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ELIMINATION OF POLLUTION FROM COTTAGE CHEESE WHEY BY DRYING AND UTILIZATION

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Industrial Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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September 1976

ELIMINATION OF POLLUTION FROM COTTAGE CHEESE WHEY BY DRYING AND UTILIZATION

by

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Project #12060 DEQ

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environment Research Laboratory - Cincinnati (IERL-CI) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

"Elimination of Pollution from Cottage Cheese Whey by Drying and Utilization" is a summary of this grant project to demonstrate the utilization of converted acid whey components for food purposes. Part of the effort in this grant project is reported in the annual reports by the grantee for calendar years 1974, 1975, and 1976. Based on information from the grantee, there were no new, reportable inventions as a result of this grant. For further information, contact the Food and Wood Products Branch of IERL-CI.

David G. Stephan
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ABSTRACT

A spray drying process for cottage cheese whey has been demonstrated as a viable method for pollution control from the cheese making industry. The process produces a saleable product consisting of protein lactose sugar and other nutritious ingredients. The product, readily usable for animal feed, has recently been accepted for human consumption. The process was demonstrated by the Dairy Research and Development Corporation in its plant adjacent to the cottage cheese plant of the Dairylea Cooperative at Vernon, New York, at a scale of 500,000 pounds of raw whey per day.

The process consists of five major steps, evaporation of the raw whey, crystallization, spray drying, after drying and packaging of the dry powder.

Operation of the demonstration plant was successfully concluded after a period of lengthy and troublesome shake-down and start-up. The cottage cheese whey is now converted to a saleable dried product. The technology appears amenable for use in regional service facilities where sufficient cheese whey supplies can justify essential processing facility. The projected capital cost for a 500,000 pounds a day (raw whey) plant of minimum size is approximately $3,000,000. The operating cost projection is approximately $450,000 per year based on 9,000,000 pounds a year of dried whey powder.

Profitability for this size plant is determined proportionately by the sale of the product to the human food market as against the animal feed market.

This report was submitted in fulfillment of the requirements of Project #12060 DEQ awarded by the Environmental Protection Agency to the Dairy Research and Development Corp.

CONTENTS

Section		Page
I	CONCLUSIONS	1
II	RECOMMENDATIONS	3
III	INTRODUCTION	4
IV	DEMONSTRATION PROJECT	14
V	HISTORY OF PROJECT	24
	DESIGN OF PLANT	24
	PROCESS DESCRIPTION	24
	OPERATING EXPERIENCE	26
	DIFFICULTIES	26
	SENSITIVITY OF PROBLEMS	28
	MODIFICATIONS	33
VI	FEASIBILITY	35
	CONSOLIDATED CHEESE OPERATION	35
	WHEY DRYING PLANT ADJACENT TO CHEESE PLANT	35
	OTHER CHEESE WHEY	36
	REGIONAL SERVICE POTENTIAL	36
VII	INTEREST AND IMPACT TO CHEESE INDUSTRY	37
	PROJECT INTEREST	37
	PRODUCT INTEREST	37
VIII	WHEY DRYING PLANT PROJECTIONS	39
	PLANT DESIGN AND LOCATION	39
	CAPITAL COSTS	40
	EQUIPMENT	40
	BUILDING AND LAND	40
	OPERATING COSTS	42

		Page
	SUMMARY - PLANT SIZE AND ECONOMICS	42
IX	REFERENCES	44
X	APPENDIX	46
XI	GLOSSARY	61

FIGURES

		Page
1.	PROJECT 12060 DEQ ORGANIZATION	8
2.	DAIRY RESEARCH AND DEVELOPMENT CORP. PLANT AT VERNON, NEW YORK - EXTERNAL PHOTOGRAPH	20
3.	SAME PLANT - EQUIPMENT PHOTOGRAPH	21
4.	SAME PLANT - INSTRUMENT PANEL PHOTOGRAPH	22
5.	WHEY DRYING PROCESS SCHEMATIC	25
6.	WHEY DRYING PROCESS EFD (ENGINEERING FLOW DIAGRAM)	27
7.	PROJECTED CAPITAL AND OPERATING COSTS	41

TABLES

		Page
1.	U.S. CHEESE WHEY PRODUCTION/1972	4
2.	COTTAGE CHEESE WHEY POLLUTION - WASTE VOLUME AND CHARACTERISTICS AND EQUIVALENTS	5
3.	SUMMARY OF VERNON, NEW YORK, PLANT RUNS DURING PROJECT PERIOD-MONTHLY AVERAGES OF DAILY PRODUCTION	11
4.	U.S. CHEESE AND WHEY PRODUCTION AND UTILIZATION (1950-69)	13
5.	TYPICAL ANALYSIS AND VITAMIN CONTENT OF ACID WHEY POWDER	16
6.	EXAMPLES OF THE UTILIZATION OF WHEY IN FOODS	18

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The research and analysis support of the U.S. Department of Agriculture, Dairy Products Laboratory, Eastern Utilization Service, contributed greatly to the direction of the project. Dairy Research and Development Corp. is grateful to all the staff members of the Dairy Products Laboratory but particular mention should be made of Dr. Byron E. Webb, Dr. Michael J. Pallansch, Frank E. McDonough and Virginia Holsinger.

Appreciation is also accorded to Richard Meyer of the Food and Drug Administration, U.S., for his interest and encouragement and patience throughout the numerous meetings.

Particular recognition is in order for the support furnished by Dairylea Cooperative, Inc., Pearl River, New York, in providing technical personnel and the physical plant with some of its facilities at Vernon, New York, without charge during the term of the project.

This report was prepared by Sidney Boxer and Robert W. Bond; its development and execution were under the direction of Sidney Boxer, with the aid and support of staff members of the Environmental Protection Agency.

SECTION I

CONCLUSIONS

1. Cottage cheese whey, popularly referred to as acid whey, is a difficult substance to dry because of inhibiting factors, such as its acid content. This is compounded by the lack of uniformity in the raw whey feed stock due to many factors, the varying nature of milk in different regions of the country, handling and sanitary conditions and most prevalent, the non-standard methodology in the making of cottage cheese.

2. Of all the processes reviewed for potential use, including roller drying, reverse osmosis, ultra filtration and others, the spray drying process was chosen from the standpoint of achieving pollution abatement in accordance with the stringent regulations of the various governmental agencies and at the same time providing the greater potential for market penetration.

3. Equipment and technology currently available on the market is not suitable for the extreme requirements of drying acid whey. Each project should be separately engineered to the particular needs of the plant or number of plants being serviced.

4. The processing of the whey must be controlled from its raw state through the finished product under rigidly controlled conditions to achieve a high standard of powder with uniformity and quality that will be acceptable on a continuous basis to the food industry. In many instances, this may require the whey processor to be involved in the cottage cheese making in order to assure day-to-day standard operational procedures. Training and supervision of personnel is important in developing their understanding of the sensitivity of whey drying.

5. The process itself achieved its primary purpose of producing a nonhygroscopic acid whey powder. The processing steps are the evaporation and condensing of the acid whey, crystallization, spray drying and after drying, milling and bagging the powder. Critical process parameters are the chemical consistency of the raw condensed whey, drying temperatures, product moisture level, air temperatures and humidity. The varying conditions and changes can be partially overcome by operational procedures within the design limits.

6. The production of non-hygroscopic acid whey powder of a uniform quality, within the limits of proposed edible grade standards, is a basic requirement in the

penetration of a highly sophisticated food market of today. This is particularly true if the product is to be accepted in the formulations of national food companies, necessary to absorb the tremendous quantities of whey powder expected on the market in the not too distant future.

SECTION II

RECOMMENDATIONS

Based upon the conclusions and results of this project, following are the recommendations:

1. It has been shown that cottage cheese whey can be dried, the ultimate need for uniformity requires the initiation of an intensive study into the basic chemical components of whey as affected by the various factors in different parts of the country including feed, handling, cottage cheese making, etc.

2. Development of more sophisticated equipment and technology for the drying of whey, particularly acid whey should be undertaken with a view toward the engineering of more economical equipment incorporating processing procedures presently "hand-done" by the operator.

3. A regional whey processing facility should be undertaken to investigate the feasibility of collecting whey from satellite plants, the size of the area that can be served, the transportation costs, the methodology of collection of the whey, i.e., raw or condensed, the uniformity and quality control factors, etc.

4. Wider utilization of whey in the edible grade food market requires extensive research in food formulations, which should be undertaken commercially by the whey processors.

SECTION III

INTRODUCTION

HISTORY AND NEED

The United States is one of the largest, if not the largest, dairy producing and consuming nations in the world. The dairy industry, one of the most widespread in the United States, produces over 120 billion pounds of milk yearly. (U.S. Department of Agriculture - Economic Research Service). A major portion of the dairy industry is dedicated to cheese production which concomitantly produces large volumes of whey as shown in Table 1.

TABLE 1

CHEESE PRODUCTION/1972*

Cheese (All Types except Cottage):	2,604,000,000 lbs.
Cottage Cheese:	1,115,000,000 lbs.

-0-

FLUID WHEY (Calculated From 1972 Cheese Production)**

(A)	Sweet-type Whey (from all cheese except Cottage):	Cheese x Factor 2,604,000,000 x 9
		23,436,000,000 lbs.
(B)	Acid-type Whey (from Cottage Cheese):	Cheese x Factor 1,115,000,000 x 6
		6,690,000,000 lbs.
Total Whey Production:	(A) + (B)	30,126,000,000 lbs.

-0-

CALCULATED WHEY SOLIDS/1972

Total Equivalent Whey Solids:***	Fluid Whey x % solids 30,126,000,000 x 0.065
	1,958,000,000 lbs.

* Crop Production Board, SRS, USDA, Da 2-1 (73)

** Whey Production: approximately 9 lbs./1 lb. cheese produced (except Cottage)
approximately 6 lbs./1 lb. Cottage cheese produced

*** Average total solids content of whey: 6.5%

Unfortunately, the whey waste from cheese is one of the worst offenders because of its high biochemical oxygen demand (BOD concentration) (See Table 2).

TABLE 2

WASTE VOLUME AND CHARACTERISTICS OF COTTAGE CHEESE WHEY (1)

4. Dan Franklin Dairy (2)

a) Cleaning

Design Flow		0.0717 MGD
Susp. Solids	256 ppm	153 ppd
Vol. Susp. Solids	182 ppm	109 ppd
5-Day BOD	480 ppm	288 ppd

b) Cheese Wash

Design Flow		0.0317 MGD
Susp. Solids	270 ppm	72 ppd
Vol. Susp. Solids	245 ppm	65 ppd
5-Day BOD	2,625 ppm	695 ppd

c) Whey

Design Flow		0.012 MGD
Susp. Solids	3,900 ppm	390 ppd
Vol. Susp. Solids	3,600 ppm	360 ppd
5-Day BOD	37,400 ppm	3,740 ppd

d) Total Flow, Excluding Whey

Design Flow		0.103 MGD
Susp. Solids	260 ppm	225 ppd
Vol. Susp. Solids	210 ppm	174 ppd
5-Day BOD	1,190 ppm	983 ppd

e) Total Flow, Including Whey

Design Flow		0.115 MGD
Susp. Solids	640 ppm	615 ppd
Vol. Susp. Solids	555 ppm	534 ppd
5-Day BOD	4,920ppm	4,723 ppd

POLLUTION EQUIVALENT

POUNDS OF RAW WHEY	PEOPLE
30,000,000,000	20,000,000

(1) Reference 17 - FORT PLAIN-NELLISTON SEWERAGE STUDY
(2) 11,000 pounds cheese per day

Many of the cheese operations are located in small communities in or near the rural milk production areas. Because of excessive waste load of whey, the waste treatment facilities of most communities cannot tolerate the cheese whey. The cost of facilities to treat cheese whey would be prohibitive for the industry, as well as non-productive. (Reference 1-pgs. 400-413). As concluded in the Harper Report on pg. 413 (Reference 1) from a survey of 175 consulting engineering firms -: "All organizations are in agreement in their opinion that whey and the wash water from cottage cheese operations should be excluded from biological treatment facilities."

The larger communities with adequate waste treatment facilities accepting the discharge of the cheese whey, are required by governmental regulations to charge proportionate treatment costs which ultimately will become prohibitive as costs escalate in the improvement and maintenance of these plants. Further in adding these costs to the price of cheese, the cheese itself will lose its competitive value in the market place. Waste treatment lacking a future, the recovery of the cheese whey becomes a better alternative. (Reference 2).

