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Dissolved Air Flotation Treatment of Gulf Shrimp Cannery Wastewater

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DISSOLVED AIR FLOTATION TREATMENT OF GULF SHRIMP CANNERY WASTEWATER

by

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Grant No. S 803338

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New Orleans, Louisiana

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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 Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report covers the construction and evaluation of a plant scale dissolved air flotation system which was used to treat shrimp cannery processing wastewater. Various types of coagulants and polyelectrolytes were used with the flotation system and they resulted in significant removals of organics, solids, and oil and grease.

An extensive inplant water use and wastewater management program was instituted and it resulted in large overall reductions in the quantity of pollutants generated per unit of production.

Further information on this project can be obtained by contacting the Food and Wood Products Branch of IERL-Ci.

David G. Stephan
Director
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ABSTRACT

This study reports on the operation of a plant scale dissolved air flotation (DAF) system installed to define and evaluate attainable shrimp cannery wastewater treatment levels. The system was operated in all three modes of DAF pressurization. Destabilizing coagulants investigated included alum, lignosulfonate (PRA-1), and cationic polymer (507-C). Using alum and anionic polymer 835A as a coagulant aid, significant removals of BOD, TSS, and oil and grease were achieved. Operating data are presented that characterize the Gulf shrimp cannery wastewaters and show the removals attained. Data on oyster processing wastewaters are also presented.

In conjunction with the project, water use reduction and wastewater management practices were instituted at the study cannery, resulting in large overall reductions of pollutants. Costs for the wastewater treatment system installation, operation, and maintenance are presented. Average annual wastewater treatment equivalent costs and costs per case of finished product are estimated.

Oyster canning wastewater can be treated, and pollutant discharge can be reduced using the DAF shrimp wastewater treatment system. The problem of the handling and disposal of the DAF skimmings sludge (and screenings solids) has not been solved. Preliminary dewatering investigations are reported in this study.

This report was submitted in fulfillment of Grant No. S-803338 by Domingue, Szabo, & Associates under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers the period July 1974 to December 1977, and work was completed as of August 1978.

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ABBREVIATIONS AND SYMBOLS

ASCA	- American shrimp canners association
BAT	- Best available technology
BATEA	- Best available technology economically achievable
BOD	- Biochemical oxygen demand
BOD_5	- 5-day biochemical oxygen demand
BPCTCA	- Best practical control technology currently available
COD	- Chemical oxygen demand
DAF	- Dissolved air flotation
FFP	- Full flow pressurization
gpd	- gallons per day
gpm	- gallons per minute
mg/l	- milligrams per liter
NTU	- Nephelometric turbidity units
O & G	- Oil and grease
P	- Partial pressurization
ppm	- Parts per million
PRA	- Lignosulfonate, commercial
R	- Recycle pressurization
s	- Standard deviation
TKN	- Total Kjeldahl nitrogen
TS	- Total solids
TSS	- Total suspended solids
TVS	- Total volatile solids
VSS	- Volatile suspended solids
$\bar{x}$	- Mean value

CONVERSION FACTORS

TO CONVERT	INTO	MULTIPLY BY
acres	hectars or sq. hectars	0.4047
acres	square meters	4,047
Celsius	Fahrenheit	$^{o}C(9/5) + 32$
cubic feet	cubic meters	0.02832
cubic feet	liters	28.32
cubic feet/minute	cubic meters/minute	0.02832
dollars/pound BOD_5	dollars/kilogram BOD_5	2.2
Fahrenheit	Celsius	$(^{o}F - 32)\ 5/9$
feet	centimeters	30.48
feet	meters	0.3048
gallons	cubic meters	3.785×10^{-3}
gallons	liters	3.785
gallons	cubic feet	0.1337
gallons	cubic yards	4.951×10^{-3}
gallons	kilo-liters	3.79×10^{-3}
gallons/minute	liters/second	0.06308
gallons/minute	liters/minute	3.79
gallons/minute/square foot	liters/minute/square meter	23.68
gallons/1000 pounds	liters/1000 kilograms	8.338
horsepower	kilowatts	0.7457
inches	meters	2.54×10^{-2}
inches	centimeters	2.54
inches	millimeters	25.4
microns	inches	3.937×10^{-5}
miles	kilometers	1.61
millimeters	inches	0.0394
million gallons/day	cubic meters/second	1.54723
parts per million	milligrams per liter	1.0
pounds	kilograms	0.454
pound/pound	kilogram/kilogram	1.0
pounds/hour	kilogram/hour	0.454
pounds/square inch	kilograms/square meter	703.1
pounds/cubic foot	kilograms/cubic meter	16.06
pounds/hour/square foot	kilograms/hour/square meter	4.893
square feet	square meters	0.0929

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SECTION I

INTRODUCTION

Gulf Coast shrimp fisheries are an important part of the shrimp industry of the United States. The total shrimp catch varies from year to year and government statistics show that the U.S. average for a recent five-year period was approximately 375,000,000 pounds per year. Of the Gulf catch of approximately 200,000,000 pounds (heads-on), around ten percent is handled by the canning industry. Some two million cases per year of canned shrimp are produced. The canners receive most of their product from the fisheries in Louisiana and Mississippi with small amounts from the other Gulf states. The remainder of the Gulf catch is handled as fresh product or is processed and marketed as various frozen products.

The canners of the Gulf Coast are located in Louisiana and Mississippi and have an average operating period of approximately 120 days per year. With some plants adding freezing facilities, extended operating periods will probably occur in the future. The canners are an important segment of the industry, processing much of the catch from "inside" waters, bays, estuaries and the coastlines of the Gulf states. The raw shrimp are very perishable. The shrimp die as they are caught and brought to the surface of the water and onto the decks of the boats where the catch is iced until it is delivered to the processor. Because of the remote locations of the fishing areas and the time required to reach the market and/or the processor, the shrimp vary in age when delivered to the cannery and may be from one to four or five days out of the water. It is absolutely essential that the product be processed rapidly to preserve its freshness and wholesomeness. Therefore, canneries normally have capabilities of peeling and processing at a high rate per hour. When conservation agencies open the regulated inside fishing waters there is generally a high rate of production which gradually lessens until the season is closed. Cannery operation, then, may be from an almost continuous status during the abundant product availability periods down to a half day or less operation on intermittent days as the raw product becomes less available.

The wastewater production from shrimp processors results from the peeling operation, cleaning, grading, deveining and preparation for preservation. In a cannery there is further wastewater from the blanching and cooling operations and from retorting of the canned product. These wastewater flows vary, dependent upon the shrimp supply, the size of the shrimp being processed, the age and location of the catch of the shrimp, unique individual plant characteristics and many other factors which are difficult to completely define. The result is a strong organic wastewater containing the conventional pollutants of oil and grease, suspended solids and biochemical oxygen demand. There are no toxic or non-biodegradable substances in the wastes. Since shrimp processors and canners are near the source of the raw product and were at one time supplied only by boat, most are located on coastal waters. Although they may now receive their supplies by truck from distant docks or landing locations, the canners continue to operate in the original facilities. They are generally located on sites with limited land holdings, and many of them are in remote developed, non-metropolitan areas. The wastewater has traditionally been discharged to the waterways or streams on which these processors are located, although a few urban plants discharge to public sewers. As area development has occurred and stream conditions have varied, some few have encountered pollution control problems. Others have not yet seen evidence of any detrimental effect on the streams.

Shrimp Canners have for many years been concerned with a solution to the problem of wastewater disposal. In the mid-sixties, some urban canneries faced the removal of their wastewater from over-loaded public sewer systems into which the plants were discharging. Investigations were started at that time to seek proper methods for disposing of such wastewater. In 1971, the non-profit trade group, the American Shrimp Canners Association, initiated action to actively investigate the cannery wastewater. In February, 1972, an application was submitted to EPA for a research, development and demonstration grant to investigate shrimp cannery wastewater treatment. Studies were subsequently conducted under the grant to establish wastewater characterizations, determine effectiveness of screening of shrimp cannery wastewater, and test pilot plant performance of dissolved air flotation as a treatment method. The project report, "Shrimp Canning Waste Treatment Study"[1] published in June, 1974, recommended that there be further investigation to: (a) establish the efficiency of a DAF treatment system on a plant scale: (b) study process changes and operating procedures to reduce and control water use in the cannery; and (c) investigate methods for handling separated solids and sludges developed by wastewater treatment.

This project was intended to provide the plant scale testing of a dissolved air flotation system for shrimp cannery wastewater treatment. Dissolved air flotation (DAF) is a physical, solid-liquid separation process which has been proven to be effective for wastewater treatment in many areas of the seafood processing and canning industry.[2] DAF operates on the principle of minute air bubble attachment and specific gravity reduction of suspended and colloidal particles, causing the subsequent rise of the solid material. The process also becomes chemical in nature when pH adjustment is employed and/or coagulating and flocculating chemicals are added. Being a physical-chemical treatment operation, dissolved air flotation is particularly adaptable to intermittent flows since start-up is relatively more quickly effective than a biological system, for example. Similarly, dissolved air flotation has relatively low land area requirements. Both of these factors are of major concern to Gulf shrimp canners since the plants operate seasonally and intermittently, and are usually located on bays or bayous where land is a scarce commodity.

Subsequent to the enactment of P.L. 92-500 in October, 1972, the Environmental Protection Agency was charged with establishing measures and regulations to reach the interim and ultimate goals to preserve the waters of the United States. Accordingly, industry effluent limitation development studies were conducted and guidelines were established. Seafood industry guidelines were published in June, 1974, and were subsequently amended on: January 30, 1975; December 1, 1975; July 1, 1976; July 30, 1976; February 4, 1977; and February 17, 1977. Regulations of prime concern to Gulf shrimp canneries are designated 40 CFR 408.120-408.126, which establish effluent limitations for "non breaded shrimp processing", and 408.270-408.276, which establish effluent limitations for "steamed and canned oyster processing". These regulations based best practicable control technology currently available (BPCTCA) 1977 effluent limitations on screening of the processing wastewater. The 1983 best available technology economically achievable (BATEA) for shrimp processing is based on dissolved air flotation treatment while oyster processing is based on aerated lagoon treatment, except that oyster processors who are also shrimp processors will have limitations established on a case-by-case basis.

The BATEA limitations were established without the benefit of plant scale operational data. Limited shrimp wastewater pilot study information and transfer of data from studies or operation of treatment systems on other seafood and food processing wastewaters were utilized in preparing the guidelines for attainable effluent reductions. No data were available on oyster wastewater treatment.

It was,therefore,of importance to establish and operate a plant scale wastewater treatment system to determine the actual degree of pollutant discharge reductions which could be attained. ASCA again sought and obtained a demonstration grant from EPA to follow up on the findings of the earlier 1972-74 shrimp cannery wastewater treatment pilot plant. The project was expanded to obtain data on the treatment of oyster processing wastewaters as well as shrimp canning wastewaters.

The purposes and objectives for this project were to modify cannery process or product handling to reduce organics in wastewater, to establish a cannery water use program to limit wastewater discharge, to design and install and operate a full scale wastewater treatment system,and to monitor the raw wastewater and treated wastewater effluents.

The project grant was received in July, 1974. An on-site laboratory was then designed,installed and equipped in time to begin wastewater flow measurement and characterization during November and December. The year 1975 was spent in the accumulation and analysis of water use data, the sampling and analysis of unit process and total wastewater streams, the preparation of a water use conservation and wastewater management plan, and the design and bidding of a wastewater treatment system. The treatment system was delivered and installed by late May, 1976. Start-up problems prevented effective operation during the May-July, 1976, summer canning season. After modifications in August and October, 1976, and in early 1977, the wastewater treatment system was operated and monitored during the October-December, 1976, and May-July, 1977 shrimp canning seasons and during February-March, 1977 oyster canning operations. Some additional data were collected in August, October and November during the shrimp processing season. Data collection was completed in November, 1977.

The project has been accomplished. Water use and management was modified, product handling changes were instituted, the wastewater treatment system was installed and operated, and operational data were collected.

SECTION II

SUMMARY

This study reports the findings of a project in which a plant scale dissolved air flotation system was installed and operated at a Gulf shrimp and oyster cannery in an effort to define and evaluate attainable wastewater treatment levels. The system was sized to treat the entire wastewater flow from the study cannery. It was designed to provide treatment in all three DAF modes, to utilize various chemical additives and application points, and to permit pH adjustment and control. Treatment effectiveness was determined by monitoring selected conventional wastewater parameters, including BOD, COD, oil and grease, total Kjeldahl nitrogen, and suspended solids.

The cannery shrimp processing wastewater was characterized over several canning seasons with regard to both volume and pollutant loads. Oyster processing wastewater was studied for a short period. It was found that there was a great deal of variability in the content of the pollutants in the wastewaters. This is undoubtedly due to the variable sizes, age, source and volume of the raw product being processed. The system was chemically sensitive, and varying removal efficiencies were reached. Day-to-day operation of the DAF wastewater treatment system in this seafood application was demonstrated. Promising chemical destabilizing agents (coagulants) used were alum, lignosulfonate (PRA) and polymer (American Cyanamid 507-C). At an acidic pH, with an anionic polymer (Magnifloc 835A) as a coagulant aid, good pollutant removals were achieved. Oyster processing wastewaters were also effectively treated with the DAF system.

Skimmings sludge disposal from the DAF system was found to be a new, unsolved problem which requires further study. Limited project investigations developed data on quantities and characteristics. Bench scale tests of chemical oxidizing, centrifugation and heating are reported. Data on testing a pilot scale evaporator dryer are also given.

Shrimp processing and handling requires large volumes of water, both by process equipment design and by established procedure and custom. Water use conservation and management measures were instituted in the study plant with resultant significant wastewater flow and pollutant load reduction. Minor product handling modifications contributed to waste load reductions.

Data obtained from system operation are given in the report. These data confirm the preliminary, pilot plant study conclusion that a DAF system can be an effective

treatment method if the biodegradable shrimp and oyster cannery wastewaters are to be treated prior to discharge into the marine environment. The DAF treatment system was found to be sensitive to wastewater changes and requires very careful and knowledgeable control to obtain the maximum removals.

The study demonstrated that: (1) water use management and control is possible and can help to significantly reduce wastewater pollutant discharge, (2) processing modification and control can contribute to reduction of pollutants in wastewater, (3) DAF treatment may be expected to reduce conventional pollutants in shrimp and oyster processing wastewaters, and (4) the DAF treatment system will require careful operation and full chemical addition.

SECTION III

CONCLUSIONS

1. One purpose of this project was to investigate water use and to institute water conservation measures. This was done and wastewater flow was reduced more than 43% from 7,730 gallons per 1000 pounds (64,300 liters per 1000 kg) of raw shrimp processed in 1975 to 4,420 gallons per 1000 pounds (36,800 liters per 1000 kg) in 1977.

2. Another objective was to consider cannery processing or product handling procedures for possible modification to reduce pollutant load in the wastewater. Several modifications were considered but were not feasible at the time. One change from wet fluming to dry conveying was demonstrated to reduce the concentration of pollutants in the wastewaters. The pollutant increase in weight by wet conveying over the same length was on the order of 10%. Water use and wastewater management techniques resulted in an overall pollutant load reduction of 60% BOD_5, 13% TSS and 40% O & G.

3. The screening of wastewaters prior to discharge is the current BPCTCA for shrimp and oyster processors. This practice at the study cannery was found to be effective as a pollutant load reduction mechanism, particularly with regard to TSS. A removal of 45% TSS was found. This reduction was in addition to that achieved by water use and wastewater management.

4. The further characterization of wastewaters from cannery unit processes and the total discharge was undertaken. An attempt was made to correlate wastewater pollutant load to source, size and age of raw product, but this was not successful. The data from the effort confirm the variability and unpredictability of the cannery wastewater content. Such variations have a direct effect on the success of the wastewater treatment effort. Review of the data will also indicate that variations are such that average and ranges (or standard deviations) of values are more applicable than "typical" or "optimum" values.

5. The primary project purpose was to determine the achievable levels of pollutant removals from the cannery wastewater with a plant scale dissolved air flotation (DAF) treatment system. With some start-up difficulties, requiring a project time extension, the system was successfully operated under various normal cannery operating conditions and with careful control of treatment. Conclusions with

regard to DAF treatment of the biodegradable shrimp canning wastewater are:

(a) Pre-screening of shrimp processing wastewater is essential to satisfactory treatment system control.

(b) Physical-chemical treatment of Gulf shrimp processing wastewater is a valid technology, but it requires knowledgeable operation and control.

(c) Treatment without chemicals in the DAF system resulted in low removal efficiencies.

(d) Chemical addition is required to control pH, coagulate and flocculate the suspended solids and obtain significant removals of the conventional pollutants. Acid, alum, polymer and caustic are required.

(e) The recycle mode of DAF operation can give more consistent results, in the opinion of the investigators.

(f) With minor modifications, a DAF system to treat shrimp processing wastewater can be successfully utilized to provide a comparable degree of treatment for oyster processing wastewaters.

(g) Findings on the cannery wastewater treatment should also be applicable to any shrimp processor where similar mechanical peeling, cleaning, grading, and deveining are practiced.

6. The DAF treatment of shrimp cannery wastewater was not demonstrated to achieve the degree of effluent reduction called for in BATEA guidelines. It is concluded that revision of the guidelines (40 CFR 408.123) would be required. The present guidelines and the practicable, achievable, average pollutant discharge in lbs/1000 lbs (kg/1000 kg) of raw shrimp are:

PARAMETER	GUIDELINES	ACHIEVABLE
BOD_5	10	20
TSS	3.4	10
0 & G	1.1	1.4

7. Oyster canning wastewater pollutant removals by DAF system installed to treat shrimp cannery wastewater can be expected to reach the average removal reflected by the achievable limitations shown below, as compared to BATEA guidelines in 40 CFR 408.273, in lbs/1000 lbs (kg/1000 kg) of finished product:

PARAMETER	GUIDELINES	ACHIEVABLE
BOD_5	17	20
TSS	39	20
O & G	0.42	1.0

8. Achievable removals of some parameters are apparently related to initial concentration. Oil and grease appears to be so related. A lesser percentage of oil and

grease was found to be removed from the less concentrated oyster processing wastewaters than from the shrimp processing wastewaters.

9. Because of the varying seasonal and intermittent operation by shrimp and oyster canneries and processors, the land limitations faced by most operators, the highly putrescible nature of both the raw product and the resultant processing wastes, the Dissolved Air Flotation system appears at this time to be a viable wastewater treatment method. With careful and constant control, it can effectively reduce the pollutant load in the wastewater prior to discharge. Variable operating conditions of from two hour to 24 hour periods, delicate instrumentation to control pH and the addition of three or four chemicals and the amount of mechanical equipment involved will necessitate fully staffed, highly trained operators if adequate results are to be regularly achieved.

10. Project records of capital costs and operating and maintenance costs were used to develop typical DAF wastewater treatment system average annual costs for an 8 peeler and for a 4 peeler processor. These costs are in year-end 1977 dollars and include capital costs, power, labor, chemicals, sludge disposal costs, amortization and operation and maintenance:

Size Plant	Average Annual Cost
8 peelers	$ 131,500
4 peelers	$ 104,100

11. It was concluded from this project that the wet (5% solids), highly putrescible and odorous sludge produced from DAF treatment of shrimp canning wastewaters will average about 5,400 gallons (20,400 liters) or 27 cu. yds. (21 cubic meters) per day and may be as high as 10,000 gallons (37,850 liters) or 50 cubic yards (38 cubic meters) per day. Since by present practice shrimp peeling hulls are screened out and disposed of as solid wastes to landfill, it has been assumed this may be one way of disposing of sludges produced. However, this is not an acceptable alternative and a better solution is needed. Storage, treatment and disposal of DAF skimmings sludge and screenings solids requires further investigation.

SECTION IV

RECOMMENDATIONS

1. Best Available Technology effluent limitations guidelines for shrimp processors should be re-examined in view of the experience with this plant scale wastewater treatment system. The levels of removals established in the guidelines do not appear to be achievable under normal operating conditions. It is recommended the average discharge of conventional pollutants based on DAF treatment removals, using a complete physical-chemical system, be established as:

PARAMETER	AVERAGE DISCHARGE LIMITATION
BOD_5	20 lbs/1000 lbs (kg/1000 kg) raw shrimp processed
TSS	10 lbs/1000 lbs (kg/1000 kg) raw shrimp processed
O & G	1.4 lbs/1000 lbs (kg/1000 kg) raw shrimp processed

2. Best Available Technology effluent limitations for oyster processors which utilize DAF systems installed to achieve shrimp processing limitations can be expected to discharge average conventional pollutant quantities of:

PARAMETER	AVERAGE DISCHARGE LIMITATION
BOD_5	20 lbs/1000 lbs (kg/1000 kg) canned oysters
TSS	20 lbs/1000 lbs (kg/1000 kg) canned oysters
O & G	1 lbs/1000 lbs (kg/1000 kg) canned oysters

It is recommended this limitation be considered in each such case.

3. The economics of achieving the above suggested limitations should be re-examined in view of the data developed in this project.

4. Should there be no change in the current concept of requiring the separation of conventional pollutants from seafood processing wastewaters as solids prior to discharge into the marine environment, there will remain a pressing need to solve the solids disposal problem. Wet disposal on land is not practicable. An adequately funded comprehensive study, or studies, should be conducted to determine the most feasible, cost effective method of handling and disposing of DAF skimmings and shrimp processing screenings, including; chemical conditioning, belt press or

filter press dewatering, evaporator drying, kiln drying, centrifuge dewatering, etc.

5. Individual canners and processors of shrimp and oysters are encouraged to adopt effective water use management and control measures and to plan plant and processing modification with a view to reducing water use for transporting product, substituting dry conveying, and using substitute methods for product cleaning, such as low velocity air. Efforts should be directed toward keeping solids out of water and thus out of wastewaters. Water re-use under controlled conditions may offer promise. All of these items will require considerable time and effort to develop and accomplish, if feasible.

SECTION V

BACKGROUND

A. Literature Review

There exist three basic mechanisms of air flotation: Dissolved Air Flotation, Dispersed Air Flotation, and Vacuum Flotation. All are classified as unit operations and seek to bring about the separation of solids and liquids in a two-phase medium by combining a gas, usually air, with the solid materials for the subsequent rise of the solids with air bubbles attached. Each process differs in the method by which air is brought out of solution. Dissolved air is the most widely used of the flotation mechanisms and has found application in many industrial wastewater treatment systems, as well as in municipal sludge thickening.[2]

In order to dissolve air into water, pressure must be applied. This follows Henry's Law which states that the solubility of a gas in a liquid is directly proportional to the absolute pressure of the gas above the liquid at equilibrium. In mathematical form, Henry's Law may be expressed as:[3]

$$P_g = H\chi_g, \qquad (1)$$

Where: P_g = Partial pressure of gas, atmospheres

Symbol χ_g = Equilibrium mole fraction of dissolved gas

$$= \frac{\text{Moles gas } (M_g)}{\text{moles gas } (M_g) + \text{moles water } (Mw)}, \text{ and}$$

H = Henry's Law constant

The constant, H, is a function of chemical and physical characteristics of the liquid. A re-arrangement of equation (1) yields:

$$\chi_g = \frac{P_g}{H} \qquad (2)$$

In this simple form, Henry's Law states that the theoretical level of saturation of a gas in a liquid is greater at a higher liquid-gas interface pressure. A widely accepted theory of mass transfer, the two film concept, contends that both gas and liquid films exist at the gas-liquid interface. The transfer of gases into solution will only occur at pressures sufficient to establish the needed gradient across the gas-liquid film. When the induced pressure is released, the gradient is essentially reversed and the gas is forced back across the interface to come out of solution as tiny bubbles. Such is the case in dissolved air flotation. Air is mixed with water and the mixture is pressurized. Under pressure, the air is forced across the gas-liquid interface to become saturated in the water. A shift in the pressure gradient occurs when the pressure is released, and the air comes out of solution in the form of minute bubbles with diameters of 50-100 microns.[4] Thus, the air portion of the flotation process has been supplied.

Mechanisms of DAF

Dissolved air flotation can occur by three different processes:[2,5] (1) adhesion of gas bubbles to a suspended phase, (2) gas bubbles becoming trapped in the floc structure as the bubbles rise, and/or (3) adsorption of gas bubbles in a floc structure as it is formed. The first process can occur by the precipitation of the gas on the solid or liquid surface, or can occur by contact between the suspended and gas phases. This contact between suspended and gas phases is thought to be more difficult to bring about since it relies on a direct contact between the participating phases. Vrablik[2] notes that the adhesion process, (1), is best carried out in a full pressurization situation. Solids in the waste stream act as nuclei for bubble formation in this mode, and the retention time allows for greater bubble-solid contact.

Process (2) is a variation of the first case of process (1) whereby contact between particle and bubble is necessary and dependent on the irregularity of the particle surface. Here, coagulating chemicals are employed to increase the size of the particle through flocculation. It is to be noted that laboratory results are often not applicable to full scale systems due to dynamic differences.[2]

Finally, dissolved air flotation may occur by trapping both gas bubbles and solid materials in a floc structure. This process (3) occurs after the pressure is released and the gas is coming out of solution.

Air To Solids

One of the primary operating variables of a dissolved air flotation system is the air to solids ratio. This is a function of and is controlled by the factors of pressure, water temperature, and suspended solids level. Air to solids ratio (A*/S) is an expression representative of the ratio of pounds of air released to the pounds of solids applied. The following expressions are used to calculate A*/S and assume that an excess amount of air is applied:[4]

$$A^*/S = \frac{Cs}{Xo}[f(P/14.7 + 1) - 1] \quad \text{(no recycle)} \qquad (3)$$

$$A^*/S = \frac{RCs}{QXo}[f(P/14.7 + 1) - 1] \quad \text{(with recycle)} \qquad (4)$$

The terms in the above expressions are defined as follows:

A^*/S = air to solids ratio, pounds air released per pound solids applied,

Cs = gas saturation at atmospheric conditions, mg/l,

Xo = average influent suspended solids, mg/l,

f = fraction of saturation of air dissolved in the pressurization system,

P = gage pressure, psig,

Q = influent flow, mgd, and

R = recycle flow, mgd.

Generally speaking, the higher the A^*/S ratio, the better the treatment will be because more air will be available to float the solids.

Colloidal Destabilization

Many particles found in wastewater are colloidal, i.e., their diameters are in the range of 0.001 to 1.0 microns. Such particles have an extremely low settling velocity, and are smaller than the air bubbles which are precipitated by the dissolved air flotation process. By the addition of coagulating chemicals, and coagulant aids, these particles can be drawn together to form larger particles.

