.	NONE	.
78	STICKLOS	BS	[illegible]	[illegible]	.	NONE	.
79	[illegible]	BS	[illegible]	[illegible]	.	NONE	.
80	SANSEWER	BS	[illegible]	[illegible]	.	NONE	.
81	CONNECT	BS	[illegible]	[illegible]	.	NONE	.
82	SUPAP	BS	[illegible]	[illegible]	.	NONE	.
83	STAMIL	BS	[illegible]	[illegible]	.	NONE	.
84	[illegible]	BS	[illegible]	.	.	NONE	.
85	[illegible]	BS	[illegible]	.	.	NONE	.
86	[illegible]	BS	[illegible]	.	.	NONE	.
87	CREAM	BS	[illegible]	[illegible]	.	NONE	.
88	EMILY	BS	[illegible]	[illegible]	.	NONE	.
89	RUTMIPWD	BS	[illegible]	[illegible]	.	NONE	.
90	[illegible]	BS	[illegible]	[illegible]	.	NONE	.
91	[illegible]	BS	[illegible]	[illegible]	.	NONE	.
92	[illegible]	BS	[illegible]	.	.	NONE	.
93	[illegible]	BS	[illegible]	.	.	NONE	.
94	[illegible]	BS	[illegible]	.	.	NONE	.
95	[illegible]	BS	[illegible]	.	.	NONE	.
96	[illegible]	BS	[illegible]	.	.	NONE	.
97	[illegible]	BS	[illegible]	.	.	NONE	.
98	[illegible]	BS	[illegible]	.	.	NONE	.
99	[illegible]	BS	[illegible]	.	.	NONE	.
100	[illegible]	BS	[illegible]	.	.	NONE	.
101	[illegible]	BS	[illegible]	.	.	NONE	.
102	[illegible]	BS	[illegible]	.	.	NONE	.
103	[illegible]	BS	[illegible]	.	.	NONE	.
104	[illegible]	BS	[illegible]	.	.	NONE	.
105	[illegible]	BS	[illegible]	.	.	NONE	.
106	[illegible]	BS	[illegible]	.	.	NONE	.
107	[illegible]	BS	[illegible]	[illegible]	.	NONE	.
108	HUMMAR	LL	.	[illegible]	.	NONE	[illegible]
109	[illegible]	BS	[illegible]	[illegible]	.	NONE	.
110	[illegible]	BS	[illegible]	.	.	NONE	.
111	[illegible]	BS	[illegible]	.	.	NONE	.
112	[illegible]	BS	[illegible]	.	.	NONE	.
113	[illegible]	BS	[illegible]	.	.	NONE	.
114	[illegible]	BS	[illegible]	.	.	NONE	.
115	[illegible]	BS	[illegible]	.	.	NONE	.
116	[illegible]	BS	[illegible]	.	.	NONE	.
117	[illegible]	BS	[illegible]	.	.	NONE	.
118	[illegible]	BS	[illegible]	.	.	NONE	.
119	[illegible]	BS	[illegible]	.	.	NONE	.
120	[illegible]	BS	[illegible]	.	.	NONE	.
121	[illegible]	BS	[illegible]	.	.	NONE	.