Production of raw whey amounts to over 30 billion pounds per year, equivalent to the pollution by 20 million people. The building of new sewage plants or the addition to old ones necessary to accommodate the whey waste would cost approximately 1½ billion dollars not including the sewers. The additional cost of maintenance annually would amount to well over 40 million dollars annually. In a Comprehensive Sewerage Study undertaken by New York State of a small town with a moderate plant producing an average of 11 thousand pounds of cheese per day, the annual costs for handling the whey wastes from that cheese plant would be 90 thousand dollars annually. (Table 2 and Reference 18).

Faced with these economic and environmental pressures, many cheese plants closed and more may have to be closed. The economic disposition of whey is still recognized as the most compelling problem facing the cheese industries throughout the United States. Besides the serious implications in the towns and villages where cheese plants are the dominant industries, there will be the additional impact in the reduction of farms and the satellite businesses and services.

Some whey has always been dried or condensed with the bulk of the product destined for the animal feed market. This was mostly sweet whey of inferior quality, viewed as a "waste" with marketing in the form of a "dumping" operation.

The dairy industry and government and universities, long concerned with this problem, have undertaken at various times research looking toward a solution. However this has been limited by funds, economics, lack of continuing communication and a "hit or miss" approach striving usually for solution of one phase of the overall problem. (Reference 6).

Approximately 3.8 billion pounds of cheese is now produced in the United States resulting in over 30 billion pounds of fluid sweet and acid whey. If all this whey were dried, there would be approximately 1½ billion pounds of sweet whey powder originating from the cheddar and other hard cheeses and over 500 million pounds of acid whey powder originating from cottage, cream and soft Italian cheese. (Table 1).

Much of the fluid sweet whey and practically all the fluid acid whey that had been produced in this country was diverted to streams or municipal sewer systems and irretrievably lost as a food. Not only does the unused food whey pollute the waterways and place heavy burdens on the sewage system, the nutritional loss is incalculable since 54% of the nutrients of milk are left in the fluid sweet whey while 73% of the nutrients of milk appear in the fluid acid whey from cottage cheese.

SOLUTION OF THE PROBLEM

Dairy Research and Development Corp. was organized to undertake a research and development program to accomplish the twofold task of abating the pollution by whey waste and utilizing the whey components for food purposes. (Figure 1). In 1968 Dairy Research and Development Corp. received a grant #12060DEQ from Environmental Protection Agency to demonstrate the feasibility of eliminating pollution of acid whey waste by conversion to a dry powder and the utilization of the acid whey powder for food purposes.

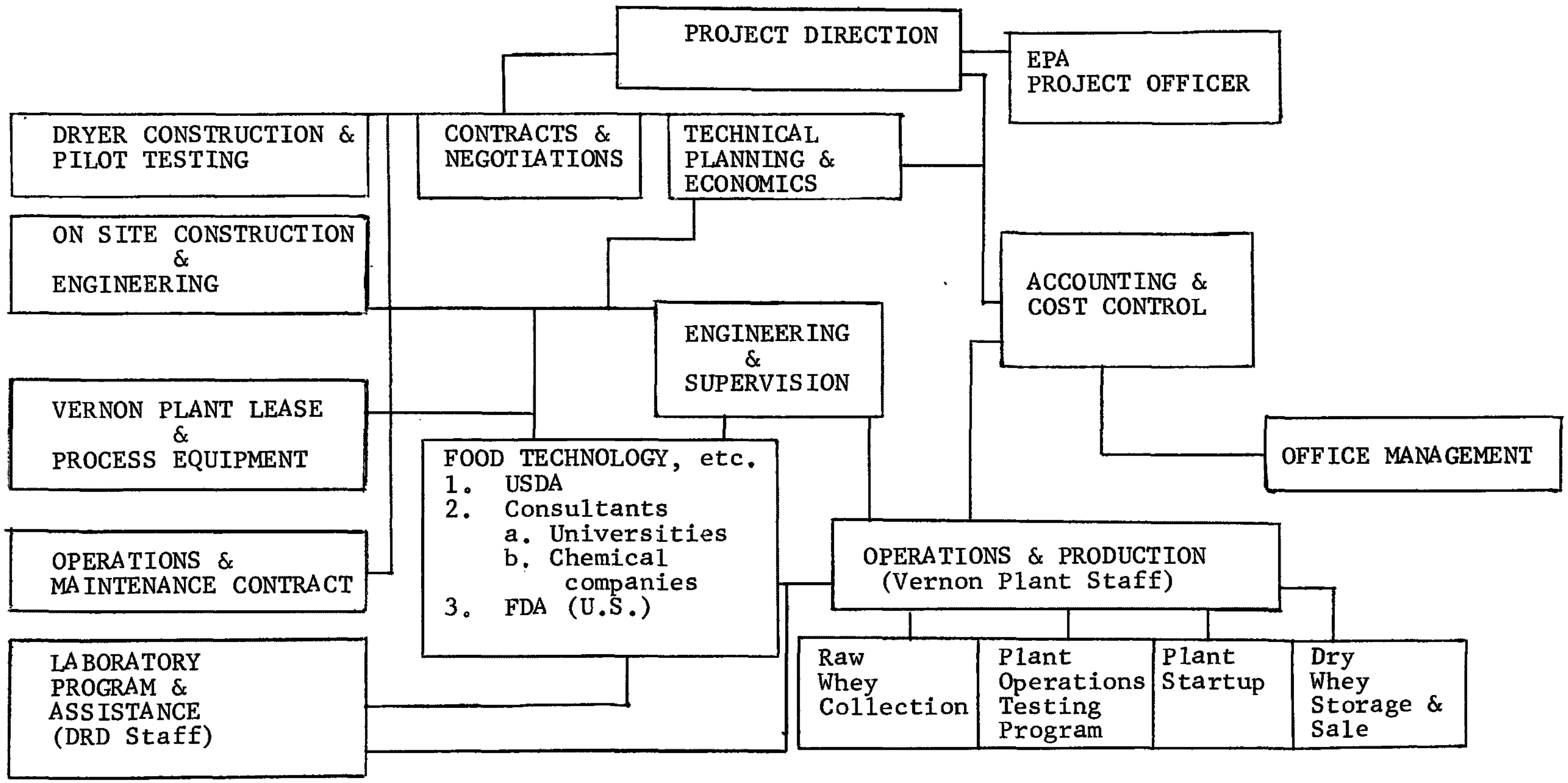
In the course of deciding on the project objectives, numerous types of equipment and processes were evaluated for their potential in resolving the whey problem - roller dry equipment, reverse osmosis, ultra filtration, electro-dialysis, etc. It was determined that the most suitable method for attaining the objectives of the project was spray drying. (References 6, 7 and 8).

During the course of the evaluation, it was decided to investigate readily available spray drying equipment and processes on the market for adaptation, rather than spend years in engineering and development which would undoubtedly require a pilot plant phase.

FIGURE 1

DAIRY RESEARCH & DEVELOPMENT CORP.

PROJECT 12060-DEQ ORGANIZATION



The De Laval Separator Company offered a process, equipment and the use of its pilot plant in which limited tests had demonstrated capability of drying acid whey. Accordingly, the basic objectives of the project, that is, the drying of acid whey to a non-hygroscopic consistency in a scaled up commercial size, appeared possible. Their system was accepted with some qualifications and the project was able to proceed quickly with location of a site and installation. The scale of operation chosen satisfied the requirement of the project that the commercial feasibility be proven, rather than the more conservative approach of intermediary scale of pilot plant testing, to establish a firm technological basis. (Reference 23).

The Dairymen's League Cooperative Association, Inc. of New York, NY offered facilities at Remsen, NY together with personnel, labor, engineering and laboratory technicians for the project. The final site selected was Vernon, NY in a powder plant next door to a new cottage cheese plant being erected by Dairylea. It was felt that this would be more convenient, providing better control of the raw whey since the raw whey could be piped over directly from one plant to the other.

Plans were drawn in late 1969 and early 1970 and by 1971, the necessary building construction and installation of the equipment was completed. As explained later in this report, the equipment modifications were made during the course of the next year while various tests of the equipment and the process were made. There were many failures as was to be expected but the knowledge gained resulted in the gains later described. One of the most important lessons learned was that the pilot plant technology was not a criterion for scaling up to the commercial size plant due to the differences in contact "time-temperature" change and unknown scale up parameters.

During the late 1971 and into all of 1972, the commercial size plant at Vernon, NY became a large scale pilot plant with the disadvantages of large costs and the lack of fine, controlled conditions available at a small pilot plant. This was outweighed however by the advantages of obtaining true results on a commercial scale without the conjecture of a scaled up operation from a pilot plant, and, most important, successful outcome of the testing resulting in an instant commercial operation.

A significant increase in the amount of material processed was achieved in October, 1972, and day to day production was instituted by November, 1972; the major factor was quality control of the feed stock, by pasteurization as drawn from the vats to inhibit bacterial action, and by maintaining the moisture level of the feed stock from the main dryer within a 10% to 14% range. The next three months were then devoted to varying the conditions of production, pressures, temperatures, time and condensed solids, resulting in mostly poor quality product. Such wide ranges were tested as to be meaningless, except for the condensed whey solids (Table 3). By the end of January 1973, the plant was producing a high quality, edible grade of uniform non-hygroscopic whey powder. The basic conditions for achieving these results were settled at a range of 41% to 44% condensed whey solids, running at a rate of 1600 to 1800 pounds of powder per hour with moisture not to exceed 2.5% (range of 2.0% to 2.5%).

The unit cost per lb. for drying the whey during the final year of the project, 1973, ranged from a monthly low of $.0432/lb., to a high of $.1045/lb. The month of May, which ran $.3850/lb., is not considered as representative. During the project period, the most probable cost is estimated at $.088/lb. As can be seen from Table 3, the day to day production ranges, during the 1973 project period, had such low and high ranges as to render the cost data erratic and misleading.

The major factors in achieving low unit cost are high hourly rate of production and large volume of feed stock input. Neither of these was achieved during the 1973 project period, except in rare instances insufficient to draw satisfactory conclusions as to unit cost with any exactitude.

By October 1973, the entire production of the plant was sold for the balance of the year 1973, 80% into human grade products and 20% into animal feed. Market acceptance of the product was aided by the prior development of uses of whey by the U.S. Department of Agriculture and Cornell University. (References 13, 14, 16, and 17). Dairy Research and Development Corp. had also instituted research and developed products for the utilization of acid whey powder. It is anticipated that numerous processes and greater facilities for conversion of whey to beneficial food products will be developed. (References 3, 4, 5, 11 and 20).

TABLE 3

SUMMARY OF PLANT RUNS DURING PROJECT PERIOD AT

VERNON, N.Y. PLANT OF DAIRY RESEARCH & DEVELOPMENT

CORP. - MONTHLY AVERAGES OF DAILY PRODUCTION

	Condensed Whey Percent Total Solids		WHEY POWDER POUNDS DAILY Production	
1971	RANGES Low & High	AVERAGE	RANGES-Low & High	Average
MAY	48.68-50.67	50.01	400-1000	630
AUGUST	43.36-51.45	49.39	Test Runs - No Prod.	
SEPTEMBER	48.31-50.32	49.32	"	
OCTOBER	ONE RUN	51.61	"	
NOVEMBER	47.53-51.99	49.13	"	
DECEMBER	40.91-52.54	46.00	600-1350	820
1972				
JANUARY	ONE RUN	52.65	450	
APRIL	ONE RUN	43.82	2050	
MAY	40.55-44.88	42.07	1350-6340	3600
JUNE	ONE RUN	41.46	MODIFICATION TESTS - NO PROD.	
JULY	42.46-42.50	42.48	250-2700	1475
AUGUST	40.90-42.85	41.82	1700-7122	4465
SEPTEMBER	40.80-43.06	41.87	1500-5659	4000
OCTOBER	40.76-42.83	41.87	1100-8150	5170
NOVEMBER	39.21-45.84	41.65	4750-16,250	10,800
DECEMBER	37.19-43.57	41.33	1650-13,000	8660
1973				
JANUARY	38.56-45.54	42.47	4200-18,300	12,000
FEBRUARY	38.99-44.75	42.39	650-16,650	12,650
MARCH	37.23-45.07	42.90	5350-19,650	14,670
APRIL	38.86-44.54	42.42	2250-19,050	12,030
MAY	42.98-43.07	43.02	7900-14,850	11,375
JUNE	41.31-44.17	42.69	1650-12,950	7,685
JULY	39.70-45.03	42.30	2000-14,500	10,500
AUGUST	39.01-44.11	41.94	2150-14,550	12,450
SEPTEMBER	38.10-43.20	40.94	1200-16,400	13,500

PROCESSES FOR WHEY UTILIZATION (1969 STATUS)

The whey utilized in 1969 was almost exclusively sweet whey from the production of hard cheeses. The forms in which whey was used were as follows:

- Raw or "as is" state
- Condensed
- Dried
- Fractionated

The use of raw whey was seriously limited due to the high cost of transporting a low solids liquid and the tendency of the product to putrefy. Utilization of condensed whey enjoyed a more favorable distribution cost, more resistance to putrefication but, unless stored under the proper conditions, the crystallization of lactose was troublesome. Dry whey was the most generally accepted form because of its stability and ease of handling. (Table 4).