A common and useful coagulant is aluminum sulfate, or alum: $Al_2(SO_4)_3 \cdot 18\ H_2O$. When introduced into an aqueous system, alum reacts with alkalinity in the water to form aluminum hydroxide:

$$Al_2(SO_4)_3 \cdot 18H_2O + 3Ca\,(HCO_3)_2 \longrightarrow$$

$$2Al(OH)_3 + 3CaSO_4 + 6CO_2 + 18H_2O \qquad (5)$$

The $Al(OH)_3$ salt is actually of the form, $Al_x(OH)_y^{3x-y}$ and concentrations vary with pH. It is the $Al(OH)_3$ form however that is an effective coagulant. These positively charged counter ions can bring about destabilization of negatively charged colloids by several methods. One of the most common phenomena of particle destabilization is termed double diffuse layer compression whereby an overshadowing of the negative colloidal charge is brought about by the $Al(OH)_3$ compound. The result is destabilized colloids and larger solid particles.

Coagulant aids (polymers) do not act as destabilizing agents, but rather form larger, tougher flocs of particles which have already been destabilized and brought together by coagulants. Polymers act as bridging agents and can be charged or uncharged, and, if charged, can be either positive or negative. Polymers are very useful when used in conjunction with metal salts, but most are not effective when acting alone.

Modes of DAF Operation

There are three distinct and separate modes of hydraulic operation for dissolved air flotation systems, each with different operating characteristics. They are full flow pressurization (FFP), Partial Pressurization (P), and Recycle Pressurization (R), as illustrated in Figure 1. Each mode has its advantages and disadvantages, and usually pilot plant studies are required to determine the optimum mode for use on a particular wastewater. It is generally understood, however, that a shearing of floc particles occurs at the pressure release valve when the wastewater itself is de-pressurized. The degree to which this phenomenon affects operation and performance varies, of course, with the type of wastewater and its nature and treatability. The three modes differ in that all the raw flow is pressurized in full flow pressurization (FFP), a portion is pressurized in partial pressurization (P), and no raw flow is pressurized in recycle pressurization (R). Full flow pressurization does not require a recycle pump or special flocculation chamber and, therefore, the full flow pressurization mode is lower in capital cost than the partial or recycle modes. Delicate floc can be better handled with the other modes, however.

DAF Treatment in the Seafood Industry

The nature of most animal processing wastewaters, including seafood, is such that sedimentation processes aren't applicable; oil and grease is usually at a high level, and a large portion of solid materials exists in the wastewater in colloidal or dissolved form. Much of the pollutional character of seafood processing wastewater is in the form of soluble organics and soluble protein, which is conventionally removed by biological treatment, or chemical precipitation. However, since seafood processing is seasonal, and operates on an intermittent basis, dissolved air flotation represents a very adaptable treatment scheme which does not incur the inherent disadvantages associated with a biological treatment system such as start-up, inadaptability to intermittent loading, and large land area requirements. DAF also has the flexibility to include chemical precipitation.

Since dissolved air flotation of seafood processing wastewater is a relatively new application, pilot studies have been conducted for several segments of the industry to adequately define the treatment levels which could be expected before full-scale treatment is attempted. Basic results indicate that DAF removals of BOD_5, TSS and O & G have reached high levels in such areas of the seafood industry as tuna, Pacific NW shrimp, and menhaden bailwater.[6,7] Similarly, dissolved air flotation has been proven successful for treating salmon and other fish processing wastewaters.[8,9]

Table 1 gives a summary of DAF pilot plant testing on various seafood wastewaters.

Studies at various fish processing plants in Sweden have been conducted to

Figure 1 DISSOLVED AIR FLOTATION OPERATIONAL MODES

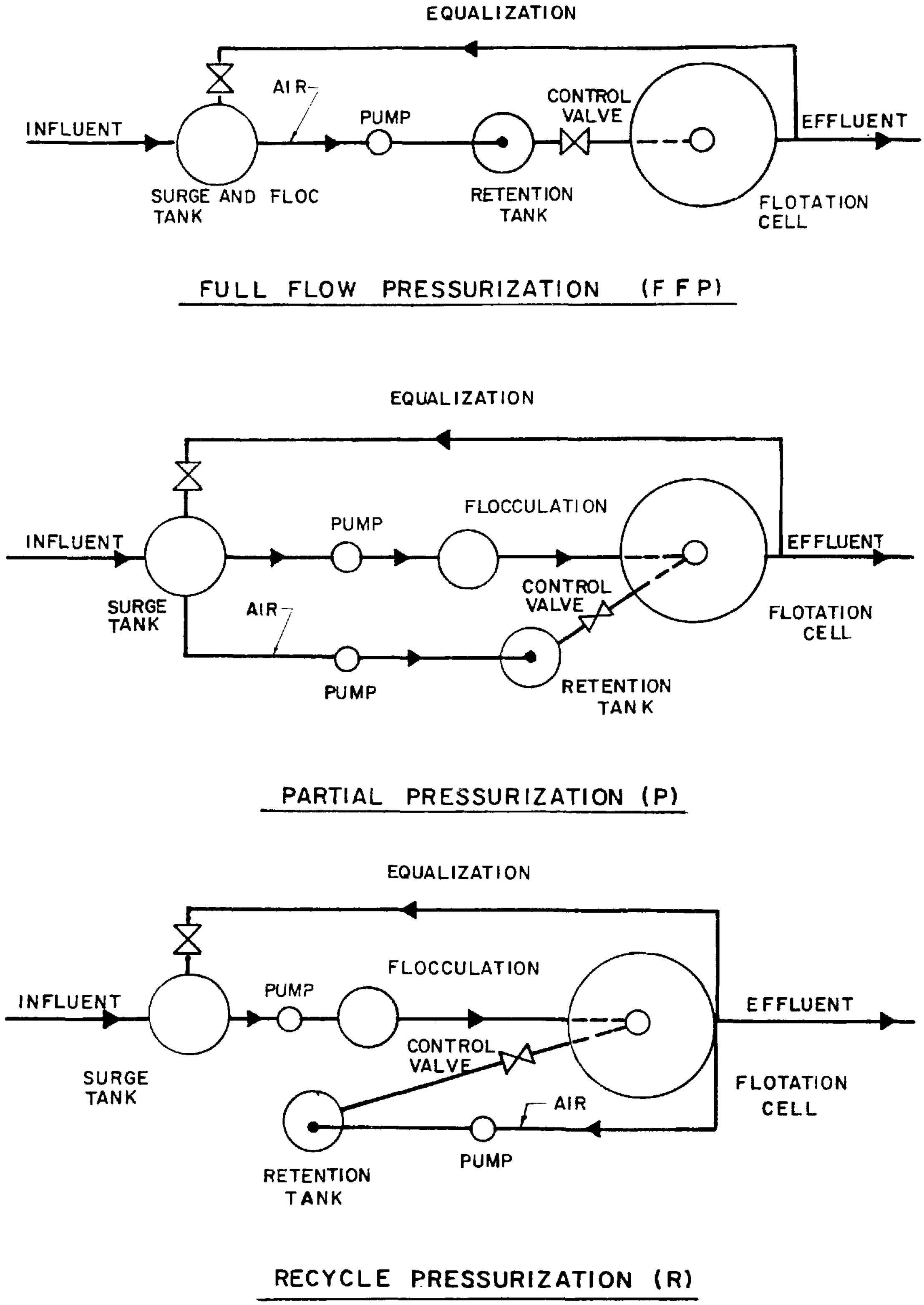


TABLE 1. SUMMARY OF PILOT PLANT DAF PERFORMANCE[6]

Wastewater Source	Chemical Additive	No. of Samples	Parameter	% Reduction
Tuna	Lime (pH 10-10.5) Polymers Cationic Anionic	1	BOD_5 TSS O&G	65 66 66
Tuna	Lime Ferric Chloride	1	BOD_5 TSS O&G	22 77 81
Menhaden Bailwater	Alum or Acid (pH 5-5.3) Polymer	5	COD TSS O&G	80 87 Near 100
Pacific NW Shrimp	Alum Polymer	22	COD TSS	73 77
Gulf Shrimp	Acid (pH 5) Alum Polymer	5	BOD_5 COD TSS	70 64 83
Gulf Shrimp	Acid (pH 5) Alum Polymer	2	COD TSS O&G	51 68 85

evaluate dissolved air flotation as a treatment method.[9] The treatment levels reported varied a great deal, but several conclusions regarding system optimization were drawn: lower recycle rates (approximately 15%), faster skimmer speeds, and screening before flotation were all conducive to better removal efficiencies. Chemicals utilized included acid (for pH adjustment), alum, and lime; and recycle (R) was the mode of operation generally employed.

Ertz, et al,[6] in their survey of dissolved air flotation treatment in the seafood industry, took an in-depth look at four DAF installations serving tuna canneries. Minor physical differences existed between the systems, but treatment efficiencies were relatively comparable at all four installations. Table 2 is a summary of the treatment levels attained, with the removal percentages which were suggested by the authors for BPCTCA guidelines. Chemical addition at these plants included small alum and anionic polymer dosages (approximately 60 mg/l and 2 mg/l, respectively), and pH adjustment. The pH

TABLE 2. TUNA DAF REMOVAL EFFICIENCIES[6]

Parameter	Mean	Range	Projected for BPCTCA
PLANT NO. 1			
BOD_5	42.9%	7.8-77.9%	40%
Total Suspended Solids	74.8%	46.5-89.6%	70%
Oil & Grease	83.5%	43.3-98.0%	85%
PLANT NO. 2			
BOD_5	24.3%	12.0-57.0%	40%
Total Suspended Solids	48.2%	18.5-62.5%	70%
Oil & Grease	64.3%	0-96.8%	85%
PLANT NO. 3			
BOD_5	-	-	40%
Total Suspended Solids	95%	94-98%	70%
Oil & Grease	88%	64-99%	85%
PLANT NO. 4			
BOD_5	-	-	40%
Total Suspended Solids	66%	23-93%	70%
Oil & Grease	57%	33-97%	85%

was not consistently lowered to the minimum protein solubility point, however, and some variability in operating pH was reported.

The problem of handling the solids produced by the DAF system has not received full investigation for treatment and disposal as yet. It appears, however, that centrifugation and/or chemical treatment may have application in the seafood industry. Based on the dewatering practices in other industries and their relative effectiveness, more study is needed for optimization of sludge utilization or treatment and disposal methods for DAF sludge from the seafood industry.

Gulf Shrimp Canning Studies

Pilot and bench scale studies were conducted on Gulf Shrimp canning wastewater prior to the installation of a full scale system. Shrimp Canning Waste Treatment Study[1] was the preliminary (pilot) study which led to the installation of the demonstration plant scale DAF wastewater treatment system with which this report is concerned. The pilot study produced much data and many conclusions that were of major consideration in the design and evaluation of the full scale system, and are of primary interest from an independent viewpoint. The pilot study investigated physical - chemical treatment of shrimp canning wastewaters and characterized wastewater flows in order to provide basic data for the design of a wastewater treatment plant.

Included in the pilot study were bench scale treatment investigations, and a pilot scale DAF treatment plant. The lab scale treatability studies included a variety of coagulants, coagulant aids, water conditioners, and chemicals for pH adjustment, which were thoroughly evaluated. Several types of screens were investigated, both for the total process flow and for discharge from the peelers, and skimmings dewatering was investigated.

The pilot scale dissolved air flotation treatment unit was sized to treat only a portion of the total process flow (50 gpm), and was designed on criteria generally accepted to be standard. Operational runs were segregated in a way to allow optimization of individual variables to establish design criteria. Operating data were used to formulate cost estimates for 4 and 8-peeler cannery wastewater treatment plants.

Research has been conducted by the Department of Food Science at Louisiana State University on the nutritional value of shrimp wastewaters and, consequently, on methods of solid-liquid separation of the protein.[10,11] In accordance with the findings of the wastewater treatment pilot study, the food scientists noted that the optimum pH for protein precipitation was 4.2, and the fresh blanch water was easier to treat than wastewater of a similar nature which had been stored. Toma and Meyers[11] concluded that ferric chloride and ferric sulfate were the most effective of several metal salts for coagulation. It should be noted that these tests were conducted at massive chemical dosages, much higher than those normally encountered in wastewater treatment.

B. Shrimp Processing at Violet Project Cannery

Violet Packing Co. is located (Figure 2) on Violet Canal, on Packenham Road, in St. Bernard Parish, Louisiana, approximately 17 miles down river from New Orleans. The cannery now operates nine mechanized shrimp peelers and is one of the largest of the Gulf Coast shrimp processors. Raw shrimp are supplied by truck from shrimp fishing producers all along the Gulf Coast, from Key West, Florida to South Texas, with the largest volume from the Louisiana Coast.

The Violet processing methods are typical of the other Gulf Coast shrimp canneries. A schematic of the product and wastewater flows is shown on Figure 3.

Raw, fresh shrimp are unloaded by hand into a water filled receiving tank (see Figure 4) where ice used in shipping is separated and removed from the shrimp. The discharge from this receiving tank represents about 2% of the total flow and approximately 5% of the total wasteload, as shown in Table 3.

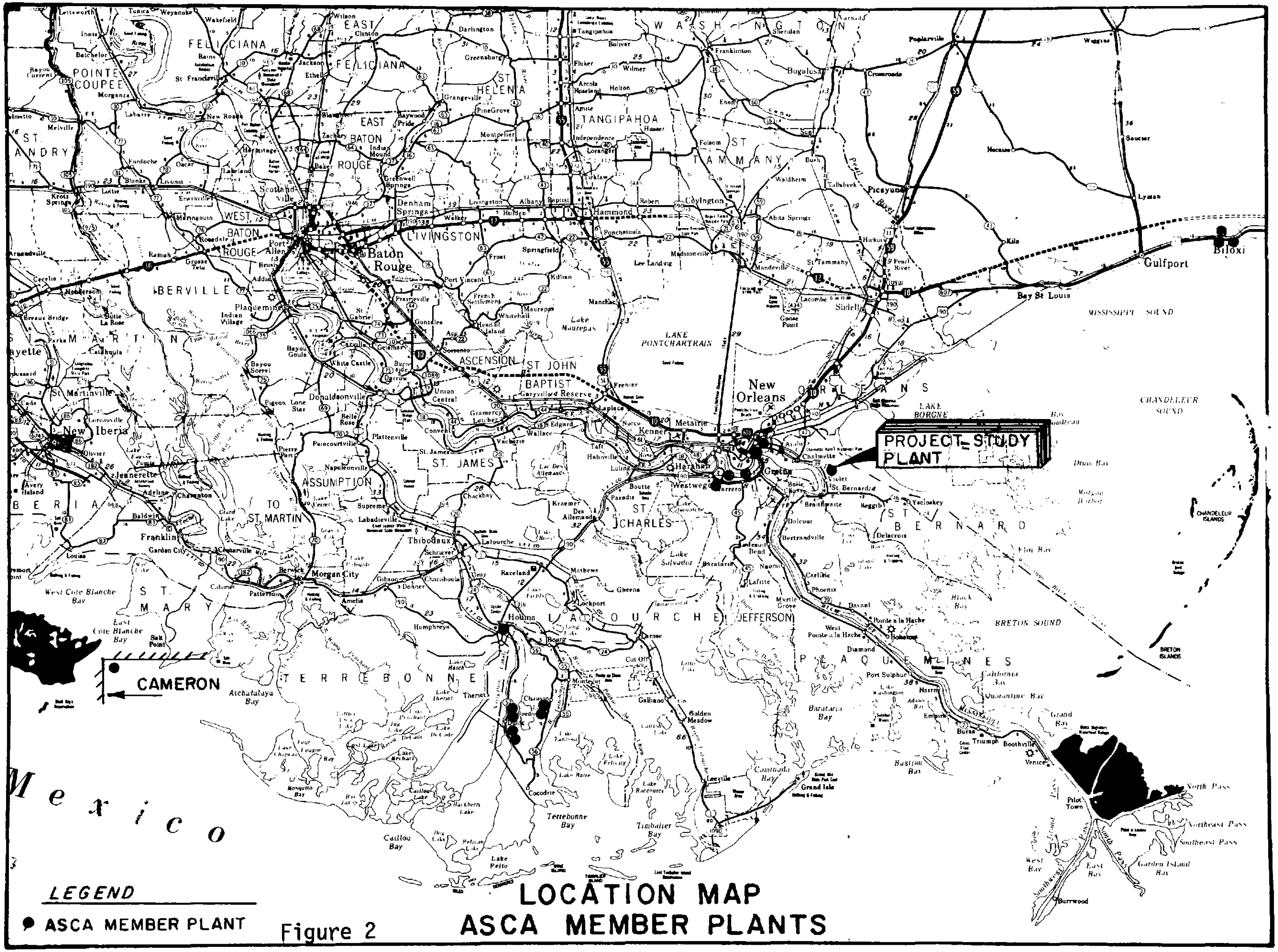
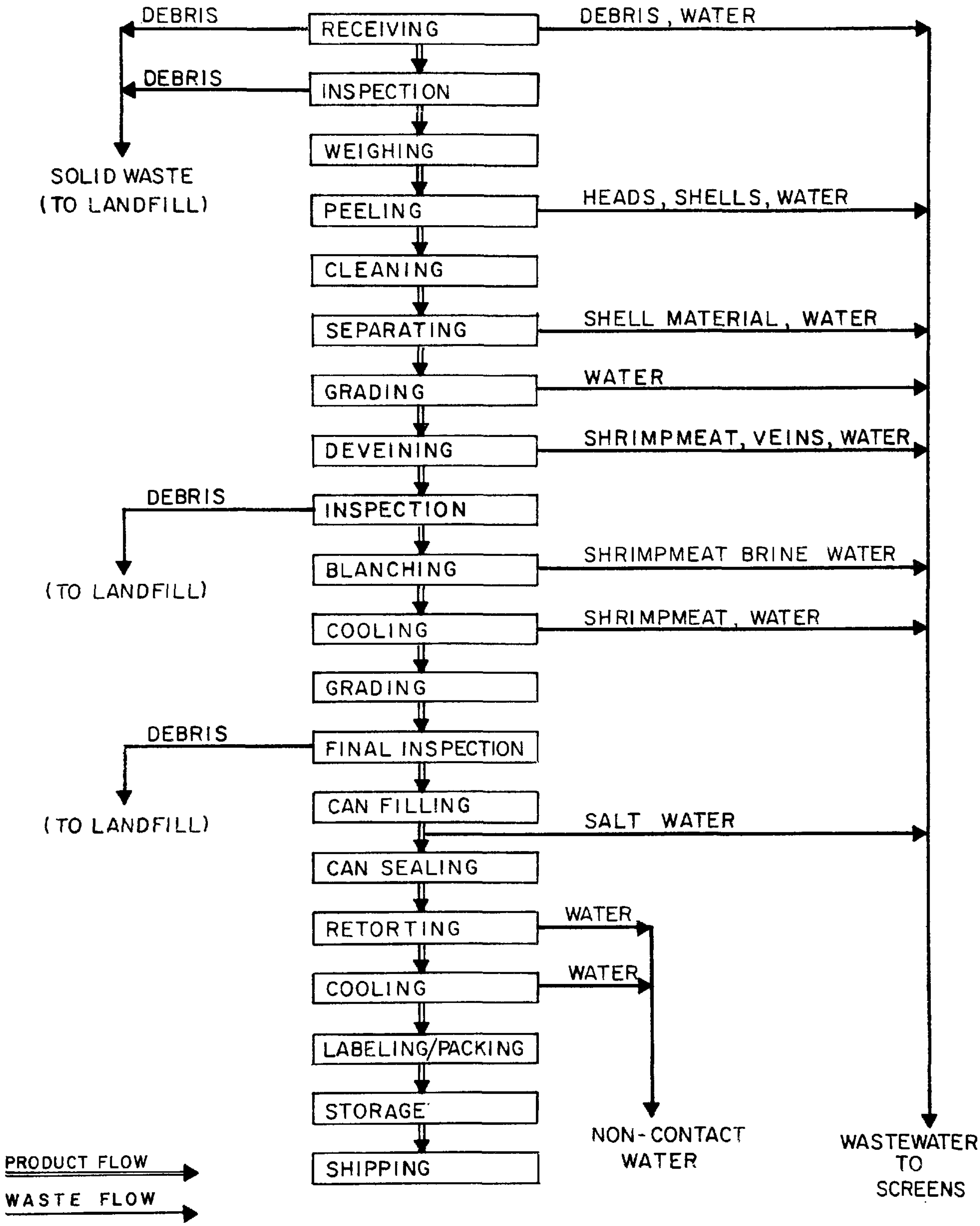


Figure 2

LOCATION MAP
ASCA MEMBER PLANTS

Figure 3 GULF SHRIMP PROCESSING SCHEMATIC



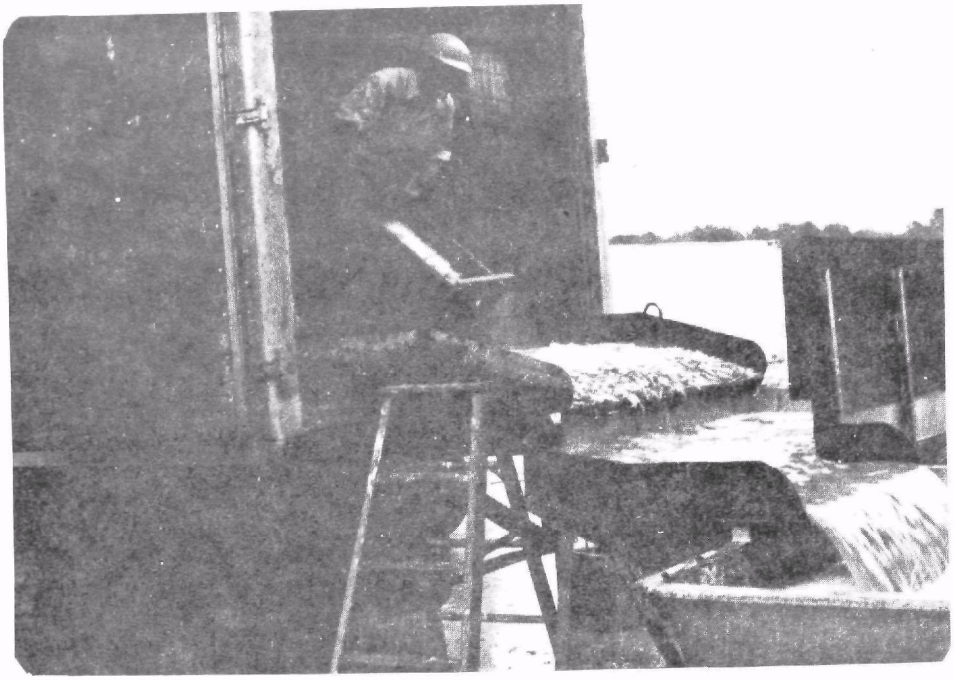


Figure 4
Unloading Shrimp

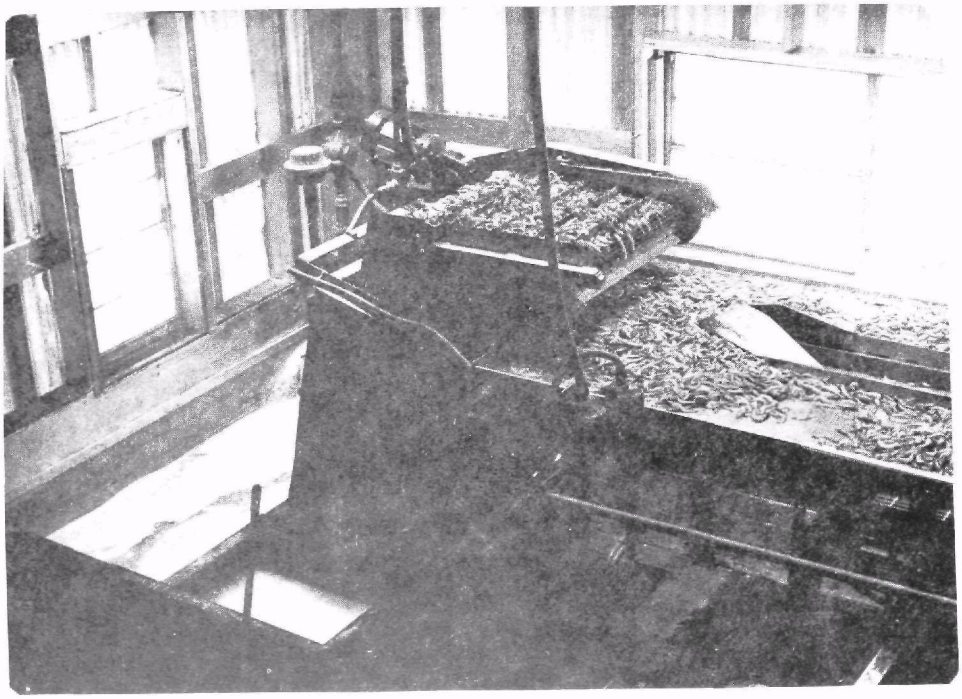


Figure 5
Vibrating Inspection Table

TABLE 3. WASTEWATER FLOWS FROM SHRIMP PROCESSING OPERATIONS

1975 DATA

	gal/1000# raw shrimp mean	gal/1000# raw shrimp Std. Devia.	No. of Observations	% of Total flow	% of Total Wasteload (lbs. pollutant)		
					BOD_5	TSS	O&G
Receiving Tank	154	63	34	2	5 (359)	5 (135)	9 (51)
All Peelers	2950	540	35	38	61 (4080)	57 (1410)	42 (244)
All Separators	950	1440	28	12	8.3 (558)	6 (159)	3 (16)
All Graders	203	80	33	3	0.3 (19)	0.8 (19)	0.2 (1)
All Deveiners	1370	350	30	18	2 (141)	0.6 (160)	1.5 (9)
All Other Streams	2100	--	--	27	23.4 (1650)	30.6 (584)	44.3 (265)
Total 1975	7730	--	--	100	100 (6700)	100 (2470)	100 (586)

Shrimp are moved from this tank by a flight type conveyor and dewatering screen onto a double sided, vibrating, inspection table (See Figure 5). Debris and trash fish are hand removed by workers as the shrimp move to an automatic, batch weigh scale shown covered with plastic wrap in the center of Figure 6. Solid wastes generated at the inspection table are removed by truck to a landfill.

Other conveyors transport the shrimp to the nine peeler machines. Shrimp are shown falling into the receiving end of a Laitram peeler in Figure 7. The next, Figure 8, shows the traveling belt which distributes the shrimp evenly across the width of the peeler. Figure 9 shows the mechanism which "peels" the shrimp. The shrimp move by gravity through the machine and then the meat is water transported by flume for further

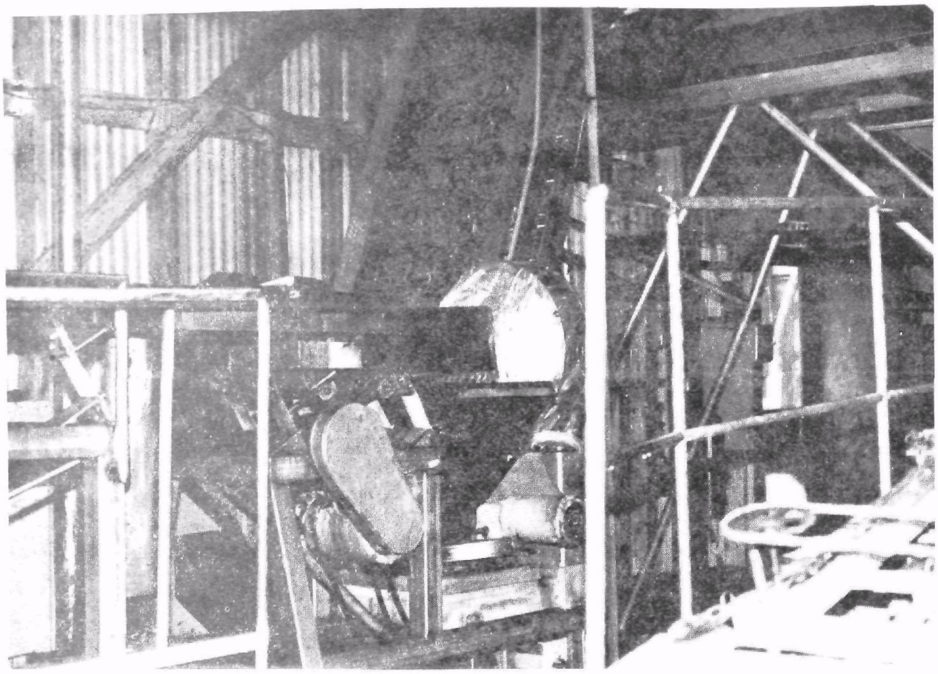


Figure 6

Shrimp Weighing Scale

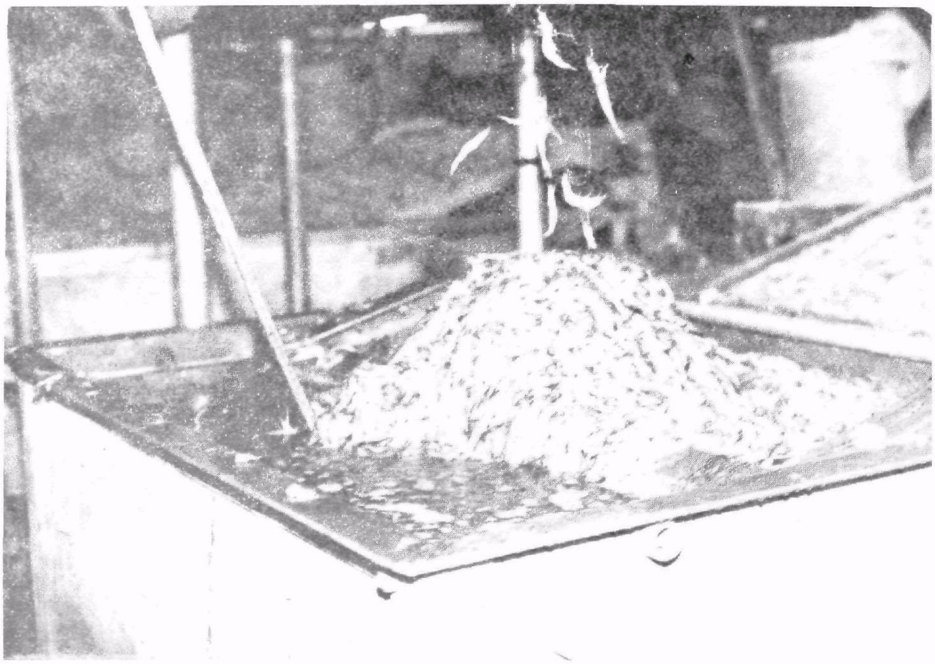


Figure 7

Shrimp Falling into Peeler

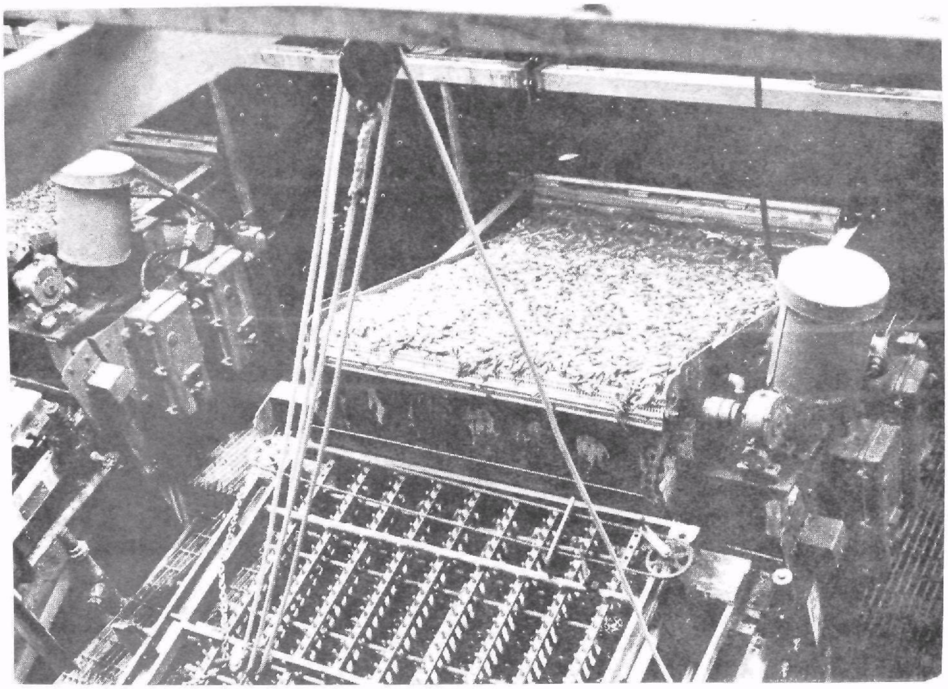


Figure 8

Belt Distributing Shrimp Across Peeler

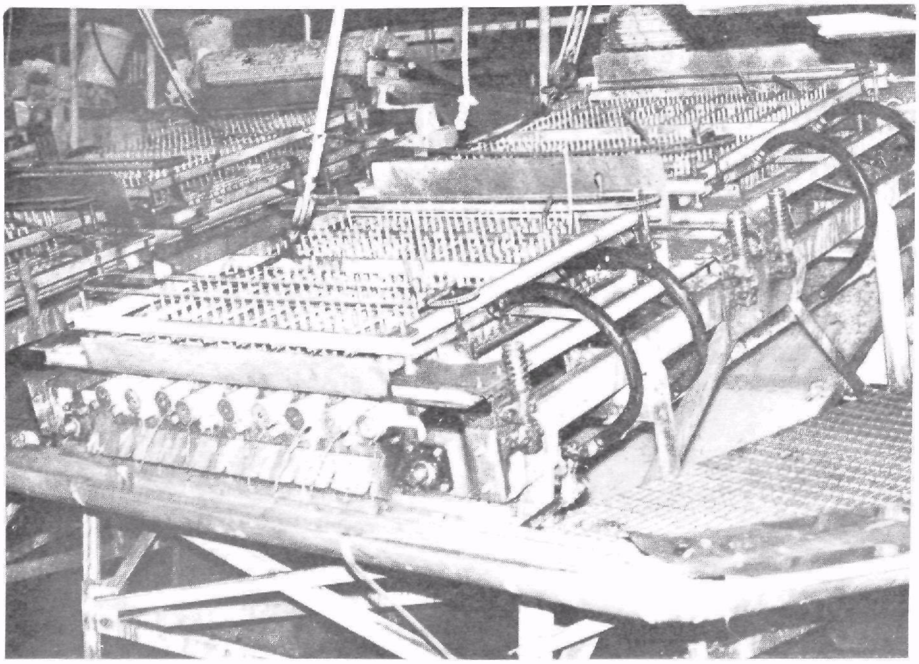


Figure 9

Shrimp Peeler

processing. Heads, hulls, and appendages are removed in the peeler machine by a series of spring loading fingers which gently press the shrimp against long rotating cylinders. Tops of fingers and rubber covered rollers can be seen in Figure 9.

The discharge from the peelers constituted approximately 38% of the total flow and a major percentage of the total wasteload in 1975 when unit processes were characterized. The peelers were targets of water reduction measures and the total consumption of water had been reduced prior to the 1977 season. No individual measurements were made to ascertain the amount of water use savings in various units brought about by water conservation, but the plan was effective in changing the total wastewater flow from 7730 gal/1000# of raw shrimp processed in 1975 to 4420 gal/1000# in 1977, a reduction of 43%.

After the peeling operation, the shrimp meat is further cleaned in agitator machines, then it is pumped in water to another cleaning operation performed by machines called separators for removal of remaining shell material from the shrimp meat. From this operation the shrimp meat is water carried through graders which separate the individual pieces of shrimp by size. Larger sizes may be sent to the deveining operation and smaller sizes may go directly to the canning room.

Deveining requires two steps for the operation. The first step is the slitting of the back of the shrimp to expose the vein and the second step is the "picking" and washing of the shrimp meat to remove the vein. Figure 10 shows the cleaning and washing drums of the deveiners in the left foreground and the bottoms of the inclined troughs which hold the razor edges that expose the shrimp vein are shown in the upper portion of the picture. A portion of the dry conveyor which transports the shrimp to further processing can be seen in the left foreground of the photograph. Dry conveying was recommended in the water conservation program and was accomplished successfully to transport product from the processing operation to the canning room. The deveining operation accounted for 18% of the total plant wastewater flow in 1975.

All shrimp are again inspected after the peeling and deveining operation. Trash particles and incompletely peeled and deveined shrimp are removed from the product stream. This inspection belt passes into the canning room. The canning room wastewater discharge is the main constituent of "all other streams" in Table 3.

In order to provide a ready-to-eat, stable product, the next step involves cooking, or blanching, of processed shrimp meat. All shrimp meat is conveyed through a tank of hot salt water where cooking occurs. The blanch tank is shown in Figure 11. There is a small continuous overflow from the blanch tank, which contributes meat fragments and other pollutants to the waste stream. Following blanching, cooling occurs in another tank similar to the blanch tank. The cooling tank, as shown in Figure 12, contributes an overflow to the waste stream, and all tankage is dumped at the end of a shift. The product is then air cooled on a slow moving conveyor and in a low velocity air blast unit which separates any remaining small trash particles.

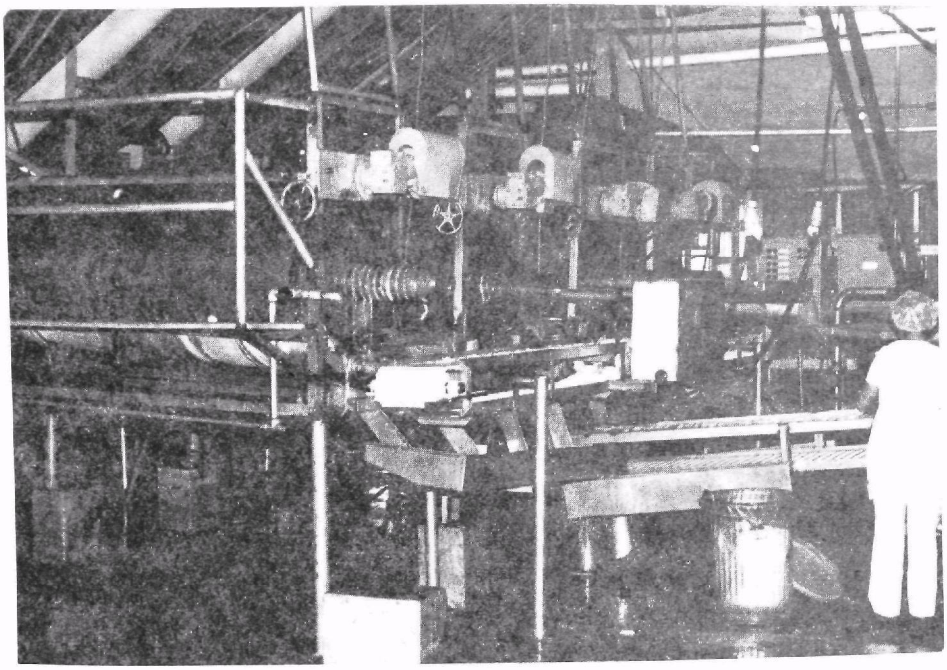


Figure 10

Cleaning and Washing Drums of Deveiner

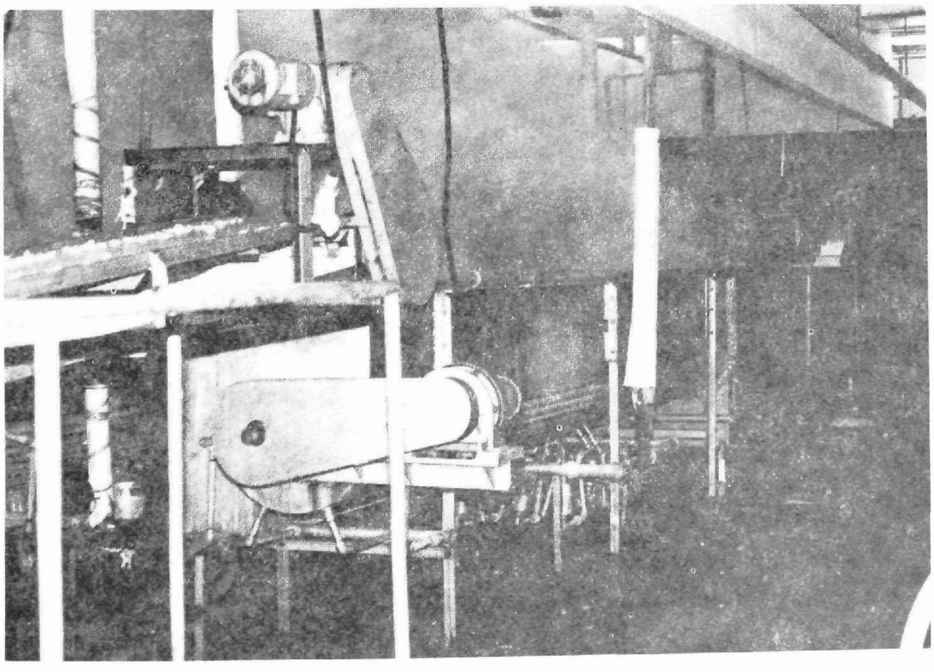


Figure 11

Blanch Tank

Since the size of the shrimp to a large extent determines their use and marketable price, shrimp are graded and canned according to size, employing such classifications as small, medium, large, deveined, etc. Following blanching and cooling, the shrimp are separated into sizes by passage through a grader. The grader consists of a vibrating pan with holes of various diameters which allow segregation of shrimp by size. A final inspection is then carried out to assure a quality product before canning.

Shrimp are placed in cans mechanically and then the weight is checked and made more exact manually. The voids in the can are filled with a brine and citric solution. Some spillage is inherent in this step, as shown in Figure 13. The cans are capped and then retorted. While in the retorts, the cans are cooled with water. This water is discharged without treatment, since it represents only a moderate thermal discharge. The cans are now ready for labeling and packaging and for shipping, which is done from another location in the New Orleans area.

Wastewater from all unit processes flows to a central collection point where it is pumped to the screening room. Here, vibrating screens remove hulls and other large debris. The screened wastewater flows by gravity to the DAF treatment system or to the cannery wastewater pump station for final disposal into the Mississippi River. Solid material removed by the screening process is either dried in rotary steam kilns or is hauled wet to a landfill.

C. Oyster Processing at Project Cannery

Oyster processing is much different than shrimp canning. Concurrent with the differences in raw product and processing methods, the wastewaters are different.

The oyster is a filter-feeding shellfish whose natural habitat is the soft bottoms of brackish waters. For this reason, the bays and estuaries of south Louisiana are ideal locations for the mollusks. Harvesting is primarily a manual operation carried out on small boats by crews of 3 to 5 men. Oysters are taken from the bottom by a clam type dredge which is hoisted to the surface by a winch. The nature of this action is quite conducive to the acquisition of large quantities of bottom mud along with the oysters. Some fishermen wash the oysters with hoses, pumping surface water, before storage on the decks of their boats in order to minimize storage area required, but many do not. The harvesting and storage methods of the oyster fishermen contribute to great variations in the pollutional character of the oyster processing and canning wastewater. In addition, the oyster catch location and the stream bottom character contribute to the nature of the oyster processing wastewater. The type and age of the oyster itself, in addition to the kinds and amounts of bottom muds, etc., could also be influential on the wastewater characteristics.

The Gulf oyster processing schematic is shown on Figure 14. An understanding of the processing methods will help give an insight into the wastewaters produced.

The Violet Plant unloads oyster boats (Figure 15) with industrial vacuum

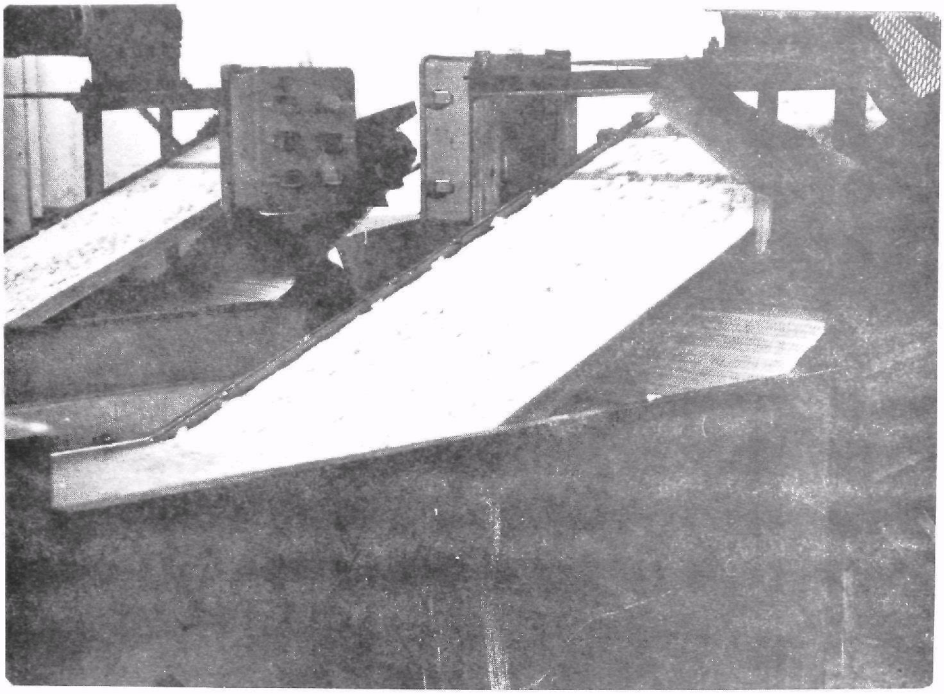


Figure 12

Blanch Cooling Tank

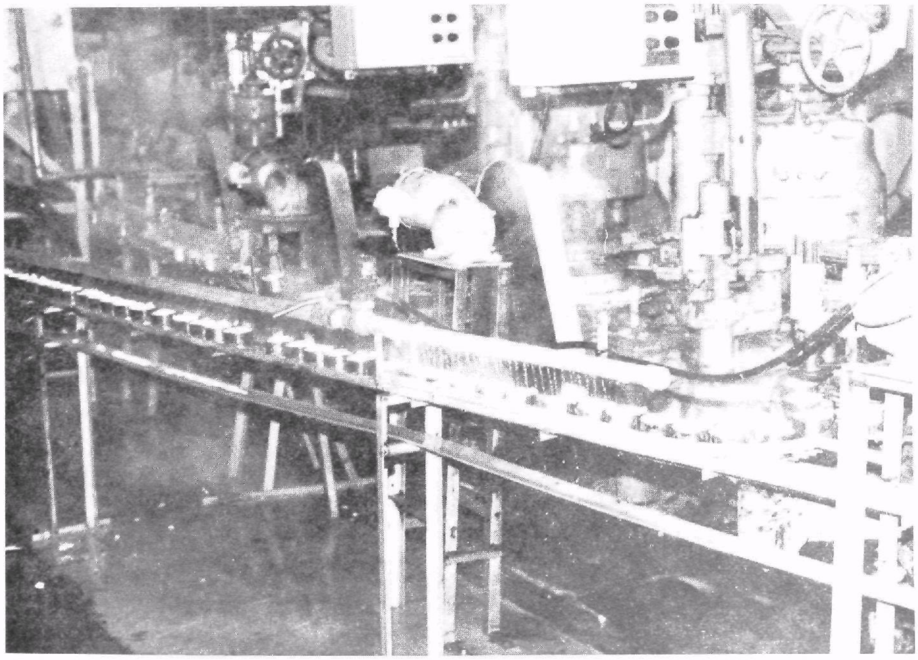
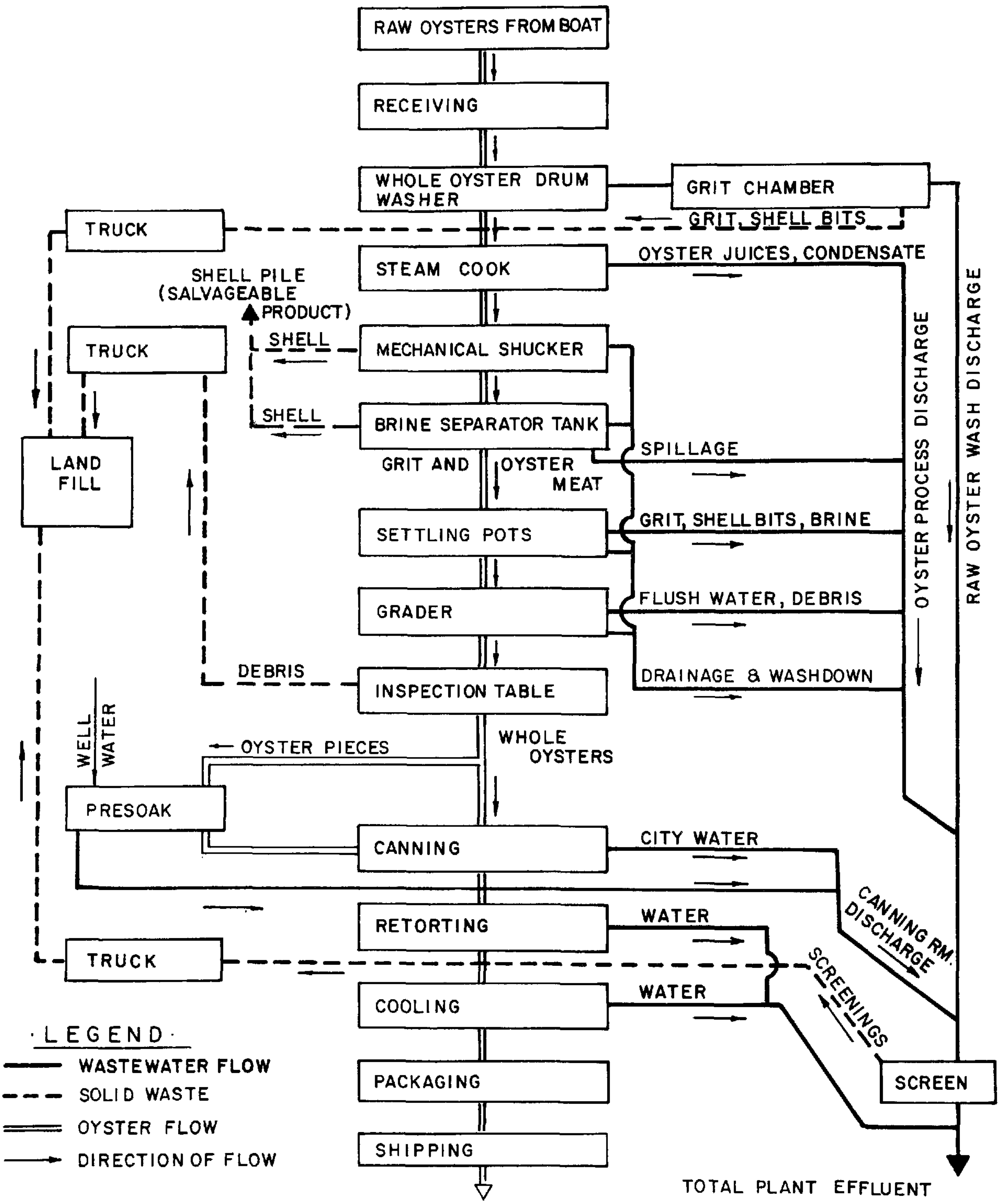


Figure 13

Can Spillage

Figure 14 GENERAL PROCESS SCHEMATIC
OYSTER CANNING



lines, which is a recent modernization. Formerly, manually loaded conveyors were utilized to transport the oysters from the boats. Oysters are conveyed to a drum washer, the first processing step.

The drum washer consists of a rotating cylindrical container with water sprays. Figure 16 shows this operation, which is designed to remove excessive quantities of mud from the closed shells of the raw oysters. Beneath this washer is a grit trap which is of a size to provide a hydraulic detention time of 5 to 6 minutes, at a flow of about 100 gpm. Settled bits of shell and mud are removed via conveyor to a container hopper on a waiting truck. Even with this grit trap, large amounts of silt (both organic and inorganic materials) remain in the waste stream from this point. The next step in the process is steam cooking of the oysters. Upon steam heating, the oyster dies, the shells are partially separated, and natural fluids are discharged. The protein juices along with steam condensate are contributed to the wastewater at this step. A mechanical shucker causes separation of meat and shell. This shucker follows the steam cook and is essentially a rotating drum with finger-like projections which carry the oyster upward until it drops. The broken shell moves upward to a conveyor and the oyster falls into a trough below the shucker which contains a brine solution. The meat floats, but shell particles settle and are conveyed from the brine tank to the outside of the plant. All shell and grit is transported to a stockpile. The oyster meat passes over inspection tables where it is rinsed and residual debris is manually removed. Final and complete separation of meat and shell is accomplished.

The oyster canning process is similar to that for shrimp, consisting of can filling, sealing, retorting, and cooling. The cans are manually filled with oyster meat, water is added, and cans are then sealed. Some liquid overflow and spillage is inherent in this step. Retorting is a batch process producing a non-contact, once through wastewater characteristic of a slight thermal discharge. This retort cooling flow bypasses the process wastewater treatment system and is routed directly for pumpage and discharge. As Figure 14 illustrates, various steps of the processing and canning operation contribute process waters which establish the nature of the wastewater.

Oyster processing wastewater, even after primary grit removal, is very high in inorganic, silty, muddy, settleable solids. Thus the suspended solids content of the wastewater is higher than in shrimp canning. The settleables tend to separate during retention periods such as are encountered in the flotation cell of a DAF system.

D. Project DAF System Design Information

Process design parameters for the Violet DAF wastewater treatment system were based to a large extent on the 1974 report "Shrimp Waste Treatment Study"[1] which gave recommendations for scale-up to full plant dimensions. Wastewater flows measured and characterized in 1975 at the Violet Packing Company plant were used for determining physical sizes of the DAF equipment. The process design summary is shown in Table 4.