SPRAY AND ROLLER DRYING

Most whey was dried in roller dryers which were unsanitary, produced many scorched particles and products of widely varying quality. Some whey was dried in spray dryers. All the dried whey was sweet whey because a commercially feasible process did not exist for drying acid whey.

OTHER

Relatively large quantities of whey were fractionated by crystallization of the lactose which was separated from the whey protein and salts. The protein and salts were generally dried in a roller dryer to a hygroscopic product.

TABLE 4.

***

.--Cheese whey production and utilization, United States, 1950-69

Year	Production 1/				Utilization						
	Total cheese 2/	Liquid sweet whey 3/	Cottage cheese 4/	Liquid acid whey 5/	Dried whey: Production	Dried whey: Whey equivalent 6/	Crude milk sugar: Production	Crude milk sugar: Whey equivalent 7/	Condensed whey 8/: Production	Condensed whey 8/: Whey equivalent	Fed, used for fertilizer or wasted 9/
	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.
1950	1,191	9,528	413	2,060	155.6	2,100	39.3	980	N.A.	---	8,508
1951	1,161	9,288	462	2,310	139.9	1,890	50.2	1,260	N.A.	---	8,448
1952	1,170	9,360	488	2,440	164.1	2,215	33.6	840	N.A.	---	8,745
1953	1,344	10,752	530	2,650	174.7	2,358	25.9	648	N.A.	---	10,396
1954	1,383	11,064	573	2,860	177.6	2,398	32.5	812	123.4	864	10,282
1955	1,367	10,936	604	3,020	211.0	2,848	36.3	908	184.1	1,289	9,555
1956	1,388	11,104	711	3,560	212.0	2,862	33.3	832	180.9	1,266	10,337
1957	1,407	11,256	745	3,720	232.4	3,137	37.5	938	139.3	975	10,414
1958	1,399	11,192	763	3,820	233.3	3,150	35.4	885	121.5	850	10,552
1959	1,383	11,064	803	4,020	247.3	3,339	47.3	1,182	103.4	724	10,201
1960	1,478	11,824	838	4,190	276.9	3,738	50.1	1,252	87.0	609	10,719
1961	1,635	13,080	824	4,120	271.5	3,665	35.5	888	99.2	694	12,300
1962	1,592	12,736	838	4,190	284.8	3,845	52.3	1,308	85.6	599	11,474
1963	1,631	13,048	855	4,280	316.9	4,278	39.4	985	114.2	799	11,666
1964	1,724	13,792	886	4,430	371.9	5,021	41.3	1,032	145.9	1,021	11,658
1965	1,755	14,040	892	4,460	404.3	5,458	65.0	1,625	151.0	1,057	10,888
1966	1,854	14,832	887	4,440	470.9	6,357	65.1	1,628	193.6	1,355	10,610
1967	1,913	15,304	890	4,450	492.8	6,653	79.3	1,982	177.8	1,245	10,496
1968	1,938	15,504	928	4,640	498.8	6,734	83.0	2,075	158.3	1,108	10,781
1969	1,986	15,888	966	4,830	502.5	6,784	92.9	2,322	179.8	1,259	10,985

*** DAIRY SITUATION - ECONOMIC RESEARCH SERVICE, U.S. DEPT. of AGRICULTURE
SEPT., 1970

1/ Excludes whey from casein, now only minor.
2/ Excludes cottage cheese and full-skim American cheese.
3/ Estimated at 8 pounds per pound of cheese.
4/ Adjusted for duplication between curd and creamed cottage cheese; includes full-skim American cheese.
5/ Estimated at 5 pounds per pound of cottage cheese.
6/ One pound dry whey equals 13.5 pounds liquid whey (USDA Statistical Bulletin 362).
7/ One pound lactose equals 25.0 pounds liquid whey (USDA Statistical Bulletin 362).
8/ One pound condensed whey equals 7 pounds liquid whey.
9/ Assumes half of reported condensed whey is dried.

SECTION IV

DEMONSTRATION PROJECT

OBJECTIVES OF PROJECT

The description of the project granted Dairy Research and Development Corp. by the Office of Research and Development, Federal Water Pollution Control Administration reads, "a development and full scale demonstration for a process for the conversion of dairy whey into saleable food products by evaporation and spray drying methods. The conversion of whey to a usable food product in lieu of its disposal as a waste product from cheese manufacturing is the pollution abatement method to be developed and demonstrated. Research will be conducted on the use of dry whey as a supplement to various food products." Restated in a concise manner, the objectives of this project on cheese whey were:

Pollution abatement
Conservation of nutritional food material
Economic feasibility

PLAN OF ACTION

The pollution abatement requirement in this project could have been solved in a number of methods had this been the only constraint. The last two requirements, conservation of food material and economic feasibility, necessitated consideration of food plant sanitation standards, process costs vs. "market value" of the finished product and therefore evaluation of the demands of the food ingredient market and the potentially competitive food ingredients.

DRD's plan of action consisted of six phases designed to achieve all requirements of the project.

Phase 1. Determine and define the food ingredient market's current opportunities for products which could be produced from whey;

Phase 2. Select the equipment best suited to carry out the basic process steps forecast from DRD's finished product selection;

Phase 3. Select a cheese plant from which to draw whey and whose management was aggressively interested in pollution abatement;

Phase 4. Construct necessary building and install equipment;

Phase 5. Develop the most desirable process conditions, equipment requirements and make such changes as required;

Phase 6. Establish a market for the whey product as a nutritious food ingredient for formulated human foods.

Phase 1 was a most important part of the project because the segment of the food ingredient market selected had to represent a large volume potential, commensurate with potential supply of whey solids. The market selected dictated the characteristic of the product required to fulfill the specific market requirements. The characteristics of the finished product, (moisture, hygroscopicity, particle size), defined within narrow limits the type of equipment required for the processing of raw whey into such a finished product. (Reference 15). Generally, equipment of this type has a very limited flexibility in the type of finished products it is capable of producing. Therefore, market selection can be a "make or break" for a project of this type.

Acid whey, by-product or co-product produced in the production of cottage and other soft cheeses, contains the desirable components which have various market demands. (Table 5).

As most nutritionists and those knowledgeable in the value of food components realize, there is strong demand by the food industries for good proteins, high protein efficiency ratio (P.E.R.) and proteins which contain large amounts of the essential amino acids in which lower P.E.R. proteins are deficient. Though knowledge is seriously lacking in the function and requirement for certain trace elements (minerals) in our diet, there exists a market demand for products containing the number of trace elements found in whey. Food acidulants are also in demand to enhance the flavor of certain formulated foods. Such market needs may be met or satisfied by the use of one or more commodity ingredients, the use of several pure or fractionated materials or, as is more common, a combination of commodity food ingredients and pure or refined ingredients. (References 3, 11 and 16).

The food formulator's choice of ingredients to be used for the production of a consumer product is based on essential considerations, such as, customer appeal, customer satisfaction, nutritional value and cost of the finished product. Consumer products which are not at least on the average competitive on these points may be expected to have a short market life. Therefore, considering the value of components of

TABLE 5

ACID WHEY POWDER COMPONENTS *

	TYPICAL ANALYSIS
Moisture	3.0%
Lactose	67.0%
Protein	12.5%
Lactic Acid	8.5%
Ash	9.0%
pH	4.4%
Acidity (as Lactic Acid)	6.0%
Calcium	1.8%

VITAMINS	mg/100 grams
Thiamine	1.06
Riboflavin	2.55
Niacin	0.675
Ascorbic Acid	2.8

* Source - References 19, 20 and 21

ESSENTIAL AMINO ACIDS

	Solid Whey Powder (mg/gm)
Lysine	8.13
Histidine	1.31
Ammonia	.766
Arginine	2.78
Aspartic	9.55
Threonine	5.18
Serine	4.98
Glutamic	20.7
Proline	7.83
Glycine	1.67
Alanine	5.03
Cystine	N.C.
Valine	5.68
Methionine	1.25
Isoleucine	5.45
Leucine	10.3
Tyrosine	3.17
Phenylalanine	3.35
Tryptophan	6.32

whey solids, the value of commodity ingredients available to food formulators and the comparative cost-price relationships, the current and near future food ingredient market requirements are volume-price related.

DRD's survey of the food ingredient market showed rapidly growing demand for materials from which nutritionally superior products could be formulated. (References 3, 11, 16 and 22). The broad competitive position of such food ingredients as flours, sugars, food acidulants and the concentrates and isolates of amino acids, whole proteins and vitamins were carefully considered. Generally the processing costs and market prices are directly related to the type and complexity of the process by which the ingredient is manufactured. As an example, a protein isolate may be priced at 3 to 10 times the price of the protein in the parent commodity. It was concluded that volume food ingredient markets needed to absorb the volumes of whey available or that would soon be available, could best be penetrated with total acid whey powder at the lowest price possible in comparison to the prices necessary to make fractionated whey products. (Table 6).

Phase 2 was limited to consideration of the best equipment available to produce a non-hygroscopic food grade acid whey powder. Consideration was given to most known methods of reducing soluble and slurry solids mixture, as found in acid whey, to a dry powder. The drying techniques reviewed for use were roller, tunnel, spray, freeze, microwave, infrared, fluid bed, air suspension and combinations of these techniques. The review was conducted by reading all the literature available, the technical bulletins from the various companies manufacturing the equipment, discussion with the engineers of these various companies, respecting the operation of the equipment where allowed, usually very limited and discussion with the staff members of the Environmental Protection Administration and the U.S. Department of Agriculture. (References 7 and 8). Based on this information and the inspection of the De Laval pilot plant in operation, it was concluded that a modification of the De Laval Separator Company's milk dryer was the best starting combination of drying conditions available for acid whey.

Dairylea Cooperative, Inc. was selected under Phase 3 as having a forward-looking management and the interest in working with DRD Corp. on the acid whey demonstration project. The initial plant selection was at Remsen, N. Y. due to its immediately available building space. However, careful calculations of the freight costs to obtain the raw whey volume required

TABLE 6

EXAMPLES OF THE UTILIZATION OF WHEY IN FOODS *

Food	Quantity of Whey Solids	Outstanding Contributions of Whey Components Besides Low Cost and Good Nutrition
Baked goods (% of flour wt.) sweet goods, bread, crackers	3.	Flavor, texture, shortens dough time, improves keeping quality
Dry mixes	10.	Tenderize, color, flavor
Dry whey flow agent to absorb oils	93.	Carrier for fats, oils
Ice cream	2.7	Flavor, acid and fruit stability
Sherbet	4.	
Water ice on a stick	2.6	Furnish Ca, P, lactic acid, retard tooth erosion
Confections (8)	10.	Flavor, body, moisture retention, whipping properties
Icings, frostings	6.	
Jams, apple butter	4.	
Batter mix (for frying)	5.	Color, flavor
Whey-soy beverage, citrus flavor	6.	Lactic acid, flavor
Whey-soy beverage sterilized, 35% T.S.	16.5	Flavor, body
Process cheese	10.	Body and flavor
Whey-2/3, Soy 1/3, dried	66.	Masks soy flavor
Whey-soy blends for food manufacture use fat free soy flour	40.	Masks soy flavor, high protein

* SOURCE - REFERENCE 16

for a minimum size, commercially feasible whey processing plant, showed this location to be impractical. Dairylea was planning the construction of a new modern cottage cheese plant at Vernon, N. Y. The planned amount of cheese production and consequently, the available raw whey, as well as other factors made Vernon, N. Y. a preferable location for the project.

Figure 2 shows the DRD plant in the background with the enclosed pipes carrying the raw whey from the new Dairylea cottage cheese plant in the foregoing, an ideal situation for maintaining quality control of the raw product from its source to the whey processing plant.

Phase 4, construction of the necessary building and installation of equipment was essentially complete in mid 1971. Figure 3 shows the main chamber, the cyclones and the conveyor, etc.; Figure 4 shows the control panel.

Phase 5, was started in the earliest stages of the project because successful completion of the project was dependent on the development of a total process for the manufacture of a uniform, high quality, non caking, non-hygroscopic food grade acid whey powder. Though sweet whey had been satisfactorily dried (Reference 22), the high lactic content of acid whey and its extreme susceptability to scorching or heat damage, had thwarted previous efforts to produce a quality powdered product. (References 15, 19 and 21.)

The first step in the development of a manufacturing process was to seek the consultation and assistance of persons experienced in the production of products in the fields of dairy, grain, protein, fermentation, sugar and chemicals, as well as experts in drying and related problems. DRD drew this assistance from EPA, USDA, universities and industry. Coupling this background with the results of previous laboratory experiments (References 9, 15 and 19), it was felt that there was sufficient knowledge of the intrinsic characteristics of acid whey to initiate plant scale testing limited at first to small batches of 10,000 to 20,000 lbs. of raw whey.

The process steps in spray drying are some of the most difficult to develop because there is seldom any way to simulate the spray dried product so subsequent process step development can proceed simultaneously. Furthermore, spray drying operations are hard to scale up from laboratory or pilot scale to full scale operations. Each scale up resembles a new start up. For these reasons the process development was more or less an "Edisonian Cut and Try" technique.

FIGURE 2 - DAIRY RESEARCH AND DEVELOPMENT CORP. PLANT AT VERNON, NEW YORK
EXTERNAL PHOTOGRAPH

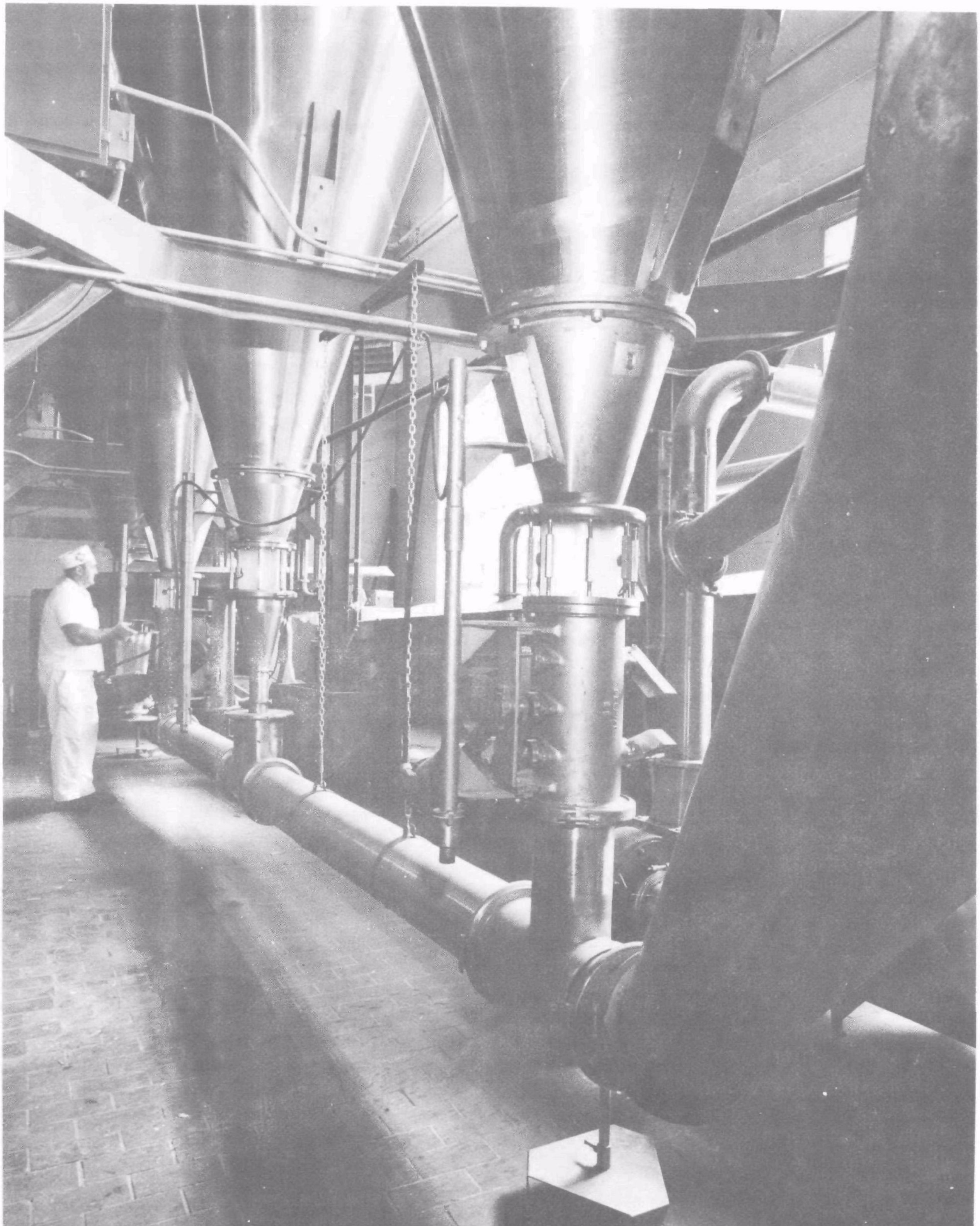


FIGURE 3 - SAME PLANT - EQUIPMENT PHOTOGRAPH

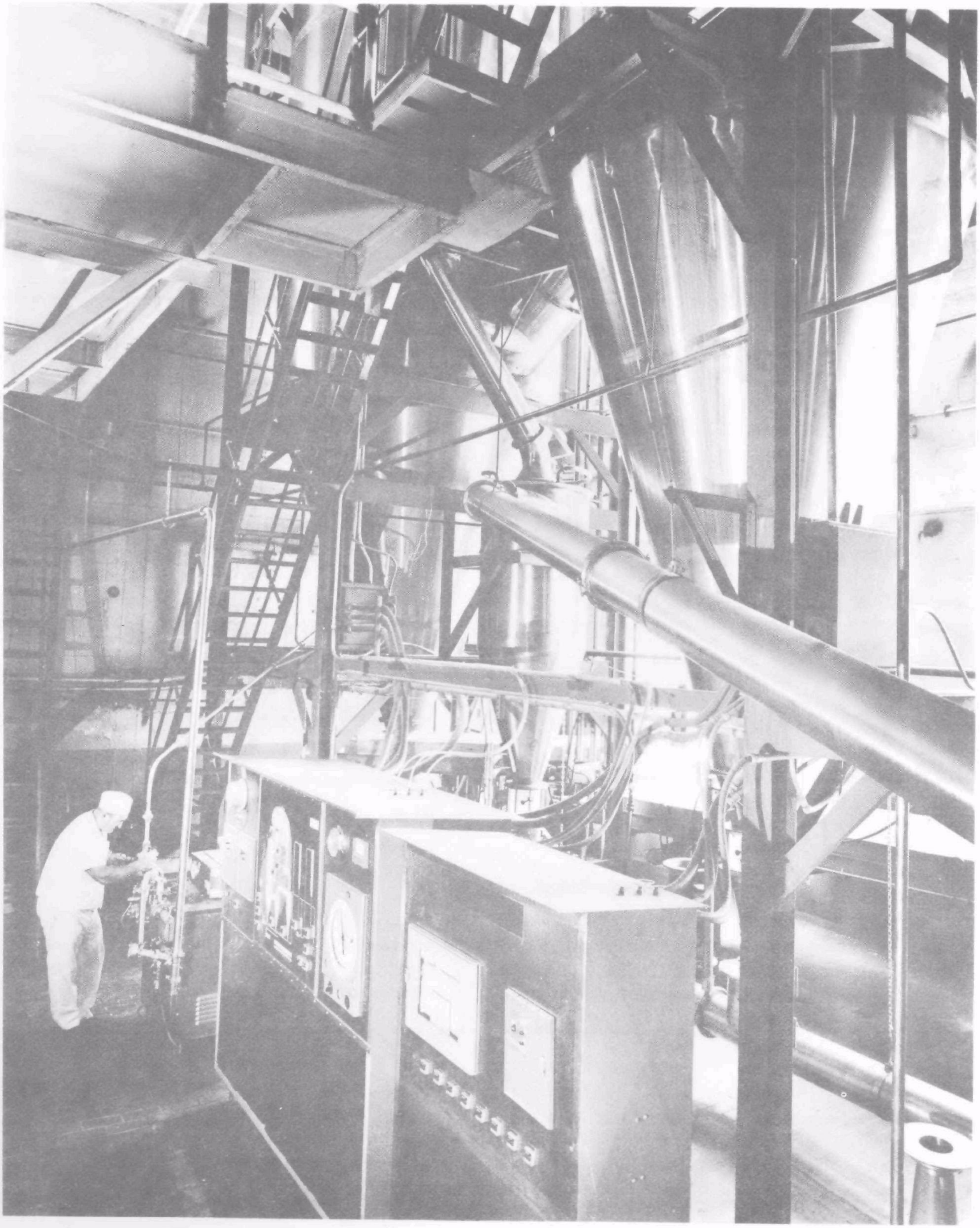


FIGURE 4 - SAME PLANT - INSTRUMENT PANEL PHOTOGRAPH

The details of the development will be given later in the report.

Phase 6, establishment of market, was outlined in a "Market Plan" prepared in 1972. This plan was held in abeyance pending confirmation of the plant's ability to produce satisfactory finished product on a daily basis. The marketing plan was initiated during the first quarter of 1973. Basically, the plan was to advertise the availability of a quality acid whey powder and recommended application. Advertisements were placed in the leading food industry journals and promotional literature was mailed directly to key personnel in potential customer organizations. Samples, detailed analysis, suggested formulations and technical assistance were used to promote interest and use of the product.

Concurrent with launching the promotion of acid whey powder to the food industry, development phase finished product in warehouse was offered on a person-to-person basis to the animal feed blending industry. The strategy was to clear the warehouse of all start-up product and establish a feed grade market to which future off-grade and start-up product might be sold.

SECTION V

HISTORY OF PROJECT

DESIGN OF PLANT

As previously explained, a modification of De Laval Separator Company's milk dryer was selected as the available equipment best suited to develop a process for drying acid whey to a non-hygroscopic food grade powder. The decision was made with due regard for the unknowns, answers to which could be obtained only by runs on plant equipment. The major unknowns at that point were the effect of the tackiness of the partially dehydrated acid whey solids on the performance of the various dryer units and the crystal growth rates of lactose monohydrate under the various dryer conditions.

The process was designed to provide the best estimate of the proper equipment for concentrating, cooling and crystallizing acid whey. The De Laval Separator Company provided the basic equipment with facilities to spray dry, convey and belt dry; also, air-borne dryers, air-borne cooler, packer and the necessary cyclone, fans, pumps, air locks, heaters and instrumentation. Early test runs indicated the belt units were not adaptable to the process and were replaced with a vibrating conveyor.