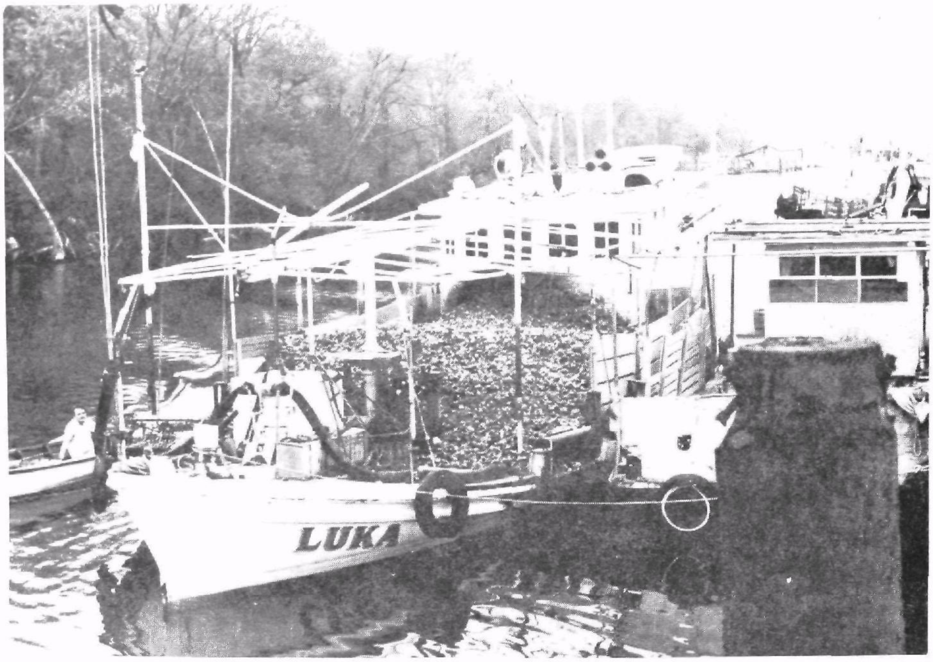


Figure 15

Oyster Boat Ready for Unloading

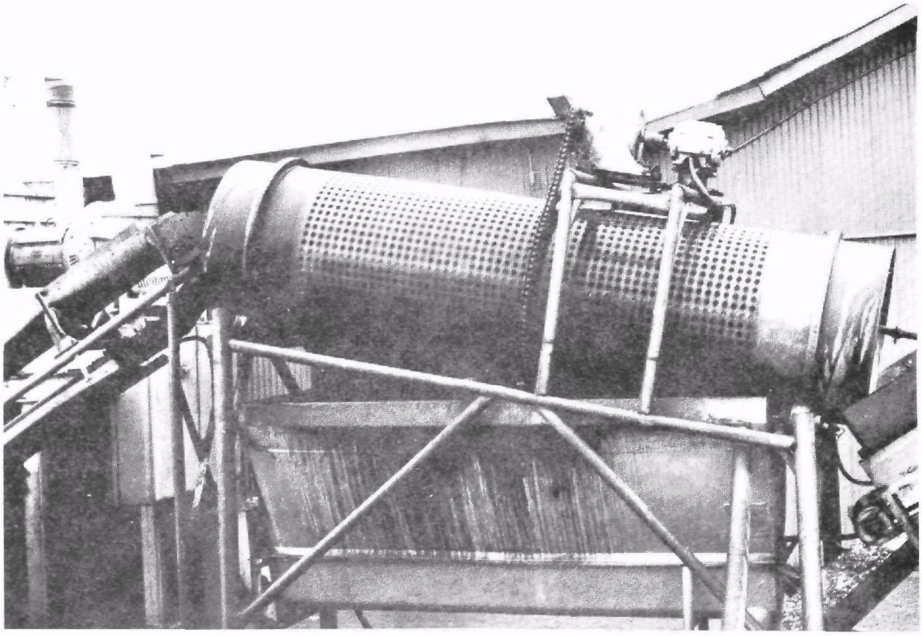


Figure 16

Drum Washer
(Oyster Processing)

TABLE 4. PROCESS DESIGN SUMMARY*
VIOLET DAF SYSTEM

	OPERATING MODE		
	FULL FLOW	PARTIAL	RECYCLE
Influent flow, GPM	700	700	700
Recycle Rate, %	-	-	40-50
Recycle Rate, GPM	-	-	350 max.
Total Flow, GPM	700	700	1050 max.
Surface loading rate, GPM/ft^2	2.0 max.	2.0 max.	3.0 max.
Cell solids loading, lb/hr/ft^2	0.5 max.	0.5 max.	0.5 max.
Cell retention time, minutes	60 max.	60 max.	30 min.
Pressure, psig	40-60	40-60	40-60
Air supply (min.%, Theo. saturation of pressure flow)	75	75	75
Air injection capacity, by air volume (min.), %	2	2	2
Air/solids ratio, lb/lb.	0.10 min.	0.10 min.	0.05 min.

*Based on Canning Plant Screened Wastewater Concentration of TSS=500 mg/l

DAF Supplier's Performance Warranty:

% Removal BOD - 60% provided soluble does not exceed 500 ppm
% Removal TSS - Minimum 75% at all conditions outlined
% Removal O&G - 95 ppm effluent discharge with 300 ppm influent.

Since it was a requirement that the system operate in three pressurization modes, full flow, partial flow, and recycle flow pressurization, the following equipment and sub-systems were specified: influent meter and chemical proportioning system, receiving (surge) tank, process pumps with metered air injection systems, air saturation retention tank with pressure release valve, flotation cell, skimmings tank and pump, flocculation tank with mixer, effluent (recycle) tank, coagulant and polymer feed systems with storage tanks and feed pumps and two pH control systems with chemical storage tanks and feed systems. The instrumentation and control panel was installed in a sheet metal building adjacent to the DAF slab. All of the process equipment was installed on a 42'-0"X 46' -3" concrete slab. Acid, caustic and alum tanks were located near the DAF slab within a protective spill levee. All DAF tanks were steel and were internally protected from low pH attack by a PPG poly-amid coal tar epoxy paint system. The wastewater piping was steel and was painted with the PPG epoxy paint system on the outside. Chemical piping was PVC. A plan view of the installation is shown in Figure 17 and a hydraulic profile of the full flow pressurization mode is schematically shown in Figure 18.

Due to the stringy nature of solids in shrimp processing wastewater, a non-

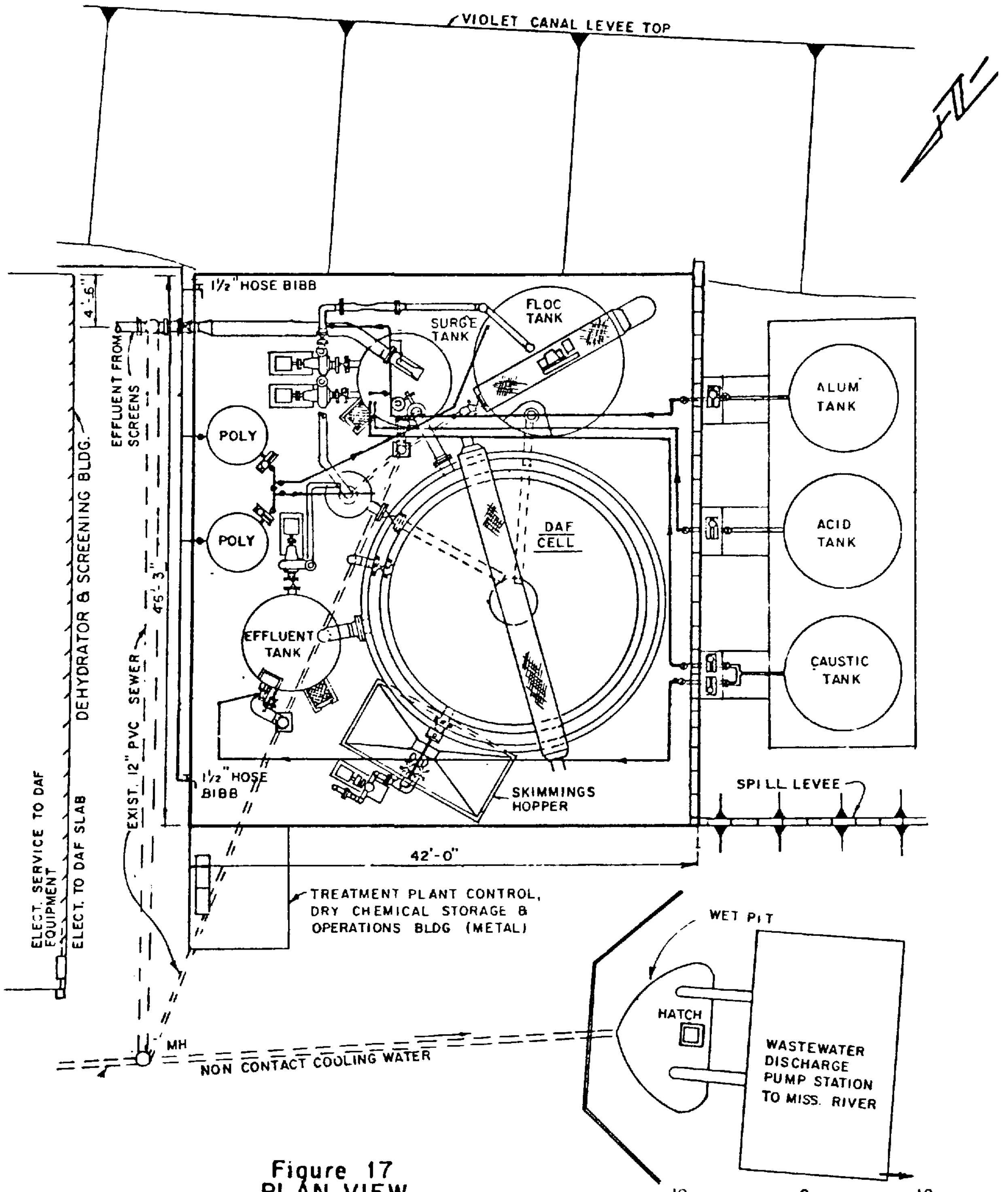


Figure 17
PLAN VIEW
VIOLET DAF SYSTEM

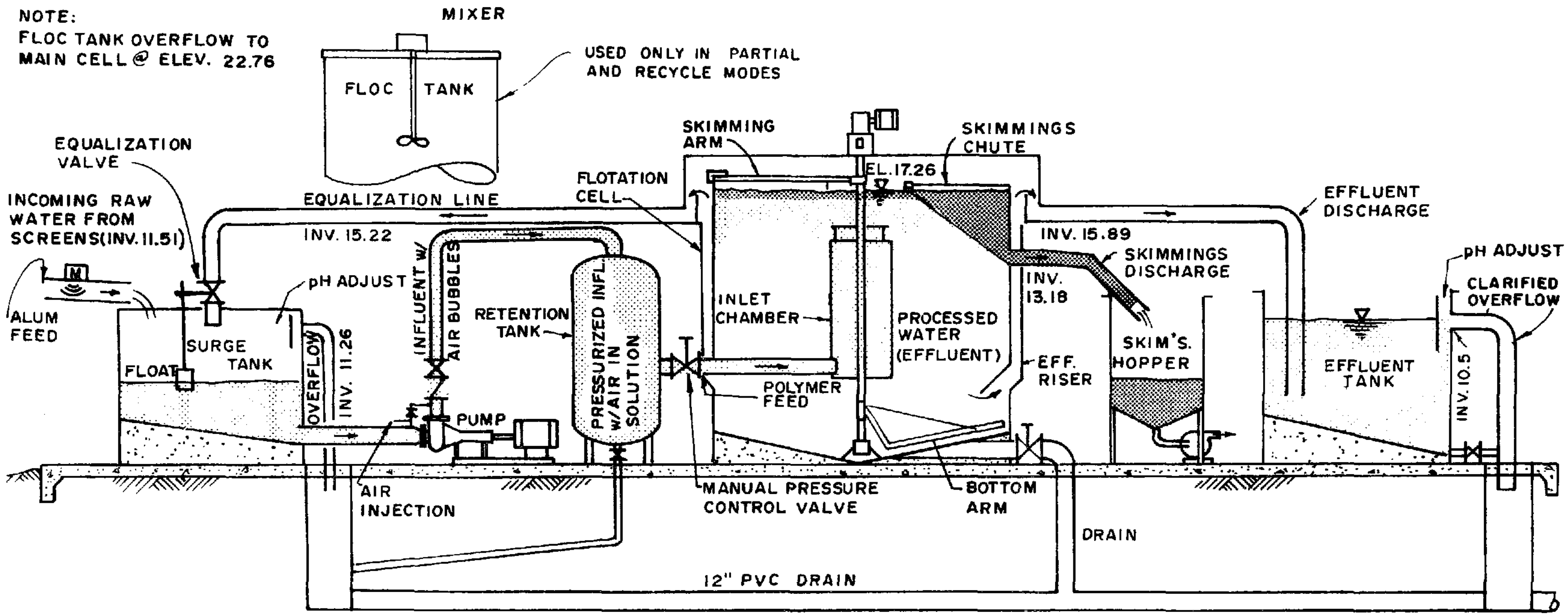


Figure 18
HYDRAULIC PROFILE
VIOLET DAF
FULL PRESSURIZATION MODE

contacting flow meter was specified. This was an ultrasonic meter which sensed the water depth in an open flow nozzle (Figure 19). The wastewater then flowed into the surge tank, an 8' -0" diameter x 8' -0" high vessel which served as a pump sump and chemical mixing vessel. Alum was added to the water as it traversed the open flow nozzle and acid was metered into the falling water stream for pH control. The surge tank also contained a low level pump shut off switch. A float operated 12" butterfly valve maintained a level in the surge tank by preferentially channeling clarified effluent back to the surge tank from the main cell in order to provide continued pump operation during periods of low wastewater flow. This flow is termed equalization flow.

Three process pumps were furnished for the project. Two pumps took suction from the surge tank. These could be routed either through the pressure tank, as in full flow pressurization, or split, one through the floc tank and one through the pressure tank, when operating in partial flow pressurization. The third pump took suction from the effluent tank and was used only during the recycle pressurization mode. Air was metered into each pump suction through a rotameter and ejector which operated on pressurized wastewater from the pump discharge.

The air saturation tank or pressure tank was specified as a 75 PSI ASME code tank with 1/8" steel thickness more than required by design in order to allow for corrosion effects. The pressure release valve was a manually set diaphragm valve which controlled the air saturation pressure (pumping head) and thus controlled the flow rate through the pressure tank. The tank volume was approximately 100 cubic feet. It is visible in Figure 20.

The flotation cell (Figure 21) had a 22' - 6" main cell diameter with the launder ring and clarified effluent flow channel extending out from the main cell giving an overall outside diameter at the top of 25' -2". The top of the tank was 13' -4" high. Inside the tank was the center inlet well, a baffle skirt with riser tubes to convey the clarified water upward to the effluent channel, a top skimmings removal system consisting initially of two arms with two added later, and a skimmings "beach" and trough area. A bottom rotating arm was affixed to the shaft driving the skimmers. A variable speed DC motor and gear system was used to drive these rotating parts continually or intermittently, by a programmable time clock control.

The sludge was scraped off the top of the main cell into the skimmings hopper. This hopper was divided into two six foot square tanks with sloping bottoms. Each tank was valved to the suction of a positive displacement sludge pump. The pump could be run manually or intermittently through a time clock control.

The special flocculation tank was a 12' diameter by 20' high vessel with internal baffling, with a 1.5 hp adjustable speed mixer. This tank was preceeded by a static, in-line mixer which served as the rapid mix portion of the chemical destabilization process. A nominal 20 minute slow mix was provided in the floc tank during recycle mode operation. Longer times were allowed during the partial pressurization operations.

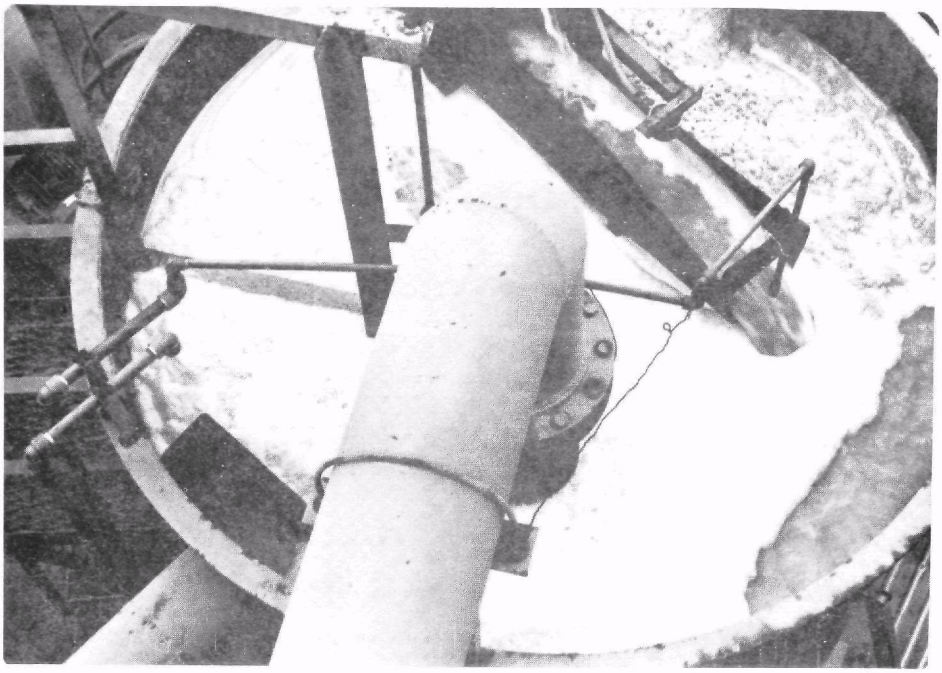


Figure 19
Surge Tank

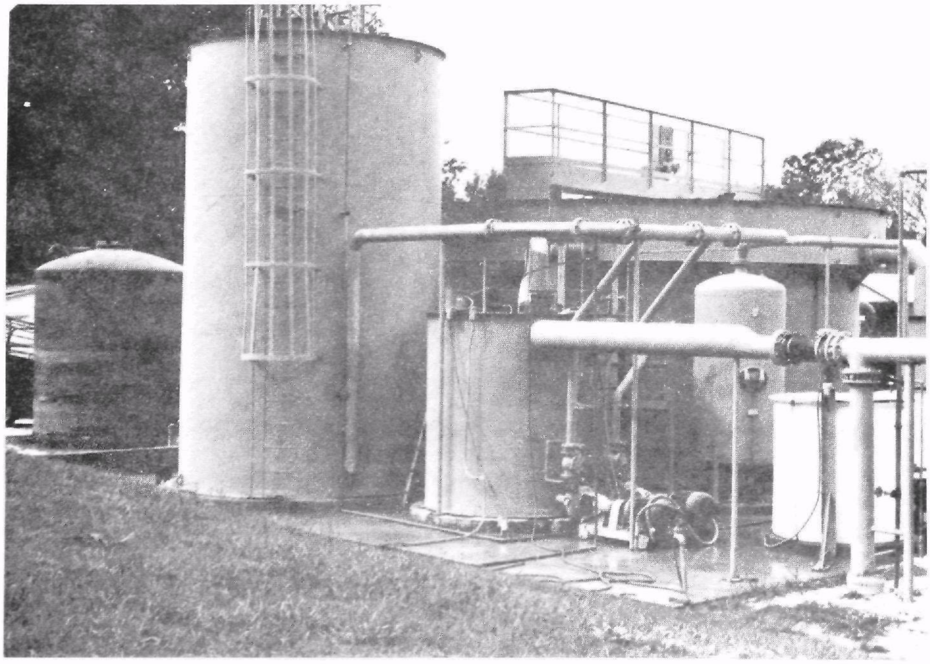


Figure 20
Violet DAF System
(L-R, Alum Tank, Flocculation Tank, Surge Tank, Flotation Cell, Pressurization Tank, Polymer Tank)

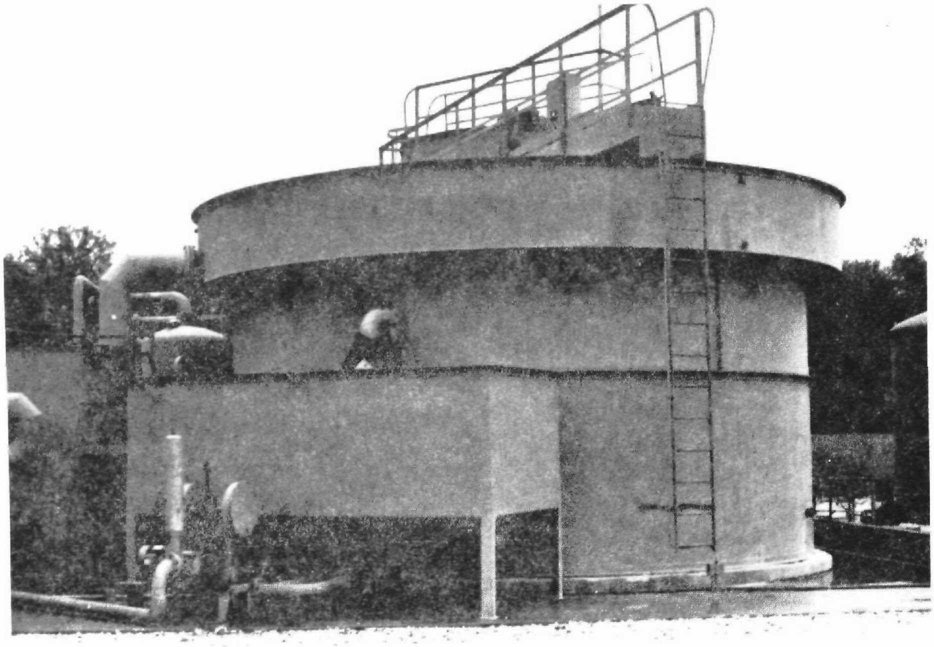


Figure 21
Violet DAF System
(L-R, Effluent Tank, Sludge Hopper, Flotation Cell, Alum Tank)

The recycle or effluent tank was also 8 feet in diameter by 8 feet high and provided a pumping reservoir for the recycle pump. A float operated switch provided a low level shut off signal to protect the pump from running dry. A caustic addition line was placed in the discharge of the tank in order to correct the pH to a level between 6.0 and 9.0, the NPDES permit requirement for final discharge into the Mississippi River.

The coagulant and coagulant aid feed systems were paced from a 4 to 20 ma signal generated by the ultrasonic flow meter. The chemical feeding was performed by chemical feed pumps(Figure 22) equipped with electric stroke positioners. Liquid alum was fed from a 5,000 gallon fiberglass storage tank. Polymer was mixed as needed in either of two 5 foot diameter by 5 foot high fiberglass tanks with a 1.5 hp mixer in each. Two polymer tanks and two pumps were utilized in order to obtain maximum flexibility when operating in either of the three DAF modes. Forty-five percent liquid alum (15.3% Al_2O_3) was fed directly and polymer was fed as a 0.25% solution.

Two pH control systems were available. The influent controller was a proportional control unit capable of pacing either acid or caustic feeders and utilizing a flow-through pH probe equipped with an ultrasonic cleaner. Similar chemical feed pumps regulated by signals from the pH controller-meter were used to feed the undiluted 93% H_2SO_4 and 50% liquid NaOH. Both of these chemicals were stored in carbon steel

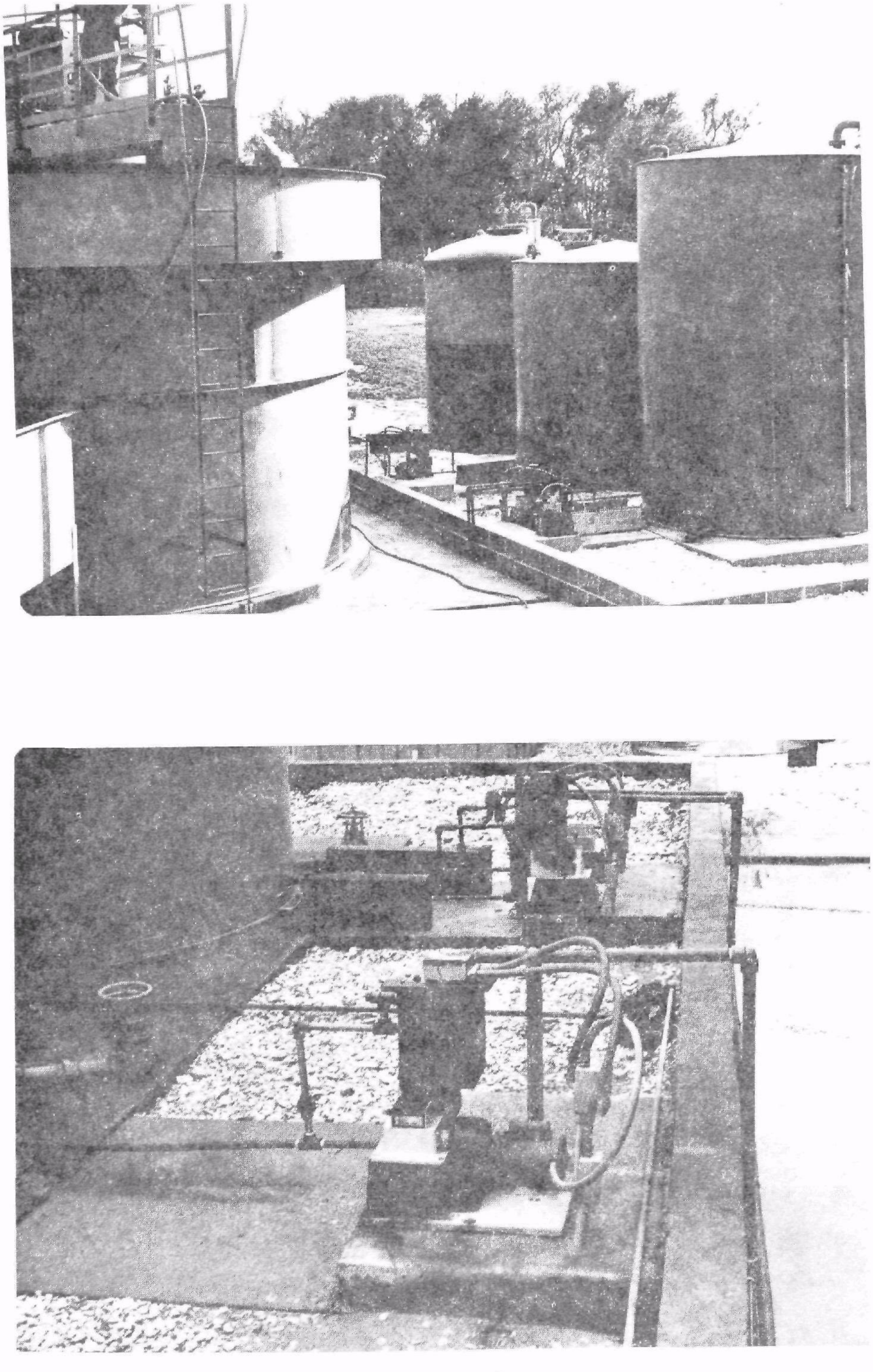


Figure 22

Alum, Acid and Caustic Tanks and Pumps

tanks. The effluent pH controller action was on-off in nature and operated a pump with manual stroke positioner to feed caustic to raise the pH value. A flow through electrode with ultrasonic cleaner was utilized here also.

The instrumentation and control panel contained all motor starters, push button stations (except that controlling the skimmer arms), the flow meter totalizer-recorder, the pH controllers and dual pH recorder, and run-time meters for the process pumps. The panel was housed in an 8' x 12' sheet metal building with a small ventilator mounted in the roof.

E. Installation and Start-up Problems

As with many experimental projects, unforeseen difficulties often arise which lead to less than anticipated data collection. This project was no different. A history of installation and start-up problems follows.

On November 14, 1975 bids were received for Violet Wastewater Treatment System equipment. The Water Pollution Control Division of the Carborundum Company submitted the low bid and was awarded the contract. The equipment was to be delivered in 120 days, later extended to 130 days. Most equipment deliveries were complete by April 22, 1976, several days late. The erection crew, and separate foundation, mechanical and electrical contractors had completed their work by May 24, 1976.

An attempt was made by the supplier's field service representative to start-up the DAF system. Three major problems were immediately obvious; two of the three process pumps were inoperative, the influent pH controller was inoperative and the flow meter was inoperative. Approximately three weeks were required to diagnose and correct the difficulties with the process pumps. The impellers had been installed backwards and the pump volutes had to be dismantled and reversed to give proper operation. The pump discharge piping had to be re-arranged, also. The flow meter and the pH controller had to be completely rebuilt by the respective factory service representatives. These problems, electrical difficulties and others continued to plague the project through June 1976. The supply of fresh shrimp dwindled after July 4, 1976, and canning operations were sharply reduced and finally ceased.

The 1976 maximum canning period, summer shrimp season, came and went without the DAF operation and data collection anticipated and required for treatment system evaluation. During this time, Carborundum representatives were performing intense operational adjustments and the project personnel were collecting and analyzing raw and "treated" samples in order to ascertain performance. The 1976 summer season closed without accomplishing the project goals.

In August, a short run of shrimp allowed operation of the equipment. Prior to this time, in an attempt to improve performance, modifications to the floc tank and rearrangement of some piping were performed by the supplier's field personnel. During the August operations, in which Carborundum technical personnel more completely analyzed the system operation, it was discovered that: (a) the center flocculation and inlet chamber in the main flotation cell was improperly sized, (b) the number of skimmer arms was inadequate, (c) certain deficiencies were noted in the flocculation system, and (d) the bottom arm in the flotation cell did not function as a scraper. Modifications to the system as originally installed were again found to be needed.

Some of the modifications were completed by the first week of October and the treatment system operation was again commenced in mid-October. There was an apparent improved performance, but the short supply of shrimp and the short operating periods prevented collection of significant data. The performance warranty set forth by the manufacturer was not demonstrated. At this time, modifications to the flocculation equipment were not complete and it was impossible to test the equipment in the recycle and partial pressurization modes, a part of the contract requirements.

It became apparent during the 1976 summer season that it would not be probable that the project would have been completed by the end of the year. EPA was kept advised of the progress and of the difficulties involved. During November, the EPA project officer visited the site and observed the progress and the difficulties. A formal request was submitted in November to extend the project through 1977. Because the project funds had been expended in trying to operate the plant and get the required data during the summer and fall of 1976 when the equipment was not capable of performing satisfactorily, it was requested that additional funds be granted to extend the operation through the season of 1977. Also, since there had been interest by EPA and ASCA in the collection of data on the performance of the dissolved air flotation method of treatment on oyster processing wastewater, it was pointed out that this facility would be available for operation and data collection during the 1977 oyster canning season. Subsequently, EPA approved the project time extension and issued a grant amendment on January 4, 1977 to permit the continuation of the study and data collection in order to complete the project and to include oyster wastewater treatment and data collection.

A meeting was held with representatives of the supplier in January, 1977 and agreement was made for the correction of deficiencies and the completion of the modifications to the equipment to provide all facilities complete for operation during the shrimp canning season beginning in May, 1977.

The dissolved air flotation wastewater treatment system was operated for four weeks in February-March, 1977 during oyster canning operations.

Carborundum completed the required equipment modifications and the system was put into full operation at the opening of the summer, 1977, shrimp canning season. Carborundum operated the system for a sufficient time to demonstrate its warranted performance in the three modes. Other than the failure and replacement of the flow meter electronics by the supplier and a somewhat abnormal service call for chemical feed pump rehabilitation, only the normally expected component maintenance was required during 1977.

SECTION VI

METHODOLOGY

A. General

This project was developed to evaluate several areas of pollution abatement in the shrimp canning industry. The expected performance of a full scale system was to be established through the control of process wastewater flows, the installation and operation of a full scale DAF wastewater treatment system, and the collection of data on costs and treatment effectiveness. The selected demonstration study canning plant (at Violet, Louisiana) was thoroughly investigated. The site, buildings, pipelines, processing unit operations, waste streams, flow measurement and sampling points and other features were located and scale drawings were prepared, as shown on Figure 23. An on-site laboratory was established, water use management measures were initiated and personnel were acquired to operate the project. Field work commenced in November, 1974 and continued, intermittently, through November, 1977.

B. Water Management

In-house water use evaluation and water conservation measures were studied by a systematic process of monitoring, evaluation and correction. Individual processes were surveyed for water use and for wastewater production. Water meters were installed on supply lines to the receiving tank, peelers, graders, deveiners, blanch tank, and on the total plant well flow and the total flow from the municipal water supply. In addition, the total wastewater flow was monitored through elapsed time meters installed on the pumps which handled the entire cannery flow. Weirs were installed on flumes which handled the waste flow from the peelers and from the agitators. Through these methods and points, the amount and distribution of water use throughout the cannery was monitored. Plant personnel were consulted in all metering and selection and evaluation of all in-process changes for wastewater control. Some of the methods used for volume reduction evaluation are outlined as follows.

1. Low and high pressure water systems were evaluated. Nozzles and orifices were investigated. The effects were reviewed.
2. It was desired to reduce fluming. Dry conveying was considered from: (a) peeler to cleaner, (b) cleaner to separator, (c) grader to deveiner, and (d) separator and deveiner to blanch.
3. A cooling tower was considered for retort cooling water.

4. Counter-flow water re-use was investigated.
5. Vacuum cleaning or non-water use cleaning procedures prior to washdown were considered.
6. High pressure, low volume washdown was evaluated.
7. Several possible experimental changes were considered including, (a) pre-treatment prior to peeling, (b) screen immediately after peeling, and (c) dry conveying screenings to disposal.

After investigation and evaluation, certain water use reduction measures were initiated. The water conservation program recommended is presented as Appendix B. In addition, the study plant modified its water supply system. It was changed from directly pumped wells to a storage tank with pressure controls and pressure regulating valves to give a much more constant pressure in the system. This change, the installation of proper hoze nozzles, and other water use management procedures were thoroughly evaluated for plant implementation.

Those process changes carried out by the study cannery for water conservation and for process improvement were evaluated by monitoring unit process discharges for pollutant concentration.

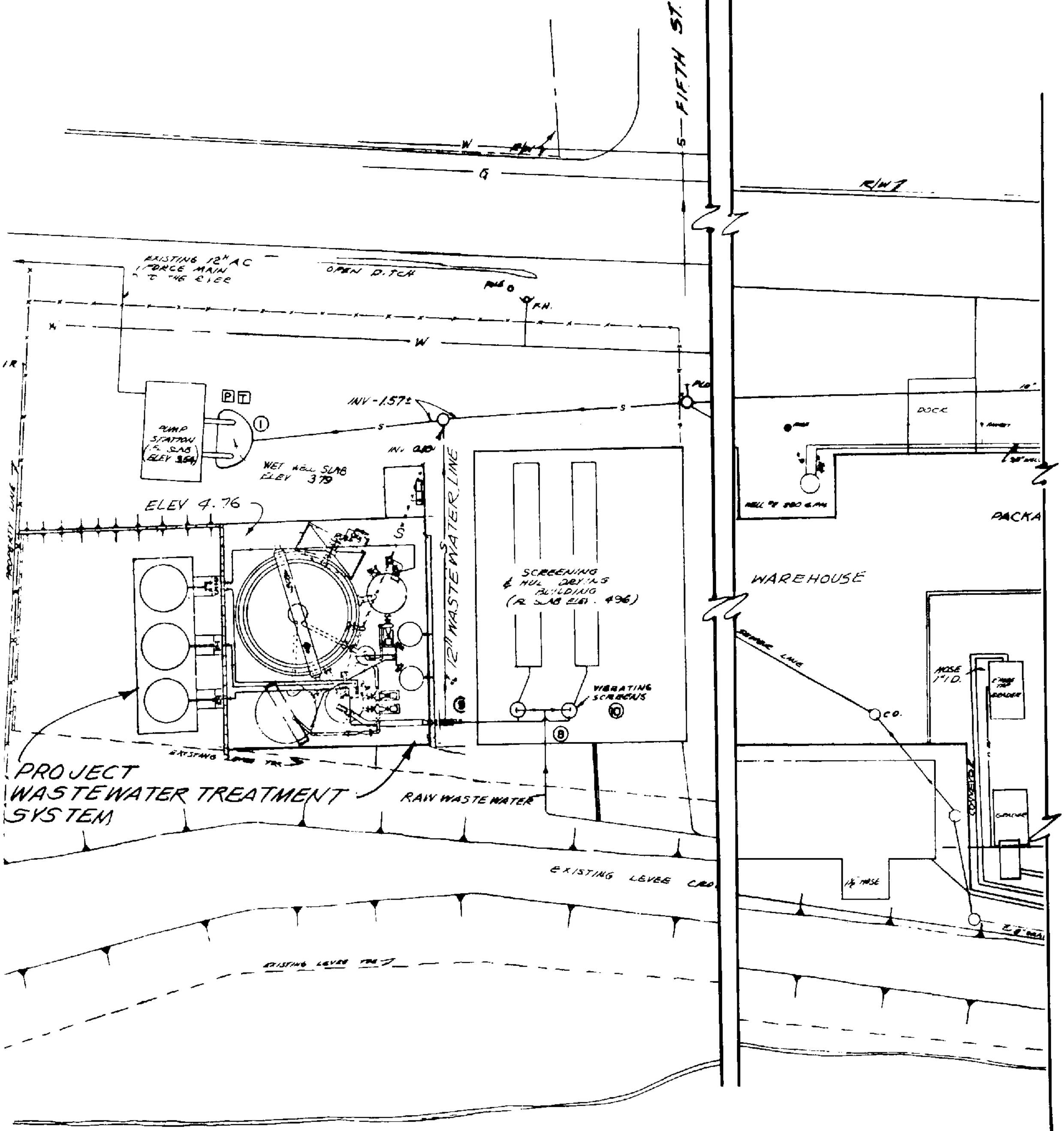
C. Sampling Procedures and Laboratory Control

Wastewater samples were collected at points throughout the cannery and the DAF system for laboratory analyses. Composite samples over a period of from 30 minutes to the entire "operating day" were used whenever possible. Prior to the installation of the DAF system, unit process discharges were evaluated in conjunction with water and pollutant reduction measures, as discussed previously. As changes were made in the cannery operating sequence, the effects were evaluated both from a wastewater volume standpoint and for the assessment of pollutant concentration reductions. Samples were collected for laboratory analyses from each process during the project. This included monitoring of the pollutant removal efficiencies obtained by screening of the raw process flow.

For DAF treatment efficiency evaluation, influent samples were taken immediately after screening and effluent samples were taken from the discharge prior to caustic addition for pH correction to between 6.0 and 9.0. These points represented the wastewater immediately before and immediately after DAF treatment, respectively. A portable automatic sampler was used for many wastewater samples. Sludge samples were taken as the semi-solid material was scraped off the flotation cell and entered the skimmings hopper.

All samples were stored on ice while aliquots were being taken to form a composite. Once the respective sampling period had ended, the samples were taken to the laboratory for analysis or refrigeration. The project laboratory was established as part of this project and included equipment and materials required to perform normal monitoring analyses. The laboratory was adjacent to the cannery so transportation time was minimal. Composite samples were tested as quickly as possible, but BOD and pH tests were always

FIGURE 23A



SAMPLE & FLOW MEASUREMENT

Ⓘ WASTE WATER SAMPLE POINT LOCATION
□ FLOW MEASUREMENT LOCATION

TYPE OF MEASUREMENT

- M METER
- T TIME
- W WEIR
- P PUMP CURVE
- O OTHER

LEGEND

— S —	SANITARY SEWER
— CW —	CITY WATER SUPPLY
— WW —	WELL WATER SUPPLY

FIGURE 23B

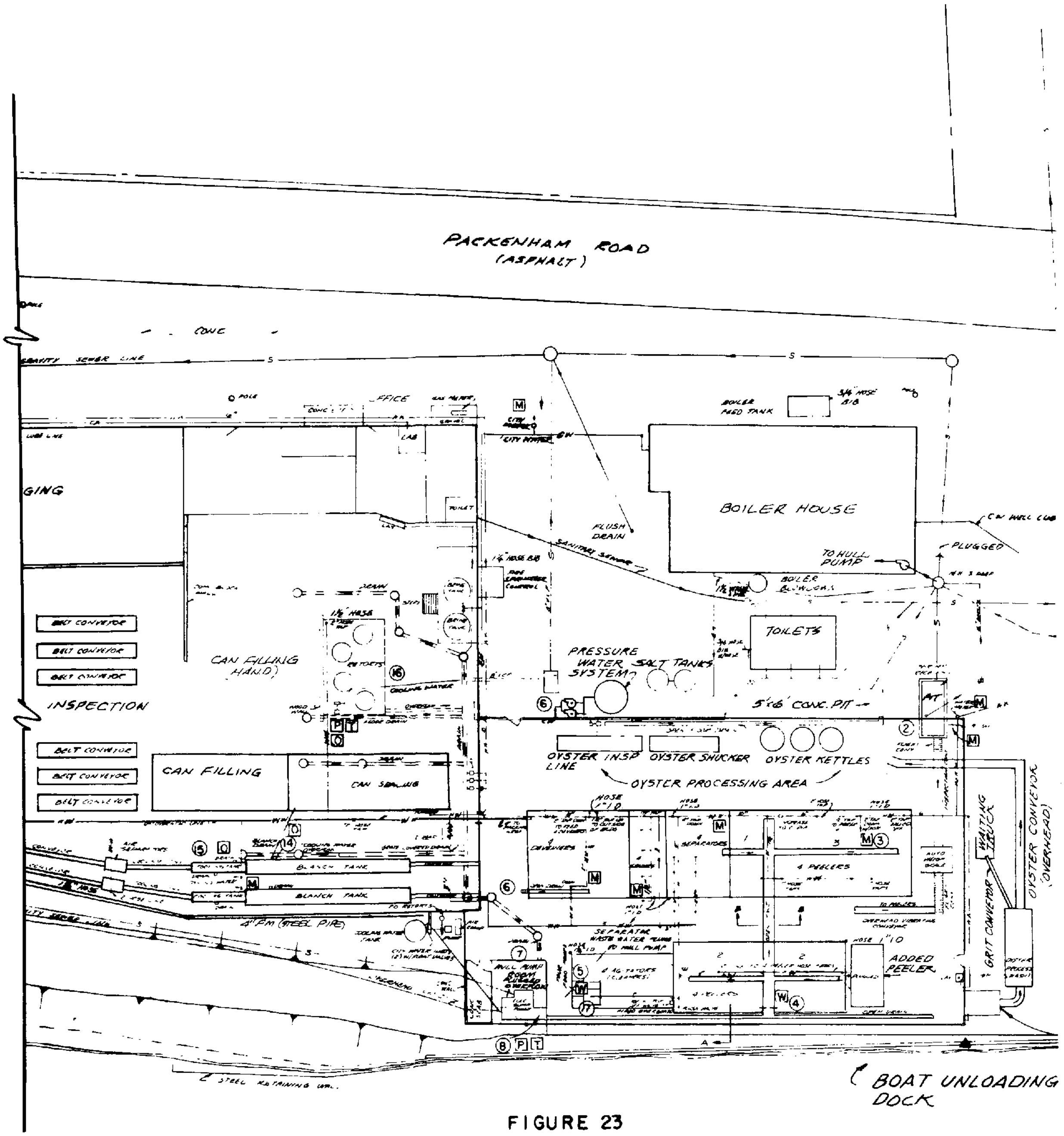


FIGURE 23
LAYOUT OF
PROJECT STUDY PLANT
VIOLET, LOUISIANA

20 10 0 20
SCALE IN FEET

initiated immediately on all samples. All storage and analytical procedures were according to Standard Methods[12], except as outlined in Appendix A.

D. Jar Testing and Other Laboratory Studies

Jar testing and lab "bomb" flotation testing were conducted throughout the study, both before and during operation of the DAF plant scale system. A variety of chemical agents were tested prior to installation of the DAF system, while those coagulants and coagulant aids employed on a full scale were also tested prior to use to serve as an operational aid. These included alum, lignosulfonate, Chitosan, cationic polymer, and a variety of polymers used as coagulant aids. Some jar testing was also conducted concurrent to the DAF system operation where time did not allow full scale study of a certain coagulant or coagulant aid. Jar testing methods are summarized in Appendix A.

Other laboratory scale investigations were conducted, such as sludge treatment methods. Included were bench-scale gravity separation investigations both at ambient and elevated temperatures. Chemical oxidation of sludge was experimentally used during the study on a lab scale. Such studies were carried out in conjunction with the DAF system evaluation.

E. Design of Treatment System

Once flow and operating characteristics of the study cannery were established, design of the project DAF system was carried out. Design criteria were based on results and recommendations of the pilot study previously conducted, the various manufacturer's standard sizing, and factors characteristic to the particular study plant. This included the design and layout of the DAF system, site preparation, foundation designs, pumping and piping system design, electrical and instrumentation system design, and the preparation of construction plans and specifications. The supplier was required to give a performance guarantee. Bids were invited from DAF equipment suppliers, these were analyzed and a contract was awarded for the DAF system. Site work was done under separate electrical, mechanical and concrete work contracts. Project engineers represented the purchaser (ASCA) in the completion of the installation of the facility.

F. DAF Treatment Operation

The DAF system operating runs were primarily conducted in the 1977 study year. In 1976, various operational problems were encountered but some treatment data were obtained during the Fall season of that year. The addition of alum and 835A polymer with pH adjustment was the major treatment mechanism evaluated, primarily in the full flow pressurization mode.

While determination of attainable treatment levels was the most important goal, efforts were made to adequately define the system and its performance under various conditions. This included initial optimization runs for operating pressure, air flow, and pH. It was proposed to seek system optimization starting with the most basic parameters, establishing the relative effect of each independent variable. The project DAF wastewater treatment system had a flocculation chamber and a recycle pump with all corresponding piping to make it operational in recycle and partial pressurization modes, in addition to the full flow pressurization mode. The optimization of operating mode was also conducted, since the mode of operation could affect both capital and operating costs.

The full flow pressurization mode was used as the mode for first optimization of the basic parameters of air flow, pressure, and pH. This mode has the feature of quick data production since minimal detention times are involved. After these preliminary tests, optimization runs were made which sought to define performance under various dosages of alum and polymer, and in various modes. All sample runs were of 1 hour to 3 hours duration. The system was always allowed at least one hour of stabilization prior to sampling the effluent, and no washdown flows were included in optimizing runs.

Due to the inherent variability of the shrimp canning wastewaters, it was of particular interest to define "day-to-day" averages, in addition to maximum performance runs. To base system performance on the best data would be unrealistic since this degree of removal efficiency would not always be attainable. Therefore, unattended runs were made at night and the effluent was collected by an automatic sampler. These runs were set up to operate on best conditions arrived at during the day runs and were then left without adjustment for operation during the night. This method of operation was thought to be more representative of that which could normally be expected with non-technically trained operators. For calculating removal performance on "unattended" runs, influent loading was based on average screened wastewater values.

Alum and 835A polymer were shown in the pilot study and by jar tests to be the optimum chemicals for DAF treatment of shrimp cannery wastewaters and these received the most attention. When it was felt that the optimums had been reached, other coagulants were investigated. One such coagulant, lignosulfonic acid (trade name PRA) was tested on a plant scale, after jar testing, in an effort to produce maximum removals. Additionally, a liquid cationic polymer, 520C (equivalent to 507C), was tested. The point of application of both the coagulants and coagulant aids were investigated by variation of feed point on several occasions.

The factors describing the operation of the DAF wastewater treatment plant were experimentally evaluated. In particular, equations which define the air to solids ratio (equations 3 and 4 on page 14) utilize an experimental degree of saturation factor(f). In order to define this factor in a logical manner for this project, it was experimentally determined at the outset of the study. Air was injected into the pressurization system at measured rates, and a dissolved oxygen probe mounted in the pressure tank yielded D.O. concentration in the water. Knowing the temperature of the water, the degree of saturation was obtained and the factor was evaluated. This was done by eliminating the consideration of solids in equation (4), yielding equation (6) =

$$A^* = C_s \; [f\,(P/14.7 + 1) - 1] \quad 8.34 \qquad (6)$$

P is an operating variable (pressure, psi) and C_s is a constant which is dependent on temperature. A* is found by measuring the dissolved oxygen in the water and relating that to the saturation concentration of dissolved air at a given temperature. The pounds of air, A*, is then determined. The only variable that remains is "f", the saturation factor. Several readings were taken under different operating conditions and "f" factors were calculated. The values of "f" ranged from 0.4 to 0.7 but most data points were centered around 0.5. For this reason, the value of "f" = 0.5 was universally applied in the calculation of A/S ratios.

G. Cost Data

Based on the operational data obtained from the DAF wastewater treatment system, average operating conditions were developed. This included the best overall operating mode, chemical dosages, expected pollutant removals, etc. On the basis of this data, cost estimates were developed for an eight-peeler and for a four-peeler cannery operation, as representative of Gulf processors. The basis for these cost estimates are included in detail in Appendix D of this report. Where gaps are present in actual data, costs are given on the basis of best available information and reasonable assumptions, as presented in the calculations.

Cost data for the project facility are based on actual installed contract costs ENR adjusted to the end of 1977, actual chemical costs, metered electrical consumption, and actual wastewater flow and cannery production data. Labor and maintenance are best estimates for the area in which the project was located.

Costs of disposing of DAF treatment skimmings were estimated from data developed during the project, information obtained from several shrimp canneries, and best estimates from the limited information available.

SECTION VII

RESULTS

A. Wastewater Characteristics

The untreated project shrimp cannery wastewater discharge was monitored to obtain as much data as possible during the course of this study. Goals were to establish the wastewater characteristics and to obtain a typical base for comparison with treated effluent. Samples were also collected and individual shrimp cannery unit process wastewater discharges were characterized. Treated DAF system effluent was sampled and analyzed. Flow data were collected. Detailed tabulations of project data are presented in Appendix C.

Table 5 is a compilation of mean values of lab analyses performed on each individual unit process wastewater within the plant. These values are for the fall 1974 and the 1975 summer and fall shrimp seasons. It is apparent that high variability occurs in the wastewater concentrations from process to process and even within a given process.

The results of cannery effluent testing are shown in Table 6, by years and by seasons, for the duration of the project. The compiled data indicate that in 1977 the shrimp cannery wastewater contained a smaller concentration of pollutants than in 1976 with regard to all parameters except suspended solids. It is also noted that the results are similar to those obtained during the earlier pilot and bench scale studies. There is, however, a wide variation of values, as indicated by the standard deviation shown and the range of values determined. Since water conservation and pollutant load reduction measures were being put into effect from season to season during the period of data acquisition, these steps contributed to variations in the pollutant concentrations.

Shown as Table 7 is a comparison of several parameters and relationships of interest in the degradability of the wastewater. Figure 24 illustrates a 30-day BOD curve performed on a screened wastewater sample in 1977. Based on these results, it is apparent that shrimp processing wastewater is highly biodegradable and is quite variable. This curve and the ratios shown are indicative of the character of the wastewater and are not to be considered a source of precise values. It is generally shown, however, that the wastewater COD/BOD_5 ratio increased during the project period, possibly related to the water and wastewater management techniques instituted.

During the course of both the pilot and full-scale studies, it was noted that

TABLE 5. SHRIMP CANNING UNIT PROCESS WASTEWATER CONCENTRATIONS

UNIT PROCESS	BOD_5	Sol. BOD_5	COD	Sol. COD	TKN	O & G	pH	TS	TVS	TSS	TVSS	Sett. Solids	Temp. °C	Protein	Flow gpm	Flow gal/1000#
Receiving Tank	4,280 (1,540)	2,460	7,130 (400)	4,930	810 (220)	640 (260)	7.0 (0.3)	9,870 (1,900)	4,450 (1,410)	1,770 (320)	1,120 (170)	24 (15)	6 (1)	5,060 (1,380)	93	143
All Peelers	2,600 (790)	1,660	4,450 (1,310)		520 (130)	180 (51)	7.1 (0.2)	8,670 (920)	2,420 (300)	1,030 150	790 (93)	108 (52)	21 2	3,250 (810)	238	2,830
Peeler #1	2,320 (840)		5,430 (3,170)			260 (57)	7.1 (0.2)	9,660 (2,440)	3,030 (1,660)	1,650 (620)	1,130 (190)	138 (88)	23 (3)		31	410
Agitators	1,070 (990)		3,400 (4,070)		136 (9)	29 (16)	7.2 (0.1)	7,390 (1,460)	3,590 (4,190)	460 (220)	386 (190)	8	23 (2)	850 (56)		
Separators			1,020 (276)		244 (69)	36 (13)	7.3 (0.2)	6,410 (290)	957 (155)	340 (87)	289 (78)	17 (5)	22 (1)	1,530 (430)	43	569
Graders	174		1,110 (690)		91 (27)	11 (6)	7.1 (0.3)	5,590 (150)	3,880	172 (81)	127 (41)	6 (6)	23 (2)	570 (170)	16	207
Deveiners	240	213 (174)	1,230 (400)	436 (153)	76 (88)	13 (13)	7.4 (0.3)	5,930 (440)	810 (300)	219 (79)	187 (70)	7.3 (0.6)	24 (2)	480 (550)	99	1,330
Blanch Tank	11,800 (2,920)		18,100 (7,490)		1,500 (270)	22 (20)	5.6 (0.7)	101,000 (12,700)	14,300 (5,950)	6,140 (1,920)	4,000 (850)		98 (1)	9,380 (1,660)		
Blanch Cooling Tank	518 (564)		783 (640)		48 (1)	10 (7)	6.8 (0.6)	8,650 (1,150)	410 (340)	152 (176)	107 (123)	0.5 (0.7)	36 (8)	300 (6)	36	480
Canning Room Discharge	781 (327)		1,880 (1,650)		294	17 (9)	7.1 (0.4)	17,100 (5,750)	817 (181)	329 (240)	216 (126)	0.7 (0.5)	29 (8)	1,840	106	1,400
Retort Cooling Water	12 (7)		19 (14)		5	5 (4)	9 (0.8)	1,140 (1,130)	108 (76)	17 (9)	15 (12)	0 0	43 (1)	31	21	278

Notes: 1. All wastewater characteristic values in mg/l, except pH (units) and Settleable Solids (ml/l).
2. Values are averages and (standard deviations).
3. Data from 1974 and 1975 seasons.