PROCESS DESCRIPTION

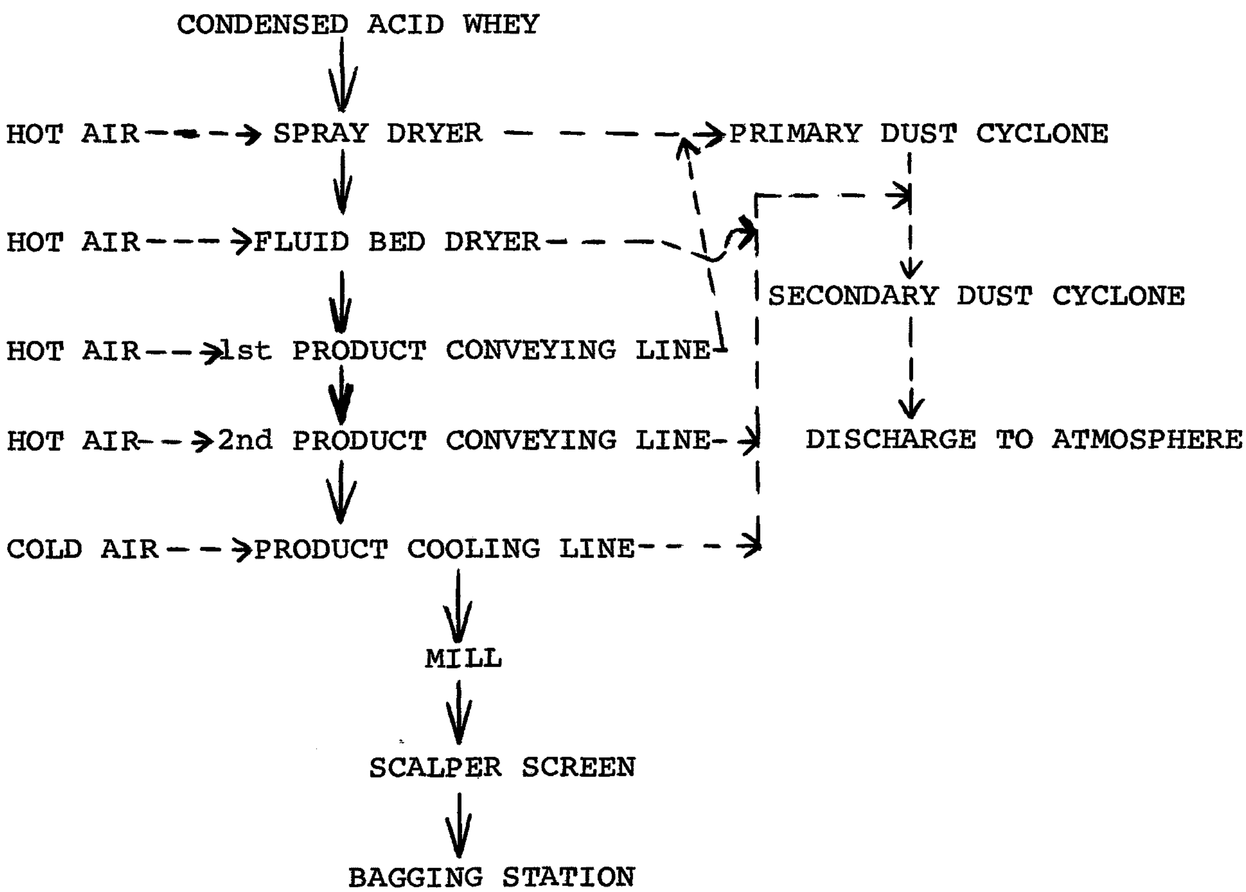
A schematic of the flow of product and air streams is shown on Figure 5. Condensed acid whey is pumped into the spray dryer from the condensed whey crystallizers through a high pressure pump. Hot air flows into the top of the spray dryer after having passed through the spray dryer inlet air heater. This is automatically regulated to dry a predetermined amount of pounds per hour of whey by a temperature controller. The air from the spray dryer is drawn by the main exhaust fan through two dust collecting cyclones before being exhausted to the atmosphere.

The product falls from the bottom cone of the spray dryer at moisture levels of 8% to 14% onto a vibrating conveyor, which transports the spray dryer product to the air-borne dryer. Product entrained in the exhaust air from the spray dryer is removed from the air stream in either the first or second dust collecting cyclones and is returned to the second product conveying line.

From the vibrating dryer, the partially dried whey solids are discharged into the first product conveying

FIGURE 5

SCHEMATIC OF FLOW OF PRODUCT AND AIR STREAMS AT VERNON, NEW YORK, PLANT OF DAIRY RESEARCH & DEVELOPMENT CORP.



__________PRODUCT FLOW

----------AIR FLOW

line and carried by warm air through the first hot tube and into the first hot cyclone from which the product is discharged onto the second product conveying line. The air discharge from the first hot cyclone is introduced into the spray dryer discharge air line ahead of the first dust collecting cyclone.

The second product conveying line carries the product from the first hot cyclone and from the first and second dust collecting cyclones through the second hot tube and into the second hot cyclone. The product from the second hot cyclone discharges into the cooling line. Cool air conveys the product through the cold tube and into the cold cyclone. The discharge air from both the second hot cyclone and the cold cyclone are drawn through an exhaust fan and discharged into the air duct between the first and second dust collecting cyclones.

The product collected in the cold or final product cyclone passes through an air lock to a mill and onto the finished product screen. The screen separates the over-size product particles from the product of desired particle size. The over-size particles (rice size) are discharged into a separate bagging system to be used for animal feeds. The finished product discharges into the duct leading to the bag packer. Figure 6 details the engineering flow diagram of the DRD dryer as modified.

OPERATING EXPERIENCE

DIFFICULTIES

Operating experience and learning were developed slowly in the initial phase of the start-up of the plant due to the lack of knowledge and data on the characteristics of acid whey solids under the conditions of this process. Our method of operating the spray dryer was not the normal method used in such equipment.

In early 1971, DRD undertook phase one of the start-up which was to institute the step-by-step start-up of the Vernon acid whey drying plant. The plan was to first develop the evaporator conditions necessary to condense the acid whey from the cottage cheese plant from 6% Total Solids to 50-53% T.S. Next, the condensed acid whey was to be cooled in such a manner as to crystallize a portion of the lactose sugar present before endeavoring to dry the condensed whey in the drying equipment. This phase of the start-up continued until December 1971. Our experiences are described later in this report.

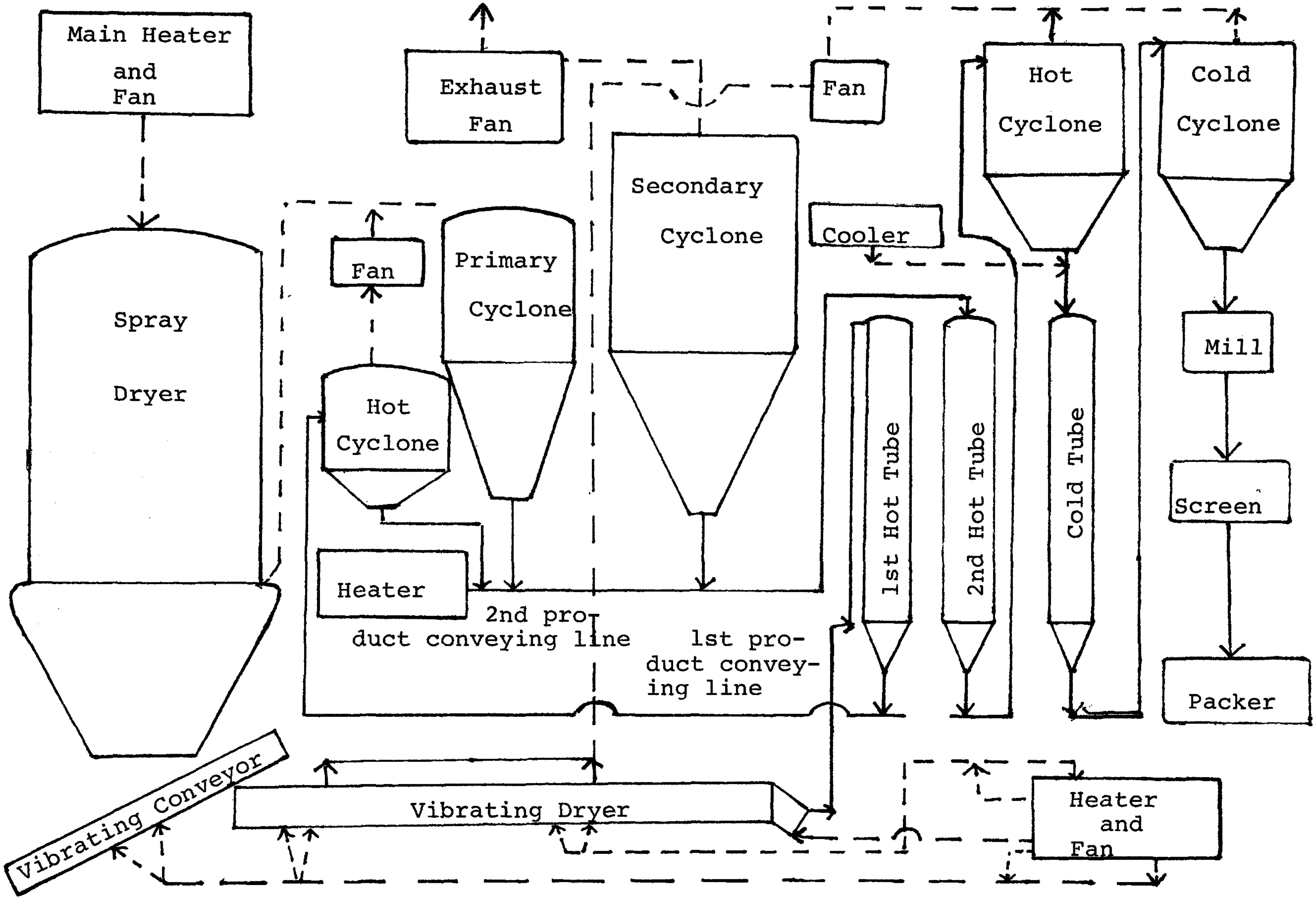


FIGURE 6 - ENGINEERING FLOW DIAGRAM AS MODIFIED OF DRYER AT VERNON, N.Y. PLANT OF DAIRY RESEARCH & DEVELOPMENT CORP.

The second phase of the Vernon whey drying project was initiated in December 1971 and continued through November 1972. During this phase of the work, there were continuing difficulties with the concentration and crystallization steps of the process. Some finished product was produced with great effort but limited to short runs due to operating problems. Between October 1972 and the end of November 1972, satisfactory progress was made as judged by the length of the dryer unit runs and the improving quality of the finished acid whey powder.

The last phase of the whey dryer start-up program, initiated December 1972, was designed to produce commercially acceptable quality and quantity of acid whey powder to support the Marketing Program. The Marketing Plan or Program included all the actions necessary to develop a customer demand for acid whey powder and establish this product as a commercially accepted human food ingredient. Both portions of phase three are considered to have been successfully accomplished. Process improvements and expansion of the markets for acid whey powder are and will be continuing activities, as in any viable industrial enterprise.

SENSITIVITY OF PROBLEMS

The reader can understand and appreciate the problems experienced during the development of this process for drying acid whey if one bears in mind the lack of adequate analytical data existing in this portion of the dairy industry. Examples of the inadequate state of the analytical methods available are undetectable changes in raw whey which are manifested in the drying characteristics, inability to determine instantaneously the extent of lactose crystallization and quantification of the degree and cause of tackiness of a semidehydrated whey product.

Raw whey as drawn from the cottage cheese vats was found to vary significantly, judging by the day-to-day analysis and operating experiences in the dryer unit. The total solids of the raw whey varied depending on the amount of wash water included and the fines present. Total acidity as lactic acid and pH varied with changes in the fermentation in the cheese vat. There also appeared to be day-to-day changes other than in solids, acidity and pH which altered the processing characteristics. Pasturization of the raw whey immediately after it was drawn from the vat and proper storage conditions prior to concentration were found to be necessary to minimize day-to-day variations of raw whey quality.

Other sensitive problems experienced with condensed acid whey included variation in total solids, lactose crystal uniformity, extent to which lactose could be crystallized, viscosity and tendency to become aerated or foam. We experienced periodic difficulty producing the desired total solids level in the condensed whey. This problem appeared to be related to the solids content in the raw whey, presence of fines and the extent of denaturation of the whey protein. Extreme problems were experienced with over 50% total solids condensed whey, as higher solids were found to maximize all problems listed above as well as adversely affecting the drying characteristic.

Obtaining the desired crystallization of the lactose to the mono-hydrate form presented problems of particular sensitivity. Crystal size and the amount of the lactose in crystal form in the condensed whey as pumped to the dryer unit have a major influence on the performance of the total dryer operation. There appeared to be an optimum level of lactose crystallization for satisfactory drying characteristics, though this area of the process has little theoretical basis to explain the behavior of condensed whey.

Variations in viscosity of condensed acid whey were to be expected from information reported by Webb and Johnson (Reference 9) on the effect of denaturation of protein and the increased asymmetry of the unfolded molecules. This problem was experienced when excessive mechanical energy or shear rate was imposed on condensed whey. The emulsifying properties of whey were encountered when the incorporation of air into condensed whey resulted in a stable air-in-whey emulsion of high viscosity and poor pumping characteristics.

Many of the viscosity characteristics of condensed acid whey were discovered in the crystallizers. The nature and rate of agitation were found to be critical. Inadequate agitation resulted in poor crystal growth rate and size, crystal separation from the mass and adhesion on the internal surfaces of the crystallizer. Excessive agitation resulted in a high viscosity, aerated product which was unmanageable. The crystallization time required to achieve the desired amount of solid state lactose is dependent on the total solids in the condensed whey, the temperature cycle employed and the rate of agitation. Periodically, abnormally slow crystallization rates were experienced, necessitating modification of the conditions.