TABLE 6. SCREENED SHRIMP WASTEWATER CHARACTERISTICS

	BOD_5	BOD_5 Soluble	COD	COD Soluble	TKN	PROTEIN	OIL & GREASE	TOTAL SS	VOLATILE SS	FLOW Gal/1000lbs.
FALL 1974										
Mean	1440	-	2580	-	-	-	124	456	370	-
Mass	88.4	-	158	-	-	-	7.6	28	23	7360
Observations	1	-	1	-	-	-	1	1	1	-
SUMMER 1975										
Mean (Std. Dev.)	1640(420)	683	2380(400)	-	214(19)	1340(120)	151(86)	452(167)	351(150)	-
Mass	108	45.1	157	-	14.1	88.4	10	29.9	23.2	7920*
Observations	7	2	9	-	3	3	8	9	9	-
SUMMER 1976										
Mean (Std. Dev.)	1660(260)	1470	3380(950)	3280	-	-	89(57)	373(200)	-	-
Mass	87.4	77.3	178	173	-	-	4.7	19.6	-	6310
Observations	7	1	12	1	-	-	8	12	-	-
FALL 1976										
Mean (Std. Dev.)	1330(370)	1070(190)	3380(590)	2480(870)	225(81)	1410(510)	138(39)	295(101)	-	-
Mass	78.1	59.9	198	146	13.2	82.6	8.1	17.3	-	7040
Observations	10	9	13	13	6	6	7	16	-	-
SUMMER 1977										
Mean/Obs.	1050/35	706/33	2710/34	1780/28	256/34	1600/34	119/33	491/34	413/33	-
(Std. Dev.)	(280)	(211)	(550)	(500)	(43)	(270)	(34)	(199)	(161)	-
Mass/Obs.	42.9/23	28.2/23	113/22	79.5/18	10.2/23	63.8/22	4.9/22	17.7/23	15.5/23	4420
FALL 1977										
Mean/Obs.	1210/6	803/6	3190/6	2320/6	287/6	1790/6	80/6	590/6	509/6	-
(Std. Dev.)	(250)	(259)	(520)	(320)	(36)	(220)	(22)	(260)	(220)	-

Values are: Mean in mg/l; (standard deviation) in mg/l, mass in lbs/1000 lbs raw shrimp processed, observations are number of individual analyses in season indicated.

* Combined Summer and Fall, 1975, average wastewater discharge was 7730 gallons/1000 lbs. of raw shrimp processed.

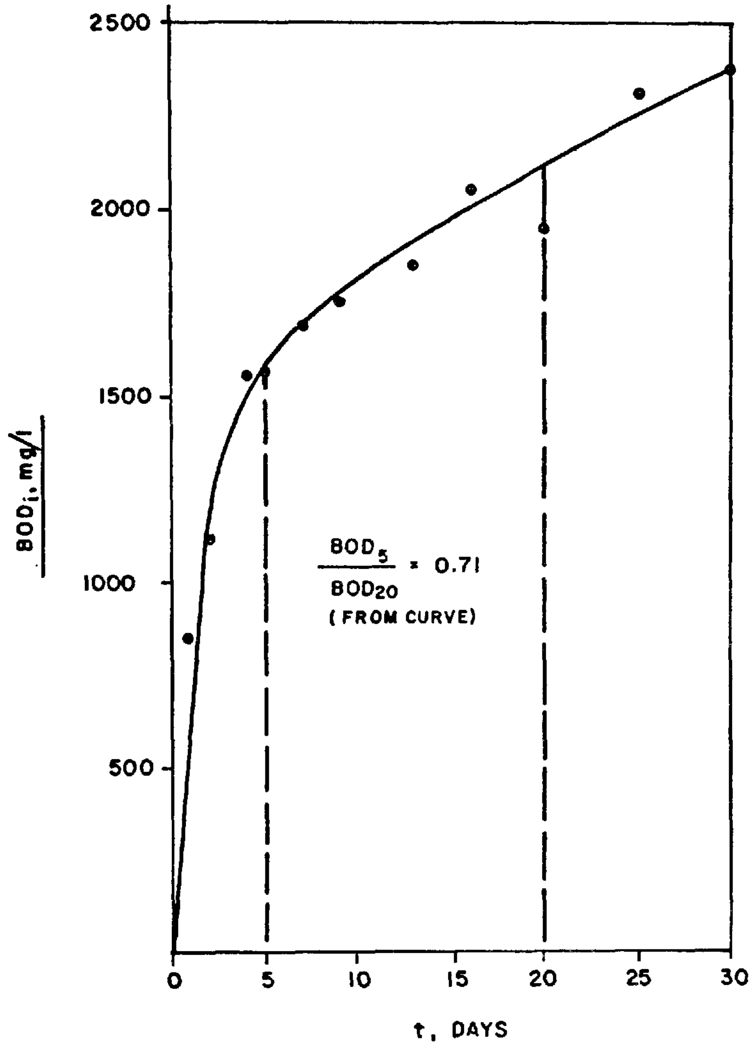
TABLE 7. EFFLUENT DEGRADABILITY COMPARISON
SHRIMP CANNERY WASTEWATER

Ratios	Summer 1975	Summer 1976	Fall 1976	Summer 1977	Fall 1977
Average $\frac{COD}{BOD_5}$	1.26	1.90	2.43	2.61	2.63
Avg. Sol. $\frac{COD}{BOD_5}$	-	-	2.88	2.52	2.89
$\frac{\text{Sol. } BOD_5}{\text{Tot. } BOD_5}$	0.89	-	0.75	0.68	0.66
$\frac{\text{Sol. COD}}{\text{Tot. COD}}$	0.46	-	0.89	0.66	0.73
$\frac{VSS}{TSS}$	0.70	-	-	0.85	0.86
$\frac{BOD_5}{BOD_{20}}$	0.56	-	-	0.69	-
$\frac{\text{Sol. } BOD_5}{\text{Sol. } BOD_{20}}$	0.53	-	-	-	-
$\frac{\text{Tot. COD}}{\text{Tot. } BOD_{20}}$	-	-	-	1.61	-

Note: From analyses of screened wastewater flows.

the strength of both the treated and untreated wastewater could be judged by the color and turbidity of the liquid. This was an operational aid in the DAF system operation evaluation. After screening, shrimp cannery wastewater usually has a pinkish brown to pinkish white color and is very turbid, with turbidity values exceeding 300 NTU. The color of the water is a reflection of the color of the product being processed; i.e., when brown shrimp are processed, the wastewater is usually pinkish brown, when white shrimp are processed, the wastewater is more pinkish white. The apparent color of the waste was high in relation to the true color since most of the color was removed by filtration at 0.45 microns. The true color was removed by coagulant addition and pH adjustment. At pH 5, even without coagulant addition, the true color will separate. Precipitation at this pH is characteristic of many proteins.

FIGURE 24
30 DAY BOD CURVE
GULF SHRIMP CANNERY WASTEWATER



While screening of the raw shrimp canning process wastewater was through a 10 mesh (0.85mm) screen, there was still a good bit of settleable material which entered the DAF system. Bits of shrimp meat and the appendages (legs) of the shrimp were not completely removed by the screens and caused some difficulties. During the 1977 season, settleable solids analyses were conducted on both the screened influent and DAF treated effluent samples to define the removal. It was demonstrated that there remained a mean value of 12.3 ml/l of settleable solids in the screened treatment plant influent. This represents significant solid material with a tendency toward settling. It was found that the project DAF system removed virtually all settleable solids.

Table 8 is a compilation of available cannery wastewater data for a portion of the 1977 oyster processing season. A mean COD:BOD_5 value of 5.70 was found. A much higher mean value of suspended solids than from shrimp wastewater was observed. Both oil and grease, and TKN are relatively low. The wide range of values given in

Tables 8 and 9 show that oyster processing wastewater is quite variable in content and in quantity of pollutant.

TABLE 8. OYSTER PROCESSING SCREENED EFFLUENT

	BOD_5 Total	BOD_5 Soluble	COD Total	O & G	TKN	TSS	VSS	Settle. Solids (ml/l)
Mean (mg/l)	510	373	2770	37	110	2280	792	30
Range (mg/l)	377-743	240-585	662-4780	3-212	59-159	704-4510	320-1080	9-49
No. of obs.	3	3	9	5	6	9	6	8

TABLE 9. POLLUTANTS IN OYSTER PROCESSING WASTEWATER*
(SCREENED EFFLUENT)

	lbs/1000 lbs. Finished Product						
	BOD_5 Total	BOD_5 Sol.	COD Total	O & G	TKN	TSS	VSS
Mean	46	34	296	3.7	10.8	180	74
Range	8-106	33-61	51-611	0.3-7.0	7-25	70-435	36-134

* Data from 1977, based on a maximum of 8 observations

The gross amount of raw material processed in oyster canning operations was dependent on the availability of oysters, a situation similar to that encountered in shrimp canning. During the 1977 oyster canning season, oyster processing was observed to occur at a mean rate of 14,250 lbs/hr. of raw product (s=3365 lbs/hr.). The standard deviation here is relatively small, indicating some stability in the processing rate. The processing time and volume varies more, as could be expected with an intermittently supplied raw product. Required washdown time was similar to shrimp. A one and one half hour wash-down was noted for each processing day, regardless of processed volume or operational time. Oyster processing was interrupted, and so was the waste flow, when boats were being docked for unloading. A longer break occurred when plant operations had to be ceased while waiting for a boat load of oysters to arrive. These interruptions in flow were irregular and often were unpredictable. Flow rate during oyster processing at the study plant was generally about 100 gpm and lasted from 3 to 20 hours per day (during 1977), depending on the amount of raw oysters available.

B. Water Use Management

Prior to the installation of the plant scale system, water use and wastewater flows at the study cannery were measured during shrimp processing in preparation for the design of the dissolved air flotation system. Water reduction and conservation measures were recommended which would eliminate unnecessary and wasteful water use in an effort to reduce the high flows. Because of the seasonal operations, there was not time to initiate the conservation measures and observe the resultant flows. The DAF system design was based on the earlier established flow rate of 700 gpm. A water management plan (included as Appendix B) was developed as a guide for shrimp canneries based on project experience. Many of the recommended conservation items are standard wastewater reduction measures, such as dry sweeping of floors, high pressure-low volume washing, and the installation of dependable valved hose nozzles. Other conservation items were more specific to the industry, such as: (a) the reduction of product water transport minimizing shrimp-water contact in order to keep dissolved protein at a minimum and (b) the operation of water using machines at higher pressures but lower flows. Several water conservation measures and other changes were made between 1975 and 1977. The changes showed that substantial flow reduction could be attained by canneries. The result of the changes at the Violet cannery was a reduction of the average wastewater flow rate from 650-700 gpm in 1975 to about 500 gpm in 1977.

As could be expected, it was shown that the flow volume was dependent on the operating time of the plant and, thus, was dependent on the amount of raw product processed. During the 1977 shrimp season, it was demonstrated that 4,420 gallons (s=600) of processing and washdown wastewaters were produced from processing 1,000 lbs. of raw shrimp. This rate of flow in 1976 was 6,150 gallons (s=1,660) per 1,000 lbs. shrimp, and in 1975, the mean was 7,730 gal/1000#. Certain non-contact waters, such as retort cooling water, are released without treatment since they represent only a slight thermal discharge. These volumes are not included in wastewater flows and volumes mentioned above. This is one water consumption where separation is essential and where re-use may prove worthwhile in some instances. The water conservation measures which were initiated at the project cannery led to a substantial flow reduction without major problems in the shrimp processing and canning sequence.

The amount of shrimp processed, expressed as lbs/hr/peeler, was shown to be relatively constant with 1976 and 1977 mean and standard deviation values of 817 $\pm$ 189 and 808 $\pm$ 120 lbs/hr/peeler, respectively. The amount of processing per day was directly dependent on the quantity of available shrimp. During peak periods, all peelers would be operative for two shifts per day, for as long as 20 hours processing time. During times of scarce raw product supply, as few as 4 peelers would operate for as short a period as one and one-half hours per day. A standard washdown took approximately one and a half hours and was required after every shift, even if the plant did not operate a full shift. When a continuous operation took place (2 shifts), two cleanups were required. The washdown wastewater flow rate was about one-third that of process flow, and represented a minimum of about 6% of the total flow for full operation to a maximum of about 25% for a one and one half hour processing period.

To a certain extent, it was shown that, like flow, the mass of pollutants produced and introduced into the wastewater system was dependent on the amount of shrimp processed. The mass rate of discharge of pollutants in the cannery wastewater as related to shrimp production (lbs per 1000 lbs) is given in Table 6. This is a significant ratio since current effluent limitations are expressed in this form. It is obvious that there is a great deal of variation in all parameters, from season to season, and from day to day. It should be noted that all of these data are based on composite samples. With the large variations in daily composite samples, it is understandable that the instantaneous concentration of a pollutant in mg/l can be an even more highly variable figure. Often a visual change was noted in the wastewater with each new supply of shrimp processed. The variation was not only observed by the truck load, but was noted within a given truckload. Attempts were made throughout this investigation to correlate parameters of the wastewater with parameters of the shrimp, such as age, type, size, and source. No appreciable conclusions were possible, however. It appears that a "typical" discharge for even a given shrimp cannery cannot at this time be precisely and reliably defined. Rather, it appears that mean and standard deviation values of given parameters are more valid expressions.

Based on Table 6, it is obvious that water use management brought about a substantial reduction in the discharge of various pollutant parameters including BOD_5, TSS, and oil and grease, as well as flow volumes. The reduction of water volumes, fluming time and other water contact contributed to a reduced waste load. This is substantiated by results of samples taken at the start and end of various flumes in the plant. Table 10 shows the increase in pollutants during water fluming from the peelers, graders and deveiners. A substantial increase in soluble BOD_5 and in TKN and O & G was found.

TABLE 10. WATER FLUMES POLLUTANT INCREASE IN PERCENT (%)

Location	BOD_5 Soluble	COD Soluble	TKN	O & G
Peelers	20.1	31.3	18.3	4.3
Graders	5.9	23.4	-	11.1
Deveiners	1.9	7.3	-	-

C. Treatment by Screening

Until recent years, no type of solid-liquid separation was practiced by most Gulf shrimp processors. Several types of screens have now been installed. At Violet Packing Co., 10 mesh vibrating screens were located immediately ahead of flow measurement into the DAF system. Table 11 illustrates the results of several analyses conducted on pre-screened wastewater to evaluate the effect of screening. Although there was some reduction in most parameters, the greatest reduction was removal of approximately 45% suspended solids. The principal materials removed by screening were shrimp heads and shrimp hulls and fragments of shrimp meat. There was a substantial reduction in settleable solids. Successful pre-screening is essential to the proper operation of a DAF system on shrimp cannery wastewater.

TABLE 11. WASTEWATER TREATMENT BY SCREENING
GULF SHRIMP CANNERY

Sample	BOD_5 Total	COD Total	TKN	Protein	O&G	TSS	TVSS	Sett. Solids ml/l
Influent								
Mean	1830	2920	460	2880	160	673	494	30
(Std. Dev.)						(217)	(141)	(7)
Effluent								
Mean	1700	2250	261	1630	132	367	223	7
(Std. Dev.)	(330)	(650)	(59)	(370)	(51)	(110)	(129)	(2)
Removal %	7.1	23.1	43.3	43.3	17.5	45.5	54.9	76.7

Data from 1975. All given project protein values calculated as TKN x 6.25.
Data by individual characterizations contained in Appendix C.
Values in mg/l, unless noted otherwise.

Improved screening effectiveness may further reduce the settleable solids, in particular, from the process wastewaters, helping reduce sedimentation problems in wastewater treatment and possibly adding protein to the screenings solids.

The screenings produced become a solid waste problem. Many canneries have no available market for this by-product and even find it very difficult to dispose of these solids in an acceptable way. The screenings disposal was not a part of this study, but some information on current practice is given in Section VIII.

D. Bench Scale Results

Bench scale testing was conducted throughout the study, primarily as an operational aid for the plant scale system. This was also a data collection mechanism that was supplementary to data obtained on the full scale DAF system. The length of time required to fully investigate a particular chemical on a plant scale basis was prohibitive in some instances.

COD and other analyses were made during initial jar testing efforts in the fall of 1974 and during the 1975 season. This testing was to confirm the earlier pilot study and to evaluate other chemicals. Data are in Appendix C. Routine evaluation of jar testing during wastewater treatment plant operation consisted of visual comparisons. This was usually sufficient due to the sensitive treatability of the wastewater. More jar testing was permitted by performing the evaluation in this matter, although the total suspended solids test was occasionally used as a measure of the relative effect of various chemical doses, polymer doses, etc.

The wide variability in the nature of the shrimp processing wastewater made it difficult to maintain a consistent optimum chemical dose. Similarly, bench scale studies witnessed a great deal of change between canning seasons and even within a canning season. Generally, however, it was noted that alum dosages in jar tests were shown to be fairly stable from 1974 to 1977, including the 1977 canning season. Laboratory optimums (for alum) during these seasons were approximately 100 mg/l, with a polymer (835A) dosage of about 6 mg/l, at a pH of 4.5 to 5.0. Sometimes the optimum pH was as low as 4.0. During the 1976 operational season, it was shown that chemical requirements for optimum bench scale treatment were generally consistent with those necessary for effective plant scale treatment. During the 1974 Fall season, laboratory investigations revealed that the optimum alum dose was 50-100 mg/l. This was at a pH similar to that found as optimum in later years, approximately 5.0.

Initially in the 1977 season, large alum dosages as high as 400 mg/l were consistently shown to be required for maximum removal. With nearly all alum doses, results were directly proportional to the amount of polymer applied. Later in the season, the alum optimum was found to decrease to as low as 75 mg/l. However, it was found to average 200 mg/l. Best removals were attained at higher (above 4 mg/l) polymer levels. While excellent results were witnessed in the laboratory under these conditions, direct application to the plant scale system was often unsuccessful. The actual plant use of the lower alum dosages produced an effluent with much residual color, indicating insufficient coagulation. This was substantiated by informal on-site jar testing which showed that adding alum to the effluent caused further clarification. Due to physical differences in the plant scale system as opposed to bench-scale, it was apparent that direct transfer of jar test treatment data was not always practicable for good results.

Limited jar testing of shrimp processing effluent using coagulants and coagulant aids other than aluminum sulfate and 835A polymer was conducted throughout this study for comparison and treatment optimization purposes. The coagulants lignosulfonate (Am. Can Co. PRA-1, Protein Reducing Agent) and Magnifloc 507C polymer were shown to be effective in the laboratory for the removal of turbidity and color, when evaluated on a visual basis, and used in conjunction with 835A polymer. A dosage of 30-50 mg/l was generally the optimum for either PRA or 507C when used at pH 5.0 in conjunction with 835A. The degree of clarification produced by either of these chemicals was found to be no better than with alum. Bench scale tests with PRA and polymer showed TSS removals approaching the 80 to 90% achieved with alum and polymer. Sufficient PRA and cationic polymer were readily available for plant scale testing, as reported in the following pages.

Chitosan, a derivative from chitinous shellfish, was also jar tested in 1974 and 1975 and was found to produce as much as 80% removal of suspended solids, with pH control. Up to 90% TSS removals were obtained in jar tests with pH adjusted screened wastewater using GTS (glucose tri-sulfate), with some residual color problem. Sufficient quantities of these chemicals were not on hand for plant scale testing. Due to the problems of supply and limited information on availability, shipping, storing, costs, standardization, etc., and the failure to demonstrate significantly greater treatment results than with the readily available alum and polymer, these chemicals were not tested further.

During the Summer 1975 season, laboratory flotation bomb studies were conducted to partially simulate the plant scale system. The apparatus used was similar to the standard Eckenfelder bomb. Direct pressurization was ineffective in the bomb due to shearing of the floc. The other mode which was investigated, recycle, used tap water as the pressurized medium and was quite successful. Chemical dosage optimums were very similar to those found in jar tests; i.e., a relatively high alum dosage with greater than 4 mg/l polymer.

In the latter part of the 1977 shrimp season, the addition of alum with no pH adjustment and no coagulant aid was investigated. Dosages of alum as high as 1200 mg/l were considered in jar testing. The results were similar to those observed with pH adjustment alone; i.e., precipitation of light, fluffy floc. This addition of alum alone appeared to serve as a pH reduction mechanism, more than as a coagulation process.

It was generally noted that the higher the dosage of 835A polymer, the better the pollutant removals, when at optimum coagulant dosage. On the basis of polymer dose, a restabilization effect was not observed either in the laboratory or in the plant-scale system at dosages as high as 14 ppm. In plant scale testing, minimum effective doses were utilized, as being more cost effective. Based on visual and TSS observations, when polymer was applied as the primary coagulant, virtually no clarification was obtained.

Double-layer compression was obviously occurring at lower alum dosages, but other destabilization mechanisms were apparently active at different ionic and colloidal strengths of the untreated wastewater. In double-layer compression, a compression of the diffuse layer of the colloidal particles occurs as a result of the oppositely charged counter ions (coagulant) introduced into the aqueous system. An overshadowing of the coulombic effect of the negatively charged colloids is the result, with a lowering of the opposing electrostatic forces. Compression of the outer ionic layer of the colloidal particles causes a reduction in stability of the particles. Hence, different floc formations were observed under varying conditions and days. Without a coagulant aid, floc size seldom exceeded pinpoint. The result was a liquid system very sensitive to alum and requiring (but not sensitive to) large dosages of polymer for effective solid-liquid separation.

Some limited gravity dewatering of sludge was investigated in the laboratory. Also, gravity dewatering of heated sludge at temperatures 30 to 40° F above ambient was attempted on a bench scale. While a solid-liquid separation did occur, it was irregular and unpredictable. An increase in temperature of the sludge was shown to hasten the separation process.

E. DAF Treatment - Shrimp Processing Wastewater

Since the DAF treatment system was not constructed until 1976, data on the operation of the treatment system was obtained only during the last half of 1976 and in 1977. Prior to the 1977 shrimp season, mechanical and other problems limited the data collection, and only sketchy information was obtained. All treatment data acquired throughout the study is tabulated in Appendix C, but the indicated limitations in the data must be considered when evaluating the results. The 1977 study year could therefore be considered to be the most important in terms of treatment data production, and thus will be the focus of discussion.

The methodology for the plant scale treatment system portion of this study has been explained previously. Operational runs were conducted by varying certain operational parameters which would allow the effect of a given system variable to be defined. The 1977 study year, in accordance with the objectives of this study, was divided into four operational sets of performance runs. The following is a discussion of each set and the results obtained for each.

1. Operational Set #1: Initial Runs With No Polymer Addition.
The first set of performance runs sought to optimize operating pressure, and to define system performance under conditions of no coagulant aid addition. The DAF system was operated under conditions of pure physical treatment, pH adjustment only, and pH adjustment with alum addition, in addition to variations in the pressure to which the wastewater was subjected. Operating conditions were based on past experience, and alum dosages were based on jar testing conducted during the 1977 summer season. Table 12 indicates the conditions of DAF system operation for operational set #1.

   Since much of the data obtained here was for reference and comparison, rather than absolute performance, these runs were not as carefully regulated and the results are not as conclusive as will be seen in the later performance runs. However, this gave a strong indication of the need for coagulant and coagulant aid addition with proper pH adjustment and showed the need for extensive monitoring control and operational adjustment.

   Table 13 contains the results of operational Set #1 by mean and standard deviation of the removal efficiency for each monitored parameter. Appendix C contains the influent and effluent data concentration for each run, by the given parameters. It will be readily noticed in Table 13 that removal efficiencies are generally low. But by referring to Appendix C, it is seen that there are several parameters, in several runs, that show an increase rather than a decrease through the treatment process. The removal efficiencies for these parameters were considered as zero in the calculation of mean values. It should be noted that the highest, most consistent removals were obtained for settleable solids. The DAF cell may have acted to some degree as a sedimentation basin since the full flow (FFP) mode was employed and no other appreciable tankage was involved.

TABLE 12. 1977 OPERATIONAL SET #1
OPERATING CONDITIONS

Run Number*	pH (units)	Air Flow (cfm)	Pressure (psi)	Alum (mg/l)
A				
100	Natural**	3.0	40	None
101	Natural	3.0	45	None
102	Natural	3.0	35	None
103	Natural	3.0	40	None
B				
104	5	3.0	40	None
105	3.8	3.0	40	None
106	4.4	3.0	40	None
107	5	3.0	40	None
108	5	3.0	40	None
C				
109	5	3.0	40	100
110	5	3.0	40	140

* All tests made in Full Flow Pressurization mode.
** Natural pH = 7.7 to 8.1.

2. Operational Set #2: Alum and Polymer Optimization Runs.
Since it had previously been shown that alum and 835A polymer were the most effective chemicals for shrimp cannery effluent[1], this operational set received the most attention and time. A total of 23 runs was recorded and sampled during this set as shown in Table 14. The average flow rate during these runs was 500 gpm. The length of each run was approximately three hours. All of these runs were seeking highest removals with the exception of a few which were seeking treatment

TABLE 13. OPERATIONAL SET #1: INITIAL RUNS WITH NO POLYMER ADDITION

	BOD_5 (Total)	BOD_5 (Soluble)	COD (Total)	COD (Soluble)	TKN	PRO-TEIN	O & G	TSS	VSS	Settleable Solids
Set #1A Runs 100-103			NO CHEMICAL ADDITION							
Influent (mg/l)	1,370	928	3,240	--	266	1,660	152	744	575	20
Effluent (mg/l)	1,320	1,130	3,510	--	292	1,820	136	216	181	0.1
% Removal	3.5	--	--	--	--	--	10.5	71.0	68.5	99.5
Set #1B Runs 104-108			pH ADJUSTMENT ONLY							
Influent (mg/l)	806	645	2,470	1,530	250	1,560	89	502	436	11
Effluent (mg/l)	573	547	2,110	811	204	1,280	72	614	535	14
% Removal	28.9	15.2	14.6	47.0	18.4	18.4	19.1	--	--	
Set #1C Runs 109-110			pH ADJUSTMENT AND ALUM ADDITION							
Influent (mg/l)	912	602	2,390	1,470	207	1,290	119	508	460	17
Effluent (mg/l)	639	512	2,200	1,240	199	1,240	75	560	474	13.3
% Removal	29.9	15.0	8.1	16.0	3.9	3.9	37.0	--	--	21.8

Values are averages.

definition at a particular level of chemical addition. Generally, most runs represent the result of adjustment of the system seeking the best possible operation for the period. Optimum treatment was reached by informal on-site jar testing using samples siphoned out of the inlet well of the flotation cell. By visual observations, chemical dosages were adjusted until an apparent optimum was reached based on the rise rate and separation of floated solids and the degree of clarification of the wastewater. Once the treatment was optimized, sampling began after allowing for the flow through retention time. All runs numbered in the 400's were conducted by the equipment manufacturer for contract compliance testing and were the best attainable for this particular wastewater by the manufacturer's experienced personnel.

TABLE 14. 1977 OPERATIONAL SET #2
DAF OPERATING CONDITIONS

Run No.	Mode*	pH	Alum mg/l	835A mg/l	Air Flow cfm	Pressure psig
111	F	5	150	2.5	3.0	40
112	F	5	130	2.5	3.0	40
113	F	5	130	1.4	3.0	40
116	F	5	175	4.0	3.0	40
401	F	5	250	4.2	3.0	50
402	F	5	260	4.2	3.0	50
403	P	5	279	5.2	3.0	50
404	P	5	280	7.6	3.0	50
405	R	5	400	10	3.0	50
406	P	5	366	7.4	3.0	50
407	R	5	287	7.0	3.0	50
408	R	5	326	6.9	3.0	50
409	F	5	296	6.7	3.0	50
410	R	5	210	6.0	3.0	50
125	F	5	290	5.1	2.5	50
126	F	5	290	4.1	2.5	50
127	R	5	95	5.8	2.5	50
128	R	4.8	130	6.8	2.5	50
129	R	5	300	7.3	2.5	50
130	R	5	400	7.3	2.5	50
131	R	5	400	10.8	2.5	50
133	P	5	400	2.5	2.5	40
134	P	5	400	7.6	2.5	40

* F = Full Flow Pressurization
P = Partial Flow Pressurization, 50% to 60% pressurized.
R = Recycle Pressurization, approximately 60% recycle.

The addition of polymer and the resulting improved system performance is clearly reflected by a comparison of Table 15 (Results of Operational Set #2) and Table 13 (Results of Operational Set #1). As shown in Appendix C, good removals were obtained at a variety of levels of alum addition, further indicating the variation in the treatability of the wastewater. Oil and grease removals were fairly consistent, as indicated by the low standard deviation, and were exceptionally good. Settleable solids which appeared in the effluent were usually of a flocculant nature and represented floc carryover. The values for effluent TKN indicate that much of the protein was dissolved and was unaffected by coagulating chemicals. Similarly, much of the BOD_5 and COD was of a dissolved nature, nevertheless, most effluent samples in Operational Set #2 were low in Turbidity, usually less than 100 NTU, and often less than 50 NTU. Table 15 summarizes the removal levels attained by alum and polymer addition with DAF treatment of the shrimp cannery wastewater.

It was proposed to either eliminate or establish the need for all additional tankage and equipment required for DAF operation in the recycle and partial pressurization modes. The Violet DAF system flexibility allowed treatment in all three modes of operation. The results of the runs performed in Operational Set #2 were segregated by modes and the removals and concentrations of pollutants in the influent and effluent are tabulated in Table 16. These results indicate that slightly higher removal efficiencies were attained in the recycle mode of operation. Different modal performances are compared in Table 16 even though chemical dosages were not always the same. However, in each instance alum and polymer dosages were adjusted during operation to the apparent optimums. A substantial difference exists in BOD_5 removal between full flow and recycle with higher removals in the recycle mode. Soluble COD removal efficiency between the two modes was also quite different, however, the influent soluble COD was higher for recycle than for the full flow runs. The results from the partial pressurization mode were generally in between full flow and recycle.

3. Operational Set #3: Unattended Nighttime Runs.
It was demonstrated in Operational Set #2 that certain levels of treatment were attainable by DAF treatment on shrimp cannery wastewater. These removals were achieved with at least one graduate engineer (and more often two) giving constant attention to plant control and with one or more college graduate students assisting in operation and laboratory monitoring. The practicable, day-to-day operation could be much different. To base expected performance on project results would be unrealistic since such careful control cannot always be maintained. Also, these performance run analyses do not reflect the pollutants in the periodically discharged tank drainage. Operational Set #3 was,

TABLE 15. WASTEWATER CONCENTRATIONS
OPERATIONAL SET #2: ALUM AND POLYMER OPTIMIZATION RUNS

PARAMETER	INFLUENT (Screened)	EFFLUENT (DAF Treated)	REMOVAL %
BOD_5 (Total)	1070 (210)	453 (122)	56.5 (13.5)
BOD_5 (Sol.)	687 (170)	386 (106)	41.5 (18.4)
COD (Total)*	3020 (376)	1370 (300)	54.8 (8.3)
COD (Sol.)*	1830 (400)	1110 (250)	37.1 (17.7)
Protein	1650 (220)	875 (194)	46.6 (10.6)
TKN	264 (35)	140 (31)	46.6 (10.6)
Oil & Grease	128 (29)	18 (8.4)	85.0 (8.7)
TSS	468 (230)	140 (72)	65.6 (19.4)
VSS	401 (185)	99 (53)	71.5 (17.9)
Settleable Solids (ml/l)	12.8 (5.0)	2.8 (3.9)	77.8 (28.1)

Notes: Values are mean and (standard deviation) in mg/l unless otherwise noted.
Total of 23 runs, all modes, 1977 data, except COD* based on 14 runs.
Average flow rate of 500 gpm, runs of three hours.

TABLE 16. TREATMENT RESULTS FOR OPERATIONAL SET #2 (ALUM AND 835A POLYMER) OPTIMIZATION BY MODE

	BOD_5		Soluble BOD_5		COD		Soluble COD		TKN		Protein		O&G		TSS		VSS		Settleable Solids (ml/l)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
FULL FLOW PRESSURIZATION (9 Runs)																				
Influent	1050	180	721	173	3080	360	1910	370	284	14	1780	90	134	26	483	211	420	196	16	6
Effluent	522	127	454	110	1530	290	1260	270	162	23	100	45	16	7.2	161	92	89	53	0.7	0.6
Removal %	48.5	17.5	33.6	21.7	50.4	7.8	33.3	12.7	42.6	9.2	42.6	9.2	87.3	6.2	62.7	22.0	75.4	16.2	94.3	6.0
PARTIAL FLOW PRESSURIZATION (5 Runs)																				
Influent	1050	120	607	178	2690	560	1180	-	222	13	1390	80	133	21	636	360	511	275	10.9	1.7
Effluent	469	52	376	36	1210	220	1050	50	130	26	813	163	21.6	7.4	135	37	116	32	4.3	4.1
Removal %	55.0	6.5	34.2	17.7	54.4	7.4	10.0	4.2	41.8	11.5	41.8	11.5	83.4	7.6	72.6	17.6	71.6	17.1	62.5	34.8
RECYCLE PRESSURIZATION (9 Runs)																				
Influent	1090	290	701	169	2700	400	1980	210	266	39	1660	240	119	37	360	70	322	56	9.9	3.3
Effluent	383	115	330	99	1040	170	912	67	124	31	775	194	17	10	122	66	100	64	4.2	5.0
Removal %	64.6	7.3	52.7	9.2	61.4	4.7	53.4	7.0	53.3	8.7	53.3	8.7	83.6	11.4	64.8	18.9	81.1	54.9	67.7	32.9

All Results in mg/l Unless Otherwise Noted

$\bar{x}$ Mean Values

s Standard Deviation

TABLE 17. OPERATIONAL SET #3
SUMMARY OF OPERATING CONDITIONS

Run No.*	pH	Alum (mg/l)	835A (mg/l)	Air Flow	Pressure
UI32	5	400	2.5	3.0	50
UI35	5	400	3.3	3.0	50
UI37	5	185	3.9	3.0	50
UI39	5	225	4.9	3.0	50

*All runs in FFP mode.

therefore, planned to exemplify the removal efficiencies typical of a day-to-day operation of the facility. Although there were only four runs conducted in this manner, they are a good representation of what could be expected if time had allowed many more runs. The operational conditions of these "U" runs (unattended runs) are shown in Table 17. Full flow pressurization mode was in effect. Chemical dosages were based on the visually determined optimum at the beginning of the operational run, and were not further adjusted during the run. Because of the variability of the wastewater character, the amount of chemical needed for most effective DAF treatment was also a variable factor and had a direct influence on the treatment levels attained. It should also be noted that these runs were approximately 10 to 12 hours in length and included washdown waters, whereas all other (optimization) data collecting runs were 1 to 3 hours in length and included only process wastewaters. Washdown and process flows were similar in total parameters, except that suspended solids were lower in washdown and, consequently, soluble parameters were higher. Washdown waters would be more difficult to treat effectively by DAF than process wastewater, since a larger portion of the pollutants would have to be first precipitated out of solution. An adjustment in alum dosage for washdown waters would probably be required. Operational Set #3 reflects the treatment produced when such adjustments were not made.

As illustrated in Table 18, a high degree of treatment was possible even with no adjustments made to the treatment process as changes occurred. The calculation of treatment efficiencies was based on average influent characteristics. As might be anticipated, TSS removals were less than during optimization runs. Raw water character and, thus, alum and/or polymer requirements may have varied during the unattended periods. Without the needed adjustment, suspended solids removal efficiency

TABLE 18. WASTEWATER CONCENTRATIONS
OPERATIONAL SET #3: UNATTENDED RUNS

PARAMETER	INFLUENT (Screened)	EFFLUENT (DAF Treated)	REMOVAL %
BOD_5 (Total)	1100	499 (70)	54.5 (6.2)
BOD_5 (Sol.)	750	380 (43)	49 (6.1)
COD (Total)	2800	1380 (207)	55.5 (4.4)
COD (Sol.)	1850	926 (97)	50 (5.6)
Protein	1660	838 (125)	49.5 (7.4)
TKN	265	134 (20)	49.5 (7.4)
Oil & Grease	125	20 (8.2)	84.0 (6.4)
TSS	473	310 (145)	34.3 (30.6)
VSS	409	266 (118)	35.0 (28.7)
Settleable Solids (ml/l)	13	1.5	88.5

Notes: Values are mean and (Standard deviation) in mg/l unless otherwise noted.
Influent values are average for period.
Total of 4 runs, average of 12 hours each, FFP.
Average flow rate of 500 gpm.

changed. Other removals are comparable to the Set #2 optimization runs. It was noted that there was a relatively small standard deviation for several of the effluent parameters, which would indicate a stable effluent quality between the four performance runs evaluated.

4. Operational Set #4: PRA and 835A Runs.
It was found in the pilot study that alum with 835A polymer was the most effective team of coagulating chemicals. It was also noted that similar results were not always obtained by the carry-over of conclusions from the bench scale to the pilot scale. Similarly, a possibility could exist that the carry-over of results from jar tests or pilot plant to the plant scale would not produce comparable results. In order to confirm plant scale performance, the lignosulfonate PRA-1 was tested in conjunction with 835A Polymer as a coagulant aid. These performance runs were conducted under the conditions shown in Table 19. During the time of this testing, the project cannery was running only a few hours per day. While this allowed time for sampling, it did not allow adequate operating time for trial and error PRA dosage optimization. It may have been possible to attain slightly higher treatment levels if time had been available to fully optimize. As shown by the results in Table 20, removal efficiencies were comparable to those obtained by the use of alum. It was found that changes in the point of application of the PRA did not appreciably affect treatment efficiencies.

TABLE 19. 1977 OPERATIONAL SET #4 - OPERATING CONDITIONS

Run No.	pH	PRA mg/l	835A mg/l	(cfm) Air Flow	(psi) Pressure
142[1]	5	60	2.5	3.0	40
143[2]	5	60	2.5	3.0	40
144[2]	4.5	60	2.5	3.0	40

[1] PRA applied in flume, 835A @ Pressure Release Valve
[2] PRA applied @ Pressure Release Valve, 835A at last sample point before inlet tube inside DAF cell.
All runs in Full Flow Pressurization Mode

Late in the 1977 shrimp season, the DAF system was operated to evaluate treatment efficiency under the conditions of: (a) alum addition with no pH adjustment, and (b) utilizing a double polymer system (507-C and 835-A). When alum is introduced into an aqueous system, a pH drop is observed due to the chemical destruction of alkalinity. As shown by Figure 25 a linear pH drop was observed with increasing alum addition

TABLE 20. WASTEWATER CONCENTRATIONS
OPERATIONAL SET #4: PRA AND 835A RUNS

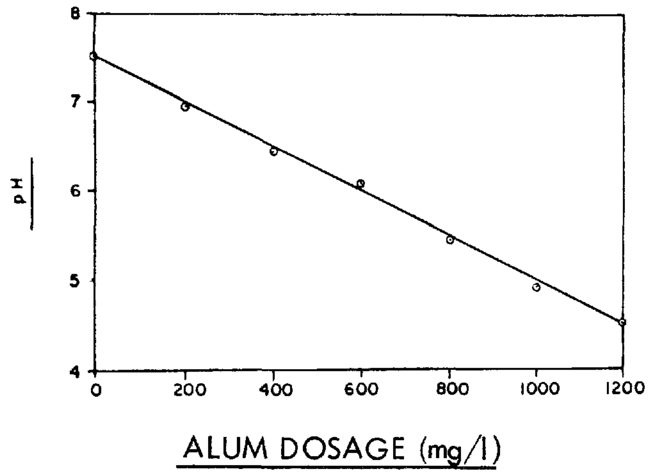
PARAMETER	INFLUENT (Screened)	EFFLUENT (DAF treated)	REMOVAL %
BOD_5 (Total)	853 (183)	385 (208)	56.7 (18.3)
BOD_5 (Soluble)	556 (151)	303 (145)	47.7 (11.2)
COD (Total)	2100 (460)	939 (252)	55 (8.7)
COD (Soluble)	1390 (140)	728 (91)	47 (9.0)
TKN	184 (39)	84 (18)	53.7 (10.4)
Protein	1150 (244)	523 (114)	53.7 (10.4)
Oil & Grease	60 (28)	19 (13)	67.7 (15.1)
TSS	529 (86)	135 (113)	75.7 (18.0)
VSS	457 (67)	126 (106)	73.3 (20.3)
Settleable Solids (ml/l)	8.4 (0.8)	4.5	42

Notes: Values are mean and (standard deviation) in mg/l unless otherwise noted.
FFP, three runs, average of 3 hours each.
Average flow rate of 500 gpm.

to shrimp cannery wastewater under laboratory conditions. A similar condition was expected under plant scale conditions. The fall 1977 runs (#151-153 as tabulated in Appendix C) illustrate that large doses of alum were not effective as a coagulant, but brought about a pH drop and the subsequent precipitation of proteinaceous material. The large increase in settleable and suspended solids and the poor BOD_5 and COD removals show that floc was formed, but it was not effectively separated from the wastewater. This would confirm that the alum alone was effective as a pH depressant at large doses, but there was not good flocculation and removals were poor.

FIGURE 25

pH RESPONSE TO INCREASED ALUM ADDITION
GULF SHRIMP CANNERY WASTEWATER



A double polymer (cationic-anionic) chemical treatment was also investigated for the project DAF system, employing Pearl River Chemical 520 C (American Cyanamid 507C) cationic polymer as the destabilizing agent and Magnifloc 835A as the coagulant aid. Two operational runs were performed with polymer dosages of 300 mg/l cationic and 5.0 mg/l anionic at pH 5.0, with full flow pressurization. There was very limited operation of the packing plant during this period, and therefore the data represent the average values of analyses performed on grab samples. The removals and the performance and operation of the system (including the extreme chemical sensitivity of the wastewater) were similar to those with alum as the coagulating agent. Table 21 shows the removals obtained.

Many industrial effluent limitation guidelines are based on mass, or pounds of pollutant per unit pounds of product, either finished or raw. The effluent limitation

TABLE 21. DOUBLE POLYMER RUNS

Parameter	% Removal
BOD_5	69
BOD_5 (Soluble)	62
COD	65
TKN	55
Protein	55
O&G	71
TSS	57
VSS	56

guidelines for the shrimp processing and canning industry are written on the basis of pounds of pollutant per 1000 pounds of raw shrimp. Table 22 expresses the results of the 1977 DAF treatment data on a mass discharge basis for Operational Set #2, Operational Set #3, three runs from Operational Set #4, and the two double polymer runs. These limited data seem to indicate that good removals were achieved with 520C and that PRA-1 may possibly be as effective as alum as a coagulant. However, before a conclusion is drawn comparing results of three runs to 23 runs, more investigation should be done. The evaluation of lignosulfonate as a coagulant should include determination of the continued availability, acquisition and transportation costs, and any special handling requirements of the material. The degree of uniformity, stability and strength should also be established. The ready availability of alum at reasonable cost in the project area made it appear to be the most suitable coagulant at this time. Due to mechanical and other problems, reliable treatment data were not obtained on the operation of the DAF unit during 1976. The results of 17 performance runs that were conducted during the fall canning season of that year are tabulated in Appendix C. Almost all of these runs were performed in the full flow mode, none in the partial mode. The optimum point for application of the alum was investigated, but results were not conclusive. It was found, however, that early, upstream addition with pH control gave best coagulation results, in both recycle (R) and full (FFP) modes. The mean and standard deviation for parameters in the 1976 treatment series are shown on Table 23. Many of the effluent analyses were on grab samples, utilizing the same influent sample for treatment evaluation. Although good data correlation may seem to be the overall conclusion, the sampling and operating con-

TABLE 22. WASTEWATER DISCHARGE
LB. POLLUTANT/1000 LB. RAW SHRIMP
(After DAF Treatment-1977)

Treatment	BOD_5	Sol. BOD_5	COD	Sol. COD	TKN	Protein	O&G	TSS	VSS
Alum & Poly. (23 Runs)	18.7	16.5	51.1*	50.0*	5.4	33.8	0.7	6.1	4.4
Unattended (4 Runs)	19.5	14.4	50.5	39.8	5.2	32.5	0.8	11.6	10.1
PRA & Polymer (3 Runs)	18.6	14.7	50.9	42.1	4.7	29.4	1.6	4.3	4.1
520C & 835A (2 Runs)	13.4	10.7	39.7	-	4.6	28.8	1.4	7.6	6.8

*COD removal based on 14 runs. Values in first line calculated by applying average removals from Table 15 to average mass influent in Table 6. Other values calculated similarly.

ditions should be taken into account when evaluating the results. The 1976 data are similar in most respects to the values contained in Table 15, results of Operational Set #2 (1977). This could be expected since both are alum and polymer performance runs seeking optimum treatment. The 1977 data are considered more representative, however, since operating conditions were normalized and composite samples were utilized. The 1976 data were used as reference values since a measure of operational expertise was being acquired during that time. This report does not contain the results of operational runs conducted during the 1976 summer shrimp season because an improperly sized center flocculation-inlet chamber was in the main cell during that time, operational start-up problems were numerous, and the data were not obtained under representative conditions.

F. Sludge Treatment

As with most wastewater treatment processes, there is a solids byproduct that is left after the liquid stream has been treated. With DAF shrimp wastewater treatment, the solids which are precipitated and floated out of the water are in the form of sludge, or skimmings. The floated material contains much air due to the method by which separation occurs. A discussion of the volume and nature of the skimmings sludge may be helpful in reviewing the problems of handling and disposing of this material.

The amount and percent solids concentration of the DAF floated material was found to be a function of the treatment which was occurring: the thicker and more voluminous the sludge, the better the pollutant removals which could be expected. By theory, the only exit for any solids which enter the overall DAF treatment system is either

TABLE 23. FALL 1976 DAF TREATMENT RESULTS

		BOD_5 Tot.	BOD_5 Sol.	COD Tot.	COD Sol.	TKN	Protein	O&G	TSS
Effluent	$\bar{x}$	464	416	1980	1060	126	788	19	352
mg/l	s	84	152	1110	230	34	212	6.5	4.5
% Removal	$\bar{x}$	64	65	47	59	39	39	88	58
	s	5.4	5.9	21.7	3.1	27.6	27.6	5.9	14.0

$\bar{x}$ Mean values (17 runs)
s Standard Deviation

through the normal effluent liquid stream, or out the top as floated material. Thus, a mass balance should always be valid, but this was not the case with the project DAF system. Mass balance relationships seldom held, probably due to unexpected forces such as sedimentation and the high variability in the wastewater and sludge. It was found that a totally representative composite skimmings sample was virtually impossible to obtain. Sludge flow averaged about 10 gallons per minute and represented approximately 2% of the influent by volume. A large quantity of the skimmings volume was air, however, causing unit weights as low as 14 lbs/ft^3 in the sludge. The content and volume of the material were not totally comparable from sample to sample since the quantity of air that was in the material changed, causing an alteration in the quality and quantity of the sludge. Generally, samples were acquired as froth was scraped off the flotation unit, and all analyses were performed immediately in an effort to minimize differences in samples.

Shrimp wastewater treatment by DAF produces skimmings high in TKN and oil and grease with polymer and alum content. Table 24 shows the average of the sludge analyses during the 1977 season. Note here that the flow rate is based only on those runs which employed alum and polymer. Without any chemical addition, DAF treatment produced sludge flow rates of less than 0.5 gpm. In addition to this data, a 1976 skimmings sample showed 7% solids and a content on a dry basis of 1.47% aluminum and 58.5% protein.

It was hoped that some data on skimmings handling could be developed during this project, even though sludge treatment was not one of the basic objectives. Accordingly, methods for volume reduction and treatment of the sludge were investigated to some degree, as time and funds permitted. The method of volume reduction which received the most investigation was a pilot scale evaporator-dryer as manufactured by Contherm. The process was essentially one of heating the sludge in a vacuum to drive away water. The manufacturer describes the principle of operation, as follows:

TABLE 24. DAF SLUDGE DATA SUMMARY

% Solids	TKN (mg/g dry sludge)	PROTEIN (mg/g dry sludge)	O & G (mg/g dry sludge)	Flow (gpm)	pH
6.6	83.2	520	85.4	7	6.2

All values are averages (1977 data)

> "The product (sludge) enters the lower end of the Convap cylinder. As the feed stream is pumped through the inner cylinder, heat of vaporization is supplied by the heating media that flows in the annular space between the heat transfer wall and the outer cylinder. Heat transfer is accomplished by conduction and aided by convection currents created by the mechanical agitation of the revolving scraping blades. These blades swing out against the precision finished cylinder wall and continuously remove the thin product film. The centrifugal action of the rotor spins the heavier liquid droplets towards the inner cylinder wall. This assures a continuous rewetting of the heat transfer surface and prevents burn-on as the scraping blades literally clean the heat transfer surface. Typically operating under vacuum conditions, the vaporization occurs in the scraped surface heat exchange cylinder. The released vapor expands, increases in volume, and causes a thin film of product to move up the cylinder wall. The product (sludge) reaches the tip of the cylinder, passes through the vapor head and is channeled into a specially dimensioned and constructed baffle. The sludge then passes through the entrainment separator where the concentrate and vapor phases are separated. The concentrated stream exits at the bottom of the separator while the vapor exits at the top where it is then condensed by an appropriate shell and tube, spiral, or barometric (spray) condensor."

The sludge evaporator-dryer unit was tested by varying operational conditions of temperature, vacuum, and flow rate. The results of this experimental operation are shown in Table 25.

It was generally true that at least a 50% decrease in volume occurred, producing a viscous liquid, or very wet mud. It was still necessary to handle it as a liquid. It was noted that as much as 22.5% solid material was present on the inside of a portion of the equipment during cleaning. With experience in operating and adequate investigation time, better results may have been produced with this unit. A 75% volume reduction to one-fourth of the original sludge volume may be achievable.

In addition to the problem of skimmings volume, there is a very rapid degradation and odor production from the highly putrescible DAF shrimp sludge. If the excess-

TABLE 25. SLUDGE SOLIDS CONTENT
EVAPORATOR-DRYER TREATMENT

Run No.	Influent (% Solids)	Effluent (% Solids)	Increase (% Solids)
1	4.8	10.4	5.6
2	4.8	9.8	5.0
3	5.8	12.6	6.8
4	5.4	13.3	7.9
5	5.4	9.7	4.3
6	5.8	14.5	8.7
7	-	14.7	-
8	-	9.2	-
9	-	17.2	-

sive putrescibility could be at least partially reduced, easier handling, processing, and storage may be possible. One method of reduction was investigated, a chemical conditioning system employing chlorine as the oxidizing agent. This was a bench scale PURIFAX system, as manufactured by BIF. It relied upon a complete oxidation of all organic material which, according to the manufacturer, made the resulting material readily dewaterable on sand drying beds. The manufacturer describes the results of the chlorine application in the unit, on sewage sludges, as follows:

> "Within 10 to 30 minutes after discharge from a PURIFAX chemical oxidizer, liquid-solid separation occurs in the treated sludge. The solids float over a substantially clear subnatant; they are buoyed-up by carbon dioxide and nitrogen gas bubbles which are evolved from and attached to the organic material in the sludge. Within 1 to 2 days the gas bubbles break off the solids and they sink with a comparatively clear supernatant forming over the solids. This unique characteristic of initial flotation of the solids can be used advantageously when dewatering sludge on a sand bed. The clear liquid beneath the floating solids quickly filters through the bed, increasing the dewatering rate. When the sludge is discharged into a lagoon or thickening tank for solids consolidation and the solids subsequently sink, a clear supernatant can be decanted if baffles are used to restrain surface scum. Another important change in the treated sludge is the elimination of foul odors. Immediately after discharge from a Purifax Chemical Oxidizer, the odor of the treated sludge has been described as ranging from "fresh-medicinal" to "slightly chlorinous." Since the process stabilizes the organics so they will not subsequently putrify, no objectionable odors develop from properly treated sludge; after long term holding the odor is usually described as 'non-objectionable, medicinal'."

During the course of this project, the bench scale chemical oxidizing system shown in Figure 26 was investigated on one occasion in the laboratory. The results were similar to above description for sewage sludges.