The spray drying principle employed when drying lacteal materials is the technique normally applied to spray drying materials. The usual spray dryer operation is one which is based on converting the liquid feed in the dryer to a solid while the material is air-borne in the body of the dryer. Precautions are usually taken to minimize the amount of material which contacts and adheres to the inner wall of the dryer body. The technique employed in this project was to adjust the air flow, dryer feed spray pattern and drying conditions to promote in the dryer, a non-tacky consistency of the material which could be readily handled in the after dryers.

Difficulties were encountered in developing the proper drying conditions. Acid whey is subject to heat damage resulting in the development of off color or brownish cast, if the whey solids are overheated.

Hygroscopic whey products exposed to room conditions have a strong tendency to absorb moisture from the air and form hard cakes or lumps. For these reasons, careful control of drying conditions is necessary to reduce the production of undesirable hygroscopic product. Air flows which permitted product to contact high temperature surfaces, such as the lip of the inlet air duct, resulted in excessive scorched particles in the finished product.

Spray dryer nozzle selection was a problem. Because of the need for curing the whey on the wall of the spray dryer, the smallest obtainable droplet size from a spray nozzle was not the optimum, as such particles were more prone to carry over with the spray dryer discharge air before becoming properly cured. Large droplet size tended to strike the spray dryer wall before having been dried sufficiently and therefore caused wetting and running of condensed whey on the wall. The net result was a spray dryer product unsuited for further processing.

The preferred dryer spray pattern and air flow was found to be the combinations which gave the maximum amount of whey solids striking the dryer wall at an optimum moisture level. These conditions were achieved by the use of a wide angle spray nozzle system and a minimum of turbulence in the inlet air.

It was found that the condensed whey feed to the spray dryer and all spray dryer conditions must be adapted to obtain a product from the spray dryer suitable for further dehydration to a satisfactory finished product. The critical whey product characteristics in spray drying are particle configuration, degree of tackiness, moisture content, crystallization of the lactose and the tendency of the particles to agglomerate after discharge from the spray dryer.

A major problem encountered was the adhesion or build up of whey solids in the ducts discharging air between the spray dryer and the first dust cyclone. The whey solids entrained in the discharge air were of two distinct types, fine semi-dry particles which appeared to have passed through the spray dryer without contacting the wall surface and large particles such as those in the spray dryer product discharge. The problem was minimized by adjustment of spray dryer conditions to the drying characteristic of the condensed acid whey feed liquor.

The DRD spray dryer unit was equipped with two dust collecting cyclones to remove solids from the various air streams before the air was discharged to the atmosphere. These cyclones discharged product through a venturi into the second Product Conveying Line. The product particles discharged from the primary dust cyclone had a slight residual tackiness and were prone to build up in the lower portion of the cyclone and approach to the venturi. This condition was minimized by accurate control of the air pressure and air balance. The second or Secondary Dust Cyclone product particles were smaller but still exhibited a tendency to adhere to the approach to the venturi. This build up was not critical.

The spray dryer product discharged onto a conveyor which transported the product to the next dryer process, a fluid bed dryer. The first problem experienced with this conveyor was adhesion of the spray dryer product to the rubber belt. This complicated the proper loading of the fluid bed dryer and created an unnecessary sanitation condition. The belt conveyor was replaced with a vibrating conveyor. The vibrating conveyor caused some accumulation of product under the spray dryer discharge which was minimized by modification of the conveyor. The period of vibration was found to be critical.

The function of the fluid bed dryer or secondary dryer in the production of a non-hygroscopic acid whey powder is multi-purpose in the DRD system. While in the fluid bed dryer, the semi-dry whey must undergo a sufficient increase in the lactose mono-hydrate crystal content to insure a non-hygroscopic final product and an adequate reduction in moisture content, in order to complete the drying process in the flash drying steps of the process. The first difficulty encountered in the fluid bed unit was adhesion of the whey product to the perforated bed plate. This was controlled by changes in the spray dryer conditions and adjustments in the fluid bed dryer. There were two problems with the fluid bed dryer which limited the capacity of the total process; insufficient retention time for the product in the fluid bed and inadequate drying capacity.

The first product conveying line as designated by De Laval Separator Co. was a flash drying unit consisting of an air filter, air heater, fan, ducts, hot tube, hot cyclone and exhaust fan. The product from the fluid bed dryer entered the first product conveying line down stream of the fan. With an air supply fan to the system, an air exhaust fan from the cyclone and a venturi discharge for the product from the cyclone, air balance was very sensitive. Air temperature had to be accurately controlled as well as the moisture entering the system, to prevent adhesion and eventual charring of product within the system. Minor problems were experienced in accumulation of product in the dead space in the low pressure side of the venturi which drew the product from the first hot cyclone in the first product conveying line into the second product conveying line.

The second product conveying line consisted of an air filter, air heater, ducts, hot tube, hot cyclone (second hot cyclone) and an exhaust fan. It should be noted that the exhaust fan for the second product conveying line was also the fan which drew the air through the product cooling system. This interlock of the two systems necessitated meticulous adjustment of the air balance between the two systems for proper operation of the unit. Most problems experienced with the second product conveying system were directly related to this critical air balance. Improper air balance caused malfunction of any and all of the four venturi by which product is introduced to the system or withdrawn from the system. The most frequent trouble was experienced with the venturi under the second hot cyclone with transferred product from the second product conveying system to the cooling system.

The product cooling system consisted of an air filter, air cooler, ducts, cooling tube, cold cyclone, mechanical air lock through which product passed from the cold cyclone to the mill and an exhaust fan in common with the second product conveying line. The two major sources of trouble with this portion of the whey drying unit, beside the air balance mentioned above, was redeposition of moisture on the product in humid weather and/or product hanging in the air lock. Proper conditioning of inlet air to the cooling system eliminated the moisture redeposition problem and much of the air-lock sticking. The air-lock was an internal double gate type and has been found to be very sensitive to product moisture. Surface moisture was most detrimental and total moisture approaching the tentative acid whey specification had been troublesome.

The mill between the cold cyclone and the scalping screen was moisture sensitive to the same degree as the air-lock. The mill was found to be of marginal capacity even under the best of conditions. The scalping screen between the mill and bag packer functioned well.

The double head manual packer supplied as original equipment was completely unsatisfactory. It lacked adequate provision for dust pick-up, the dry valves were not sufficiently tight to prevent drawing empty bags into the spouting. One packer could not handle the production rate.

The major sensitivities of DRD Corp.'s acid whey drying process may be summed up as follows:

1. Analytically undetected changes in the raw and condensed whey which altered processing characteristics.

2. Drying temperature vs. product moisture level.

3. Air balances within unit.

4. Changes in ambient conditions.

Day to day variations in the crystallization characteristics of the condensed whey necessitated changes in drying conditions. Unless drying conditions were modified to meet the changes in the condensed whey, undesirable physical states were experienced with in-process product such as high moisture, poor curing rate, plastic granules, discoloration, etc.

MODIFICATIONS

In addition to the numerous adjustments made in the course of this project, basic changes were necessary in the physical facilities.

As previously mentioned, the original rubber belt conveyor between the spray dryer and the fluid bed dryer was replaced with a vibrating conveyor with a perforated product bed. In June, 1973, the perforated bed was removed to reduce the compaction and build up of product particles under the spray dryer.

It was found early in the project that the crystallizers lacked sufficient agitation to maintain the necessary control of this important step of the process. The net change after modification was an increase in the surface area of the agitators and a reduction of agitator speed, creating better control of crystallization.

A new throat was installed in the spray dryer to improve the inlet air flow pattern and reduce the eddy currents at the top of the dryer, a source of scorched particles.

The spray dryer as originally installed was equipped with an air discharge through the vertical side wall of the dryer. This discharge was removed and the bottom cone of the dryer was replaced with a large top diameter cone which projected beyond the vertical wall of the dryer and was sealed to the dryer with a horizontal collar. The discharge air from the spray dryer was drawn through two ducts from the collar. Visual observation indicated a reduction in 50% of the solids entrained in the discharge air.

The first hot cyclone, first and second dust collecting cyclones were originally equipped with air locks for return of product to the second product conveying line. These air locks could not be operated for any extended period of time because of the tackiness and/or plasticity of the semi-dried whey solids. These three air locks were replaced with venturi to accomplish the transfer of product from cyclones to the second product conveying line.

The original installation had no provisions for controlling the particle size of the finished product by other than dryer operation. It was found desirable to place a mill between the cold cyclone and the scalping screen.

The original bag packer was replaced with a two head semi-automatic bag packer.

SECTION VI

FEASIBILITY

CONSOLIDATED CHEESE OPERATION

One of the earliest decisions, emanating from the experience in the project in its first stages, was the consolidation of a number of smaller cheese operations into one large plant. Dairylea closed its Bradford, Vermont operation and centralized its cottage cheese operations into the new cottage cheese plant built at Vernon, N. Y. The cheese operation of another independent company was also brought into the Vernon, N. Y. operation. The desirable effect was a larger source of raw whey at one point for delivery to the whey drying plant under controlled conditions. This also eliminated the problem previously explained of receiving different wheys from various sources with the usual hazards of deterioration and lack of uniformity. The economics of the operation to the cottage cheese operation are manifold, low unit cost, better control of products, increased spread of capital investment with better return on investment.

WHEY DRYING PLANT ADJACENT TO CHEESE PLANT

The placement of a whey drying plant attached to or adjacent to the cheese plant is, of course, the ideal situation. This is normally economically feasible only if the cheese plant is large enough to justify a whey drying plant for its operation. Unfortunately, as later explained, there are very few plants, particularly cottage cheese plants of a size sufficient to justify its own whey drying facilities. (Reference 22). The DRD whey drying facility is adjacent to the Dairylea cottage cheese plant at Vernon, N. Y. The results of the operation have amply proven these advantages, such as, flexibility in adjusting the processing of the whey to meet the production of the cottage cheese, adapting the technology of the equipment to meet the daily variations of the cottage cheese whey and the exchange of information between the supervisory personnel of the plants to maintain the schedules and adjustments.

Most important is the control of the whey feed stock from the moment of its production to the beginning of its processing through the whey processing plant. Because of the proximity, the whey feed stock was piped over to gain the ability to maintain temperatures and better sanitary conditions. The savings in transportation was tremendous, considering that this eliminates trucking of 95% water (raw whey) and 50% to 60% of water (condensed whey). Not the least important is the factor that in whey there is chemical and bacterial activity during the time of transport. Lastly, the economics of transporation dictate some condensing equipment at satellite plants which increases the capital investment.

OTHER CHEESE WHEY

During the Summer of 1973, the equipment was tested for its adaptability to drying whey from other cheese, particularly cheddar, known as sweet whey. It was found that the equipment was not only adaptable but it did produce a high quality, non-hygroscopic sweet whey powder. Also the production rate for sweet whey was markedly increased for the same volume over acid whey. This adds another dimension of flexibility to the acid whey drying equipment in being able to bring in sweet whey for drying when there is insufficient acid whey available. This sweet whey was trucked in a distance of over 100 miles in a condensed form and crystallized so that it was dried immediately without additional crystallization. The results were favorable enough to institute this procedure as a regular program. The advantages of lowering of unit cost, utilization of plant and equipment over a longer period of time, and retention of trained personnel far outweighed the disadvantages of tight scheduling, sanitary controls and rigid supervision.

REGIONAL SERVICE POTENTIAL

Even though the whey processor would like to have all centrally located cheese plants of a very large capacity, it is recognized that this is not the present situation which must be dealt with; nor can it be expected to change too drastically in the next five years for many reasons. There are the limitations of the milk shed that serves the cheese plants. It may be less costly in some areas to truck the milk to various smaller plants and then truck the whey to a central drying facility. The experience at Vernon, N. Y. is that the whey can be trucked without appreciable bacterial decay, distances of 200 to 300 miles, the inhibiting factor being the cost of trucking. In some areas it may be more desirable to have a number of smaller regional whey drying facilities serving a number of plants within a designated perimeter. DRD is presently inclined to a large central drying facility serving a compressed region of 150 miles to 200 miles if sufficient raw whey is available within that area. If the trend of the market of whey products continues, this will undoubtedly be the most feasible method.

SECTION VII

INTEREST AND IMPACT TO CHEESE INDUSTRY

PROJECT INTEREST

The project at Vernon, N. Y. has attracted considerable attention among the cheese processors in the United States and even some from overseas. In the past several years, stringent local and state legislation has forced the closing of a number of smaller, cheese processing installations unable to meet the new anti-pollution standards. Recent federal legislation (Federal Water Quality Acts of 1965, et. seq.) has brought the problem to a climax. Cheese processors have been or will be required to eliminate whey pollution from ground and water reception. Raw whey and probably first wash water will not be allowed into the waste treatment plants with some exceptions in very large cities where the charges, based on three factors, BOD, suspended solids and volume, will continue to escalate as the costs of improvement and maintenance increase. (References 2 and 6).

In meetings with cheese processors throughout the country, there is a growing awareness of the recovery of whey as the preferred alternative. The inhibiting factor in trying to obtain a favorable response from the cheese processors has been the "waste syndrome" attitude toward whey. It is now generally recognized that treating whey as a waste is a dead end. On the other side of the coin, the covetous interest of some members of the cheese industry is the mistaken belief that there is a "pot of gold" at the end of the whey rainbow. This may lead into a disorderly and unbridled production of poor product, not uniform or meeting standards, with the resulting market disarray and repugnance from the food formulators. This has actually happened in a number of instances creating a tremendous obstacle to overcome, and in fact leading one large food organization marketing acid whey, to discontinue the product as part of its line of dairy products. The cheese industry need only look at similar happenings in the past in the dairy industry to learn an abject lesson.

PRODUCT INTEREST

The demonstration of the utilization of acid whey powder for food purposes was completed during 1973. Preliminary marketing studies had indicated that acid whey had considerable market potential in bread baking, snacks, frozen desserts, candy, and other formulated food products. The human food ingredient market is currently the growth opportunity and the most profitable market for whey products. Product interest by the food industry was aroused but with skepticism due to prior poor products that had been offered. Once overcome, the food industry accepted acid whey powder but on very rigid specifications, such as, uniformity, high quality, etc. It was discovered that the food industry also had acquired the "waste syndrome" aspect of whey with its use limited to animal feed purposes. By offering good chemical analysis, the value of the various nutritional components in the whey and the utilization of the whey in various food formulations previously tested, the whey was finally accepted by the food industry in its own right as an acceptable food grade ingredient and extremely valuable in formulated products. The non-hygroscopic aspect of acid whey was also important for shelf life and maintenance of quality.

SECTION VIII

WHEY DRYING PLANT PROJECTIONS

PLANT DESIGN AND LOCATION

The design of the plant is affected both by the location and the source of the raw whey feed stock. From all indications, it is preferable that the building housing the drying facilities should be free standing. If the powder drying facility is located in the same building as the cheese making facility, problems can arise in the nature of contamination, introduction of undesirable cultures into the cheese making and a host of other minor problems, especially if the drying equipment is utilized in the making of blends. This is not true in the case of merely condensing the whey and holding it in a liquid form before the drying stage. Evaporation and condensing equipment can very easily be installed and integrated into the same building housing the cheese making equipment.

However, if the powder plant is adjacent to the cheese making operation, then the evaporating equipment should be in the powder plant for liquid blending, if anticipated, before the drying process. The most desirable location of a whey drying plant is next door to a cheese plant with adequate raw whey feed stock to economically justify the location, preferably a minimum of 1,000,000 pounds. In this example, there should be adequate raw whey holding tanks in the cottage cheese plant from where it is pumped and piped over to the powder plant. The powder plant facility should be designed to receive the raw whey in holding or surge tanks and into an evaporator with a finishing pan, into crystallizing tanks with proper agitation which prevents settling of solids, and into the drying equipment, the bagging room and finally the warehouse for storage and distribution.

If there is no plant large enough to justify its own drying operation, then the alternative is to build a regional drying plant large enough to service a number of cheese plants within a projected area. The size of the area that can be served depends on many factors, most important transportation and its cost, the size of the plants in the outlying areas, and the projection of milk supplies in that region. A determination must also be made as to the sizing of the evaporator with the drying equipment weighed against the alternative of condensing the whey at the satellite plants and only drying at the central facility. In depth analysis and mathmatical computation of the differential in the cost factor must be made of (a) movement of raw whey as against condensed whey, (b) the capital costs of one large evaporator against a number of small evaporators in each of the satellite plants.

In planning a regional whey drying facility, not only must all of these factors be taken into account, but the problem of obtaining from each plant on the average, a consistently, uniform raw or condensed product must be resolved. In designing the facilities at the satellite plants as well as the central facility, the maintenance of uniformity and high quality must be established. This may require close liaison during the designing period with the cheese operations and the integration of the equipment for recovery of whey.

CAPITAL COSTS

EQUIPMENT

By far, the largest capital expenditure is for equipment and installation of the equipment. The most expensive items are the evaporator and the dryer which must be designed to include present and future needs. Inflation, labor and shortages of raw material supplies especially steel, can rapidly change these cost figures.

The cost of equipment including installation for a 2,000 pounds per hour of dried powder ranges from $1,250,000 to $1,500,000 depending on the transportation and local labor costs. This includes a 10% inflation factor. It refers to a single facility and does not take into consideration evaporating facilities at satellite plants in the case of a regional project, which would of course reduce proportionately the size of the evaporator at the central facility or even eliminate the evaporator. In such case the additional amount for evaporating facilities at satellite plants, eliminating a large central evaporating facility, would probably not add too much to the capital cost expenditure.

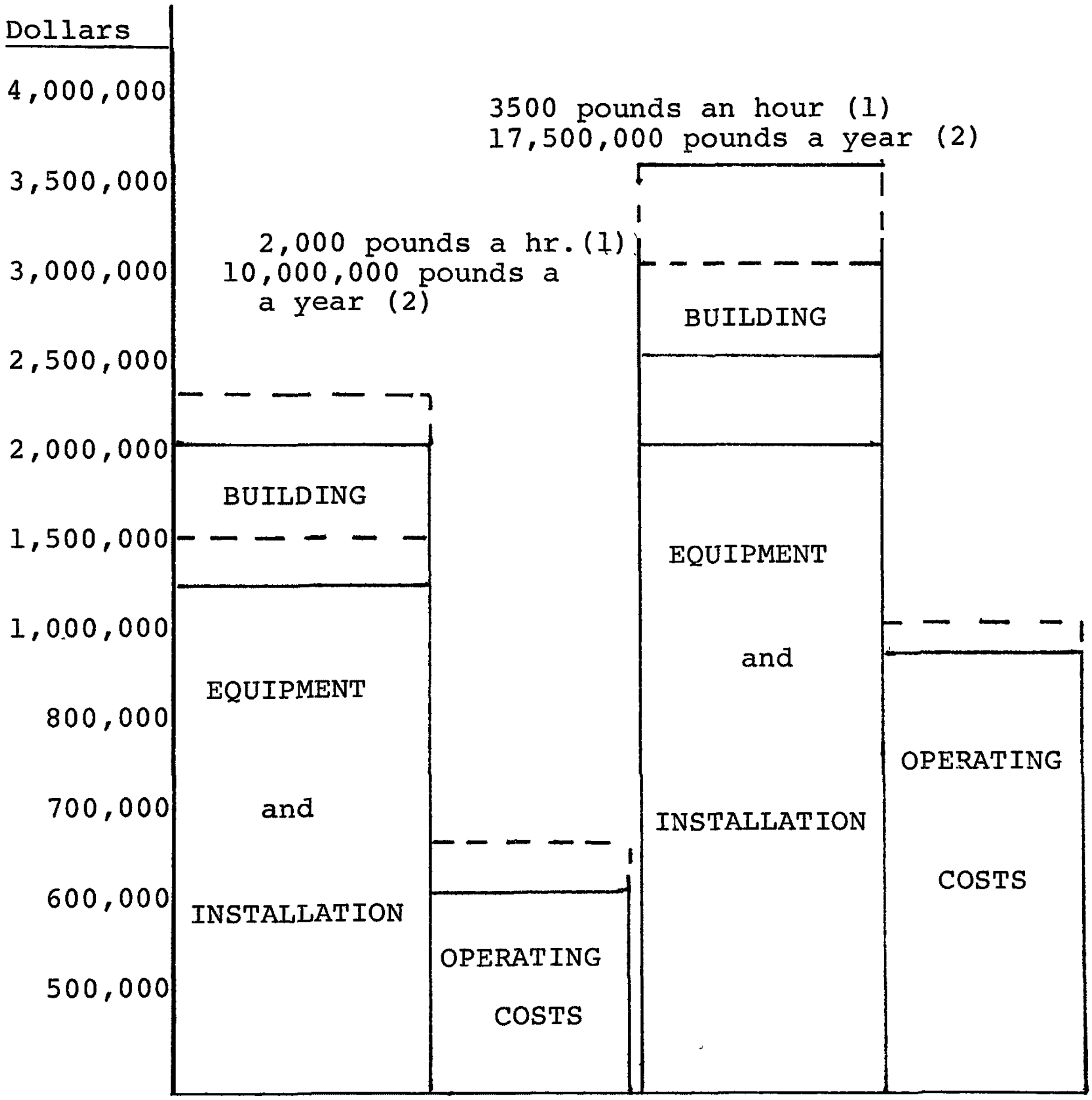
Equipment and installation for a 3,500 pound an hour plant would cost $2,000,000 to $2,500,000 with the same limitations as explained for the 2,000 pound an hour plant. (Figure 7)

BUILDING AND LAND

The building would be about 25,000 to 35,000 square feet depending on the size of the equipment and the warehousing needs. The cost of the building will vary from $750,000 to over $1,000,000 depending on the

FIGURE 7

PROJECTED CAPITAL AND OPERATING COSTS **
WHEY PROCESSING FACILITY
SINGLE FACILITY



** 1973 Prices

(1) 20 hours a day
(2) 5 days a week

--------Maximum
________ Minimum

square feet, the cost of labor and the usual variable factors. Again, this contemplates only the single facility for evaporating and drying the whey. The cost of additional building at satellite plants in the case of a regional operation may or may not increase the cost depending on the building facilities available at the satellite plants. (References 4 and 5).

Land costs cannot even be the subject of conjecture in view of the tremendous variation in land values across the country, inside and outside metropolitan centers and the amount of land needed. Two acres and preferably five acres is the minimum amount of land necessary for a project of this nature.

OPERATING COSTS

Because of the tremendous variations in utilities, labor, services, materials, etc. it is virtually impossible to set forth a fair or even average figure of the cost of operation. Using a present day average, annual production cost, based on two and a half shifts of twenty hours, at the rate of 2,000 pounds per hour, five days a week, would cost approximately $600,000. This does not include selling, general and administrative costs. These costs can easily be obtained for the local area contemplated and the actual production costs determined.

The production costs for a 3,500 pounds per hour unit would be increased, but the unit cost would be reduced for a more economical operation, if the feed stock is available. Surplus capacity, without the equivalent raw material for processing, results in higher costs per unit basis. (Figure 7).

SUMMARY - PLANT SIZE AND ECONOMICS

A plant producing 10,000,000 pounds of dried whey powder per year will cost approximately $2,000,000 to $2,250,000. A plant producing 17,500,000 pounds of powder annually will cost approximately $3,000,000 to $3,500,000. In both instances the cost of land is not included.

The minimum size for an operation that will make money at the present day market prices of the finished whey powder is 500,000 pounds a day of raw whey. 250,000 pounds of raw whey per day is an operation that may break even, sustain a loss, or a slight profit margin, depending on the initial capital expenditures and the market price of the finished product. If the price of the finished product continues to climb as it has within the past year, then this small operation can become economical and even a profit making venture.

The most economical operation is 1,000,000 pounds of raw whey per day which should be a substantial profit making operation, providing sensible procedures have been followed in the expenditure of capital for equipment and building and a vigorous marketing program is instituted for penetration of the edible grade food markets.

There are many other methods of economizing, such as, the utilization of used equipment available in excellent condition in many areas of the country, national marketing of a larger volume of product to reduce the unit cost of advertising, administration, etc.

It is anticipated that it may become necessary in the developing economics of the cheese industry that the cheese plants will have to become larger by growth and/or by consolidation in order to reduce the unit cost of both the cheese operation and the whey operation. The cheese industry must awaken to the fact that it is presently producing two food items, cheese and whey, the former being in the dairy industry and the latter destined for the food industry.

SECTION IX

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APPENDIX A

CONVERSION FACTORS
English to Metric

English Unit	Abbrev.	Multi.	Abbrev.	Metric Unit
cents per thousand gal.	¢/1,000 gal.	0.264	¢/1,000 l	¢ per M liters
cubic foot	cf	28.32	l	liter
cubic inch	cu in.	16.39 0.0164	cu cm l	cubic centi. liter
degree Fahrenheit	deg F	0.555 F-32°	deg C	degree Celsius
feet per second	fps	0.305	m/sec	meters per sec.
foot(feet)	ft	0.305	m	meter(s)
gallon(s)	gal.	3.785	l	liter(s)
gallons per day	gpd	4.381×10^{-5}	l/sec	liters per sec.
gallons per minute	gpm	0.0631	l/sec	liters per sec.
horsepower	hp	0.746	kw	kilowatts
inch(es)	in.	2.54	cm	centimeter
parts per million	ppm	1.0	mg/l	mill. per liter
pound(s)	lb	0.454 453.6	kg g	kilogram grams
pounds per square in.	psi	0.0703	kg/sq cm	kilo. per sq. centimeter
square inch	sq in.	6.452	sq cm	sq. centimeter
ton(short)	ton	907.2 0.907	kg metric ton	kilogram metric ton

APPENDIX B

PRODUCT CERTIFICATION

STATE OF NEW YORK
DEPARTMENT OF HEALTH

DIVISION OF SANITARY ENGINEERING
845 CENTRAL AVENUE
ALBANY, N.Y. 12206

December 3, 1974

Mr. Sidney Boxer
Dairy Research and Development
PO Box 312
Peekskill, NY 10566

Dear Sid:

I apologize for the confusion in getting this statement to you regarding the whey powder operation at Vernon, New York.

This department, in evaluating whey powder operations, uses the Grade A Condensed and Dry Milk Products, Supplement 1 to to Grade A Pasteurized Milk Ordinance, 1965 Recommendations of the U.S.P.H.S. The PMO requires a product to be pasteurized at the place of final packaging.

At your Vernon powdering plant, whey is piped from the Dairylea Special Products plant to the powdering plant where it is pasteurized, powdered and packaged. Such an operation meets the requirements of the PMO.

Please feel free to call me if you need further information regarding this operation.

Very truly yours,

William Y. Perez
Principal Sanitarian

APPENDIX C

DRD PRODUCTION COSTS

January 1973

Purchases	Cost	Per Unit Cost
Freight	116.40	.0006
Gas	366.22	.0018
Electric	496.92	.0024
Water	378.10	.0019
Production Labor & Fringe	2,539.68	.0124
Repairs & Maintenance	854.78	.0042
Supplies	395.10	.0019
Bags	939.78	.0046
Depreciation	4,300.00	.0210
Plant Rent	1,000.00	.0049
Consulting Fees	2,457.38	.0120
Plant Telephone	71.12	.0003
Insurance		
Misc. Expense	218.86	.0011
Plant Mgmt.	1,000.00	.0049
	15,134.34	.0741
204,300 lbs. of whey		.0741

February 1973

Purchases	Cost	Per Unit Cost
Freight		
Gas	404.61	.0022
Electric	484.80	.0027
Water	326.80	.0018
Production Labor & Fringe	2,539.40	.0139
Repairs & Maintenance	719.75	.0039
Supplies	46.48	.0003
Bags	839.50	.0046
Depreciation	4,300.00	.0236
Plant Rent	1,000.00	.0055
Consulting Fees	500.00	.0027
Plant Telephone	103.88	.0006
Insurance	356.00	.0020
Misc. Expense	435.35	.0024
Plant Mgmt.	1,000.00	.0055
	13,056.57	.0715
182,500 lbs. of whey		.0715

March 1973

Purchases	Cost	Per Unit Cost
Freight	90.50	.0003
Gas	755.15	.0023
Electric	606.00	.0019
Water	423.87	.0013
Production Labor & Fringe	3,873.68	.0120
Repairs & Maintenance		
Supplies	26.18	.0001
Bags	1,485.11	.0046
Depreciation	4,300.00	.0133
Plant Rent	1,000.00	.0031
Consulting Fees	57.92	.0002
Plant Telephone	115.03	.0004
Insurance		
Misc. Expense	210.25	.0007
Plant Mgmt.	1,000.00	.0031
	13,943.69	.0432
322,850 lbs. of whey		.0432

April 1973

Purchases	Cost	Per Unit Cost
Freight	14.93	.0001
Gas	377.17	.0016
Electric	472.68	.0020
Water	418.18	.0018
Production Labor & Fringe	2,790.45	.0119
Repairs & Maintenance	143.29	.0006
Supplies	387.48	.0017
Bags	1,075.94	.0046
Depreciation	4,300.00	.0184
Plant Rent	1,000.00	.0043
Consulting Fees	300.00	.0013
Plant Telephone	74.50	.0003
Insurance	473.83	.0020
Misc. Expense	228.35	.0010
Plant Mgmt.	1,000.00	.0043
	13,056.80	.0558
233,900 lbs. of whey		.0558

May 1973

Purchases	Cost	Per Unit Cost
Freight	30.10	.0013
Gas	33.76	.0015
Electric	242.40	.0107
Water	432.98	.0190
Production Labor & Fringe	954.94	.0420
Repairs & Maintenance		
Supplies	89.86	.0039
Bags	104.65	.0046
Depreciation	4,300.00	.1890
Plant Rent	1,000.00	.0440
Consulting Fees	272.04	.0120
Plant Telephone	72.10	.0032
Insurance		
Misc. Expenses	225.81	.0099
Plant Mgmt.	1,000.00	.0440
	8,758.64	.3851
22,750 lbs. of whey		.3850

June 1973

Purchases	Cost	Per Unit Cost
Freight	90.50	.0009
Gas	229.75	.0023
Electric	363.60	.0037
Water	364.69	.0037
Production Labor & Fringe	803.07	.0081
Repairs & Maintenance	63.19	.0006
Supplies	273.70	.0028
Bags	455.86	.0046
Depreciation	4,300.00	.0434
Plant Rent	1,000.00	.0101
Consulting Fees	233.41	.0024
Plant Telephone	83.51	.0008
Insurance		
Misc. Expense	367.50 222.53	.0060
Plant Mgmt.	1,500.00	.0151
	10,351.31	.1045
99,100 lbs. of whey		.1045

July 1973

Purchases	Cost	Per Unit Cost
Freight	9.97	.0001
Gas	390.58	.0027
Electric	375.72	.0026
Water	298.02	.0020
Production Labor & Fringe	2,851.19	.0195
Repairs & Maintenance	495.74	.0033
Supplies	2,752.50	.0188
Bags	672.52	.0046
Depreciation	4,300.00	.0294
Plant Rent	1,000.00	.0068
Consulting Fees	341.28 621.50	.0065
Plant Telephone	68.05	.0004
Insurance	60.03	.0004
Misc. Expense	232.38	.0015
Plant Mgmt.	1,000.00	.0068
	14,569.48	.0997
146,200 lbs. of whey		.0997

August 1973

Purchases	Cost	Per Unit Cost
Freight	32.20	.0002
Gas	596.04	.0031
Electric	533.28	.0028
Water	193.20	.0010
Production Labor & Fringe	3,068.81	.0160
Repairs & Maintenance	98.76	.0005
Supplies	265.41	.0009
Bags	879.75	.0046
Depreciation	4,300.00	.0225
Plant Rent	1,000.00	.0052
Consulting Fees	60.15	.0003
Plant Telephone	39.16	.0002
Insurance	140.00	.0007
Misc. Expense	259.01	.0014
Plant Mgmt.	1,000.00	.0052
	12,375.77	.0647
191,250 lbs. of whey		.0647

September 1973

Purchases	Cost	Per Unit Cost
Freight	10.40	.0001
Gas	581.94	.0037
Electric	509.04	.0033
Water	219.64	.0014
Production Labor & Fringe	4,067.10	.0262
Repairs & Maintenance	327.96	.0021
Supplies	297.38	.0019
Bags	713.92	.0046
Depreciation	4,300.00	.0277
Plant Rent	1,000.00	.0064
Consulting Fees	276.31	.0018
Plant Telephone	67.56	.0004
Insurance	1,108.00	.0071
Misc. Expense		
Plant Mgmt.	1,000.00	.0064
	14,479.25	.0933
155,200 lbs. of whey		.0933

October 1973

Purchases	Cost	Per Unit Cost
Freight		
Gas	617.32	.0022
Electric	557.52	.0020
Water	140.30	.0005
Production Labor & Fringe	2,690.41 774.80	.0123
Repairs & Maintenance	512.32	.0018
Supplies	750.80	.0027
Bags	1,299.50	.0046
Depreciation	4,300.00	.0152
Plant Rent	1,000.00	.0035
Consulting Fees	1,046.88	.0037
Plant Telephone	76.90	.0003
Insurance		
Misc. Expense	66.00	.0002
Plant Mgmt.	750.00 500.00	.0044
	15,082.75	.0534
282,500 lbs. of whey		.0534

November 1973

Purchases	Cost	Per Unit Cost
Freight		
Gas	557.20	.0023
Electric	496.92	.0020
Water	136.47	.0006
Production Labor & Fringe	4,562.75	.0185
Repairs & Maintenance		
Supplies	170.52	.0007
Bags	1,135.51	.0046
Depreciation	4,300.00	.0174
Plant Rent	1,000.00	.0041
Consulting Fees	1,287.07	.0052
Plant Telephone	76.53	.0003
Insurance		
Misc. Expense	600.00 129.29	.0030
Plant Mgmt.	500.00	.0020
	14,952.26	.0606
246,850 lbs. of whey		.0606

December 1973

Purchases	Cost	Per Unit Cost	Annual Unit Cost	
Freight	13.22	.0001	408.22	.0002
Gas	436.25	.0020	5,345.99	.0023
Electric	424.20	.0020	5,563.08	.0024
Water			3,332.25	.0014
Production Labor & Fringe	3,325.50	.0154	34,841.78	.0151
Repairs & Maintenance	693.77	.0032	3,909.56	.0017
Supplies	785.00	.0036	6,540.41	.0028
Bags	994.29	.0046	10,596.33	.0046
Depreciation	4,300.00	.0199	51,600.00	.0224
Plant Rent	1,000.00	.0046	12,000.00	.0052
Consulting Fees	986.01	.0046	8,539.95	.0037
Plant Telephone	91.57	.0004	939.91	.0004
Insurance	379.00	.0018	2,516.86	.0011
Misc. Expense	228.45	.0011	3,423.78	.0015
Plant Mgmt.	500.00	.0023	11,750.00	.0051
	14,157.26	.0655	161,308.12	.0700
216,150 lbs. of whey		.0655	Total Annual Poundage 2,303,550 lbs.	

SECTION X

GLOSSARY

ACID WHEY	- A whey derived from the making of soft cheeses, usually cottage cheese, cream cheese, etc.
AWP	- Acid Whey Powder
BOD	- Biochemical Oxygen Demand
COD	- Chemical Oxygen Demand
DRD	- Dairy Research and Development Corp.
EPA	- Environmental Protection Agency (U.S. Government)
FDA	- Food and Drug Administration (U.S. Government)
HYGROSCOPIC	- Absorbing moisture from the air.
NON-HYGROSCOPIC	- Does not absorb moisture from the air due to proper crystallization.
PER	- Protein efficiency ratio
SWP	- Sweet whey powder from hard cheeses, such as, Cheddar, Swiss, etc.
USDA	- United States Department of Agriculture

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-76-254	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE ELIMINATION OF POLLUTION FROM COTTAGE CHEESE WHEY BY DRYING AND UTILIZATION		5. REPORT DATE September 1976 (Issuing date)
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7. AUTHOR(S) Sidney Boxer and Robert W. Bond		8. PERFORMING ORGANIZATION REPORT NO.
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15. SUPPLEMENTARY NOTES

16. ABSTRACT

A spray drying process for cottage cheese whey has been demonstrated as a viable method for pollution control from the cheese making industry. The process produces a saleable product consisting of protein lactose sugar and other nutritious ingredients. The product, readily usable for animal feed, has recently been accepted for human consumption. The process was demonstrated by the Dairy Research and Development Corporation in its plant adjacent to the cottage cheese plant of the Dairylea Cooperative at Vernon, NY, at a scale of 500,000 pounds of raw whey per day.

The process consists of five major steps, evaporation of the raw whey, crystallization, spray drying, after drying and packaging of the dry powder.

Operation of the demonstration plant was successfully concluded after a period of lengthy and troublesome shakedown and start-up. The cottage cheese whey is now converted to a saleable dried product. The technology appears amenable for use in regional service facilities where sufficient cheese whey supplies can justify essential processing facility. The project capital cost for a 500,000 pounds a day(raw whey) plant of minimum size is approximately $3,000,000. The operating cost projection is approximately $450,000 per year based on 9,000,000 pounds a year of dried whey powder.

Profitability for this size plant is determined proportionately by the sale of the product to the human food market as against the animal feed market.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Industrial Wastes, *Dairies, *By-Products, Cost Estimates	*dairy wastes, human food, *animal feed, cheese whey, economics	13/B

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