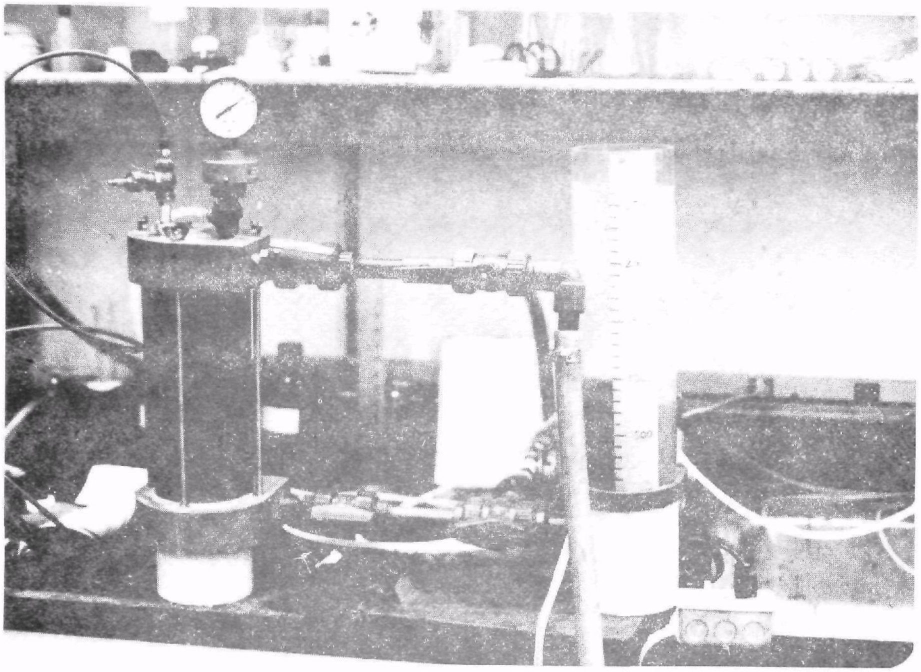


Figure 26

Chemical Oxidizer for Sludge

G. DAF Treatment-Oyster Processing Wastewaters

Operational performance runs were conducted on the DAF shrimp wastewater treatment system for four weeks during February and March, 1977, while Violet Packing Co. was processing oysters. Table 26 is a summary of the data on DAF treatment of oyster cannery wastewater. Some runs employing no chemical addition and even no air flow produced BOD_5 and TSS removals comparable to those with optimum chemical addition levels. Since a large amount of settleable solids was present in the wastewater, even after the primary grit trap, it is probable that the long detention times in the oversized treatment unit resulted in removals by sedimentation. The high settleable solids and the heavier specific gravity of these silty solids contributed to the relatively low A/S values attained in DAF system operation.

TABLE 26. DAF WASTEWATER TREATMENT EFFLUENT
OYSTER PROCESSING-1977

	BOD_5 Total	BOD_5 Soluble	COD (total)	TSS	VSS	TKN	O&G
Effluent - mg/l							
Mean	224	207	1260	230	164	50	14.3
(Std. Dev.)	(52)	(51)	(840)	(108)	(65)	(18)	(4.8)
% Removal							
Mean	43.0	23.0	58.9	88.8	80.4	58.2	56.0
(Std. Dev.)	(9.9)	(8.5)	(15.1)	(5.2)	(6.4)	(8.5)	(18.6)

Average screened wastewater flow was approximately 100 gpm.
Chemical dosage ranges: Alum, 70-240 mg/l; 835A polymer, 2-8.4 mg/l
Averages: Alum - 142 mg/l; Polymer - 4.4 mg/l

The concentration of solids in the DAF skimmings was generally higher than noted in shrimp wastewater treatment. The percent solids varied from 7.3% to 15.2%, while generally being about 12%. This could also be attributed to the high specific gravity solid materials in the oyster wastewater as opposed to the flocculent, voluminous nature of shrimp wastewater solids. Another observation in DAF treatment of oyster processing wastewaters was that pH adjustment had no apparent effect upon treatment. This was in contrast to the findings with shrimp wastewaters and the theory of protein coagulation, but was clearly observed in the performance runs of oyster processing wastewater.

Based on the results of the performance runs, Table 27 was formulated. This expresses the average pollutant load in the DAF treated discharge (alum and polymer runs only) on a pounds/1000 pounds of finished product basis. Due to the lack of complete data, most of the BOD_5 values were calculated based on the COD:BOD_5 ratio of the known data. All available data are given in Appendix C.

TABLE 27. AVERAGE DISCHARGE FROM DAF TREATMENT
OYSTER PROCESSING - 1977
(Lbs/1000 lbs Finished Product)

	BOD_5*	TSS	O & G
Mean	17.8	16.2	1.1
Range	1.2 - 88.5	6.5 - 39.2	0.6 - 2.0

* Based on actual BOD_5 values, and those calculated from COD values and the average effluent COD/BOD_5 ratios.

H. Costs

Contained in Appendix D are the analyses conducted to estimate typical costs that could be expected for a pollution abatement program at a Gulf shrimp cannery. Costs are based on actual operating data where possible, although some assumptions had to be made. In particular, the treatment and disposal of the DAF sludge is an unsolved problem. Wet hauling was used as the disposal method for cost estimating, although it is not suggested for use, nor is it known to be feasible.

Data on project equipment costs, chemical costs and power use are factual, from project records. Land values, salvage values, labor costs, maintenance and repair costs and sludge disposal costs are best estimates.

Actual cost of the project treatment system, ENR adjusted to the end of 1977, was $282,900. By estimating land value and future equipment salvage value, and assuming amortization over a 15 year period at 9% interest rate, the annual equivalent fixed costs are calculated to be $34,900. The annual variable costs include energy, chemicals, maintenance and repair, and labor. From power consumption records and an assumed power cost of 2.5 cents per KW hr, an estimated cost of $0.045 per 1000 gallons of wastewater flow gives an annual power cost of $1500. Chemical costs were calculated to be $0.257 per 1000 gallons or $8300 per year. Maintenance and repair were estimated to average about $9300 per year. An adequate labor force is based on one full time technically trained supervisor-operator, one full-time skilled assistant operator and one part time operator-helper. The annual labor cost, including fringe benefits, is estimated to be $46,200. The annual variable cost is then $63,200 and the average equivalent cost is $100,200 per year. By adjusting these costs for the average 8-peeler cannery, with an effective water use and wastewater management plan, the average cost is estimated to be $91,400 per year for the wastewater system. However, the cost of disposal of the sludge by-product from wastewater treatment must be added. Wet hauling to a processor-owned land fill by processor-owned tank truck was assumed. The average equivalent cost is estimated to be $40,100. This gives a total annual average equivalent cost of $131,500 for an 8 peeler processor. By adjusting the annual variable costs to the annual cannery production rate, the wastewater treatment cost per case of canned shrimp can be calculated. For a production rate of 300,000 cases per year, it would cost an 8-peeler cannery $0.433 per case to install and operate a DAF wastewater treatment system. If the annual production is only 200,000 cases, the cost would be $0.60 per case.

SECTION VIII

DISCUSSION

A. General

The results presented in this report address the study objectives. Gulf shrimp cannery wastewaters and oyster canning wastewaters were characterized, managed, treated and monitored in this demonstration project. Several effective pollution abatement procedures are discussed and evaluated. These include the effectiveness of water management and process control, screening, chemical treatment, and dissolved air flotation.

B. Water Use and Wastewater Management

A major objective of this investigation was to evaluate various methods of wastewater volume and pollutant load reduction. The study plant was believed to be typical of Gulf shrimp canneries, where an abundant water supply is readily available and low in cost. The tendency was to allow water use to be excessive. Control valves were generally fully open, hoses were allowed to run continuously and excess system pressures were relieved by automatic pressure relief valves or by cracking valves. At the beginning of the study, water use was established to be at the rate of 7730 gallons per 1000 lbs. of raw shrimp processed. After the water use and wastewater management plan was developed, the importance of such a system was thoroughly discussed with cannery managers and supervisors. Management accepted the recommendations, adopted the plan and set a policy for all personnel to follow. The installation of hand held, reliable, valved nozzles on hoses; the use of high pressure-low volume cleanup techniques; and other common water saving efforts brought about an overall water use reduction. In addition, plant management modified the water distribution system to include a ground storage pumping reservoir into which the two water wells now discharge. The system pressure is now maintained automatically by two service pumps and there are pressure control valves on the plant piping. Pressure is now maintained within close limits for each water using device, resulting in more constant production results and less need for adjustment, and in less water use and wastewater flow. The net result of water use control was the reduction in 1977 to 4420 gallons per 1000 lbs. of raw shrimp processed, a reduction of 43% from initial water use.

Another project objective was to consider opportunities to revise product handling procedures in order to reduce pollutant discharge. It had previously been established by others that pollutant concentration in seafood processing wastewaters is a function of the contact time. This was confirmed in the study of grader-deveiner process product fluming (Table 10). The pollutant load increase was found to be approximately 10% in this short flume. The cannery cooperation in substituting dry conveying at this point was therefore responsible for a reduction in the pollutant load in the wastewater. Other proposals for reducing product-water contact time were not possible during the project but may be feasible under other circumstances or at a later time. Re-use of process waters, re-arrangement of the processing equipment, earlier screening of wastewaters in the process and treatment schematic, and more dry conveying were considered but were not possible under the time-funding restrictions of this project. Vacuum cleaning for solids clean up and removal was also considered. It was not found to be feasible, so sweeping and other dry cleaning procedures were substituted on a continuing and prior to wash-down schedule during cannery operation. Automatic brine valves for filling cans, improvement of floor surfaces and drainage systems, pumping improvements and other cannery changes during the project also contributed to the pollutant discharge reduction.

The water use management and conservation and the other project cannery changes brought about a substantial reduction in total wastewater pollutant discharge. From 1975 to 1977, it was found that through improved techniques, substantial removals in various pollutional parameters could be brought about. Average reductions on a pounds per 1000 pounds of raw product basis were: 60% of BOD_5, 13% of TSS and 40% of O & G. The curtailment of wasteful water use and the reduction of product-water contact should be instituted by all shrimp processors at the outset of a pollution abatement program. Both in-house pollutant reduction and end of pipe treatment will be enhanced from such a program. This principle is also applicable for oyster processing, but probably not to such a dramatic extent.

C. Screening

The wastewaters from the raw shrimp processing activities also act as transport water for all portions of the shrimp body not used in canning. Screening of the wastewaters is, therefore, quite effective in pollutant removal. Project results demonstrate removals of 7% BOD_5, 45% TSS, and 17.5% O&G. These achievements are in addition to the removals obtained by water management in the present day operation at the study cannery.

Wastewater treatment by DAF requires effective screening as a pretreatment step. For example, during the 1977 shrimp canning season, the study cannery encountered screening problems. For about a one day period, an undetected hole perhaps 2" in diameter existed in one of the screens. The screening problems were discovered as a result of the pH probe continually plugging. At that time the DAF system was operating in the recycle mode and all raw flow went through the floc tank immediately after the surge tank. Several days after the screen hole was discovered, it was found that a great deal of settling had occurred in the floc tank. Approximately 3 cubic yards of settled material had accumulated in the tank and was decomposing. The tank and the entire system had to be drained and bypassed in order to remove this material manually with shovels and hoses through the bottom drain.

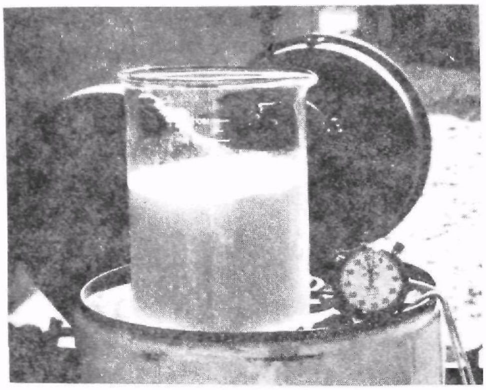
Screening can therefore be seen to be a very critical pretreatment for a dissolved air flotation system treating shrimp cannery wastewater. Even with good screening and substantial pollutant reductions there were still settleable solids which escaped the screens. These entered the DAF system, resulting in subsequent sedimentation accumulations. Screening is also recommended for oyster processing wastewaters prior to DAF treatment; however, it is not so effective or as critical as with shrimp processing. Screening installations should be as effective and as reliable as possible.

The material separated from wastewaters by screening becomes a solid waste. These wet screenings consist of shrimp heads, "whiskers", hulls, waste shrimp meat and shrimp legs. The study of this solid waste was not a part of the project. However, from project cannery data it was estimated that the wet screenings developed averaged 250 lbs. per 1000 lbs. of raw product, or about one cu. yd. per 1000 lbs. Some Gulf canneries dispose of these by hauling or by first compacting and hauling to landfills, either private or public. A few large canners (three) dry the screenings in rotary kiln dryers, pulverize and market the dry shrimp waste as a source of (35-40%) protein. Capital and operating costs for drying are high and market values are variable and undependable.

D. DAF Treatment of Shrimp Cannery Wastewater

The previous data presentations indicate that the dissolved air flotation wastewater treatment system at Violet Packing Co. was effective. The degree of attainable treatment varied with the particular conditions under which the treatment system was operated and the varying nature of the wastewater. Aside from the removals alone, there were other observations from this study which are worthy of consideration.

The Violet DAF wastewater treatment system was an extremely demanding system in terms of operator attention. The raw wastewater constantly changed and, as it did, so did its treatability. The required alum dosage varied by 400% within a 6-week period during 1977. When the correct alum dosage was being applied, it was apparent. There was distinct solid-liquid separation and it usually occurred quickly. Figure 27 shows photographs of the flotation process during an effective operation, taken on a time interval basis. The sample was siphoned out of the flotation cell flocculation chamber. At first, air, water, and floc were mixed together and there was a great deal of turbulence. When the turbulence decreased (2nd photograph) the air and floc became entrained in a complex. With time (other photos) the mixture separated into solid and liquid layers, leaving an airy sludge blanket and clear subnatant. The flotation process in the main cell occurred in a similar sequence. It should be noted that at this correct alum dosage, there was clear liquid between the solid particles. This was an indication that an effective alum dosage had been reached, and this was verified by laboratory analyses. Problems came about when the nature of the wastewater was altered by some internal or external mechanism. Often there would be no visual wastewater change, but the current alum dose would no longer produce clear subnatant. Constant monitoring, adjusting, and evaluation were necessary to produce the best quality effluent. The required alum dosage would change so that large adjustments had to be made to the chemical feed equipment in order to deliver the different rates required. Polymer was necessary for effective flotation,



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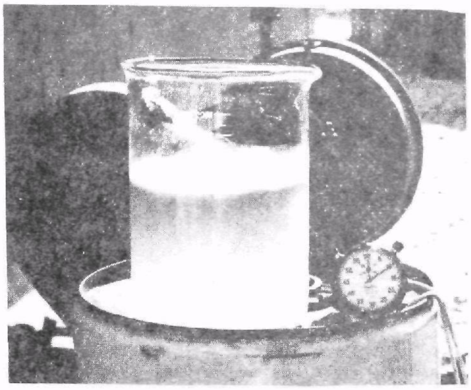

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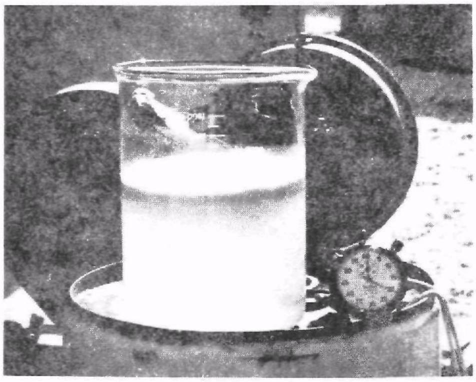

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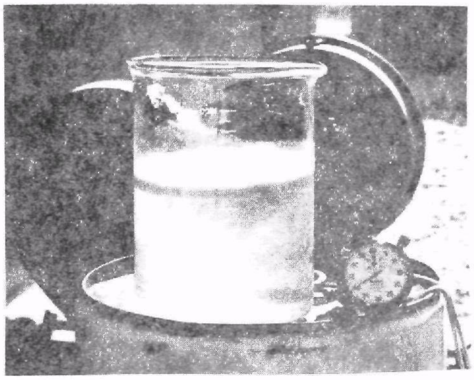

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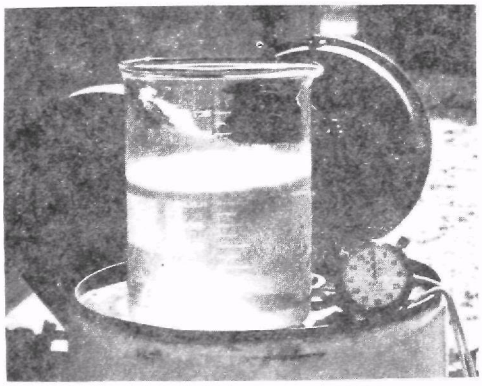

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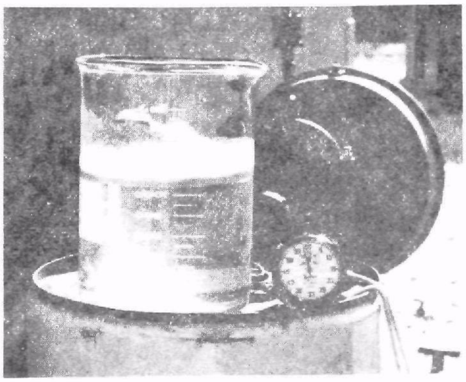


T= 2 MIN.

FIGURE 27
DAF SEPARATION PROCESS

but as long as the polymer dose was above 4 mg/l, solid-liquid separation would occur if pH and alum were at the correct levels. During the period of adjustment to an effective coagulant dosage, a discharge of poorly treated wastewater would occur. Such occurrances are not totally reflected in the operational data reported.

It was concluded in the pilot study that the point of application of chemicals was important. This project DAF system had the operational flexibility to apply chemicals in at least two places, either separately or together. Sulfuric acid for pH adjustment was added to the influent flume in order to minimize pH response time. Early acid application was recommended by the pilot study and was found to be effective in this project since acid addition at this point had the advantage of both short pH controller response time and adequate mixing as the wastewater plunged into the surge tank. The earliest possible alum addition was pointed out in the pilot study as being most effective. Alum addition was, therefore, at the meter. For evaluation, it was also added at the discharge of the screens, which provided a 10 second longer retention before entering the flotation cell, but there was no noted increase in treatment efficiency. One polymer application point was located immediately following the pressure release valve, and another was located in the bottom of the floc tank, where the wastewater entered the tank. Various trial runs were conducted with polymer in either and both places. It was observed that polymer was virtually ineffective when applied anywhere except at the pressure release valve. This would indicate that the bridging action of the polymer and the surface action of the bridging does not take effect until the turbulence of the flocculation tube is encountered. Based on these observations, it was concluded the point of alum addition was not extremely critical, and polymer application should be between the pressure release valve and the flocculation chamber.

While alum was the primary coagulant investigated, other coagulants also showed potential for effective plant scale use. Lignosulfonate (PRA-1) and cationic polymer (520C) both produced good treatment results, but they were not given as thorough an evaluation (different dosages, application points, modes, etc.) as alum. It is possible that with further investigation, each of these, and possibly other chemicals, might be found to be as effective as alum used with a coagulant aid. Economics, availability, ease of handling, long-term quality of the sludge produced, as well as wastewater treatment effectiveness, should be evaluated when selecting the most desirable coagulant.

Coagulation was influenced by other operational factors. Most alum dosages were ineffective unless the pH was at or near 5.0. Although lag time in the pH control system was minimal, the lag effects were noticed when the flow became unsteady. The cannery drainage system was arranged so that all wastewater was pumped from a central collection pit to the screens. Screened wastewater flowed by gravity to the DAF system influent meter and surge tank. The collection pump had a variable speed control installed in 1977 and could be manually adjusted to equal the plant flow in order to have steady, non-intermittent flow at the DAF unit. Prior to this, the rate of pump discharge was varied by a pulley change. Because of the time required, all needed adjustments could not be made and unsteady flow resulted. Pump speed adjustment, then, was important to maintain the steady flow conditions needed for better pH control and for better coagulation.

The design of the Violet DAF system was based on the previously conducted pilot study, which recommended solids loadings of 0.25 lbs/hr/ft^2 and A/S ratio of 0.125. However, in the design phase while balancing the cell surface loading rate and retention time with the anticipated raw wastewater concentration of suspended solids, it was concluded that the flotation cell solids loading could not be kept to the recommended level with standard manufactured units. Other literature did not indicate such low rates to be necessary. Therefore, a maximum cell solids loading rate of 0.50 lbs/hr/sq.ft. was specified. Actual operating solids loadings, based on screened wastewater concentrations of TSS prior to chemical addition, were found to range from 0.17 to 0.76 and to average about 0.40 lbs/hr/sq. ft. Higher solids loading rates would result if TSS values were determined after pH adjustment and coagulant and polymer additions. It is concluded that the pilot study recommended solids loading rate of 0.25 lbs/hr/sq. ft. was not essential for good performance.

Similarly, the pilot study conclusion with regard to an air to solids ratio (A/S) of 0.125 lbs/lb was not considered to be achievable or necessary. A minimum ratio of 0.10 lbs/lb was specified for the FFP, and 0.05 for the R and P modes. Even so, in actual operation the average A/S ratios achieved were 0.046 lbs/lbs (FFP) and 0.037 in P and R modes during shrimp processing. Values ranged from 0.019 to 0.108. During oyster processing the values ranged from 0.0085 to 0.075 and averaged 0.032 in FFP and 0.037 in P and R modes. These values are within the ranges reported by other investigators [4,5,6] and did not appear to limit system performance. Even though the A/S ratio was almost doubled on one occasion during oyster production, no significant change in treatment level was observed. From Equation (6) in Section VI, it can be shown that, if all other parameters remain constant and the saturation factor "f" can be increased from 0.5 to 0.7, then the air calculated to be released from solution nearly doubles. However, since the characteristics and temperature of the wastewater influence solubility (C_s) in Equation (6) and these cannot be readily altered, and since pressures were essentially constant throughout the system operation, it is likely that the earlier established average value of "f" did not vary significantly. Therefore, since there was not opportunity to re-evaluate the value of "f", the previously established value of "f" = 0.5 was used in calculating the A/S ratios reported in Table 28. Although the achievable air saturation and A/S ratios did not appear to limit treatment, an alternate positive source of compressed air is recommended. Problems encountered with the project ejector and rotameter air supply system were: (a) stoppages of ejectors and rotameters due to the amount and type of suspended solids in the wastewater and (b) the injected air affects the performance of the wastewater pumps. Air in the pump suction was found to reduce pumping rates and to occasionally cause surging or air binding of the pumps, and it could possibly cause cavitation damage.

It appears that the DAF system for shrimp wastewater treatment was furnished and operated in accordance within the hydraulic and solids loading rates and air supply parameters recognized and recommended in the literature. Limitations to DAF performance on shrimp wastewater treatment seem to be in obtaining optimum chemical dosages at all

TABLE 28. SUMMARY OF DESIGN AND OPERATING DATA#

PROCESS DESIGN SUMMARY*	OPERATING MODE FULL FLOW	OPERATING MODE RECYCLE & PARTIAL
Influent flow, GPM	700	700
Recycle Rate, %	--	40-50
Recycle Rate, GPM	--	350 maximum
Total Flow, GPM	700	1050 maximum
Surface loading rate, $GPM/ft.^2$	2.0 maximum	3.0 maximum
Cell solids loading, $lb/hr/ft.^2$	0.5 maximum	0.5 maximum
Cell retention time, minutes	60 maximum	30 minimum
Pressure, psig	40-60	40-60
Air supply, SCFM	1.8 minimum	0.9 minimum
Air/solids ratio, lb/lb.	0.10 minimum	0.05 minimum
OPERATING SUMMARY SHRIMP CANNING	**OPERATING MODE FULL FLOW**	**OPERATING MODE RECYCLE & PARTIAL**
Influent Flow, GPM	500	500
Recycle Rate, %	--	60
Recycle Rate, GPM	--	300
Total Flow, GPM	500	800
Surface Loading Rate, $GPM/ft.^2$	1.8	1.97
Cell solids loading, $lb/hr/ft.^2$	0.48	0.44
Cell retention time, minutes	60	45
Pressure, psig	40 ±	40 ±
Air Supply, SCFM	2.5 - 3.0	2.5 - 3.0
Air/solids ratio, lb/lb.	0.046	0.037
OPERATING SUMMARY OYSTER CANNING	**OPERATING MODE FULL FLOW**	**OPERATING MODE RECYCLE & PARTIAL**
Influent Flow, GPM	100 (200)**	100 (200)**
Recycle Rate, %	--	500 maximum
Recycle Rate, GPM	--	500 maximum
Total Flow, GPM	100 (200)**	700 maximum
Surface Loading Rate, $GPM/ft.^2$	0.5	1.75
***Cell solids loading, $lb/hr/ft.^2$	0.3	0.4
Cell retention time, minutes	150	45
Pressure, psig.	40 ±	40 ±
Air Supply, SCFM	2.5 - 3.0	2.5 - 3.0
Air/solids ratio, lb/lb.	0.032	0.037

* Based on Influent Concentration TSS = 500 mg/l

** Total Flow (100 gpm raw and 100 gpm equalization)

*** Based on Raw flow of 100 GPM at 2000 mg/l TSS, Equalization flow of 100 GPM at 250 mg/l TSS, and Recycle flow of 500 GPM at 250 mg/l TSS

\# Average values given unless indicated otherwise.

times and in properly maintaining proper physical and chemical conditions of the system.

Shrimp canning wastewater is a very rapidly biodegradable liquid. In the presence of oxygen, it will degrade aerobically; in the absence of oxygen, anaerobic conditions prevail and obnoxious odors result. It was found that as long as flow was entering the treatment system, air injection and minimum retention time resulted in a fairly fresh wastewater. However, if any of the wastewater was left in the tankage for longer than 12 hours, severe odor problems resulted. This was a critical factor with intermittent cannery operation, since a trade-off existed between clean tankage and startup time. Continuous cleaning of the wastewater treatment system was necessary during operation. Hosing all components of the system coming in contact with the wastewater was required, including drain lines, skimmings arms, surge and effluent tanks and the concrete slab. It was necessary to keep a hose running continuously into the drains to keep them flushed, and modifications were made to prevent even small accumulations in drain boxes. As much as two gallons per day of commercial bleach (sodium hypochlorite) were used to control odor. Insecticide was needed daily for fly control. The skimmings hopper required almost constant cleaning and sanitizing. When fresh wastewater did not enter the system and operation was continued in a recirculation status, foam overflowed the skimmings hopper. As the plant was idling, some of this foam collected in drain pipes. The build-up of solid material in the floc tank and flotation tank launder ring was also observed to produce odors. The launder ring had to be manually cleaned with brooms and hoses at least weekly.

In addition to the normal requirements for operation, the system as first (1976) installed was very maintenance intense. Much of this was apparently due to debugging the system, since maintenance was much less in the latter portion of the 1977 season. Throughout the 1976 shrimp season, the 1977 oyster season, and the first part of the 1977 shrimp season, the system required at least 8 man-hours every operating day for maintenance. During this time, the system would often have to be bypassed or drained and treatment would be interrupted. Some down time was caused by repairs resulting from malfunctions in the cannery equipment upstream of the wastewater system. One example was cleaning of pumps and check valves which had become clogged when plastic rings from the vibrating screens were discharged into the waste stream. DAF system problems were related to: (a) the corrosive nature of the wastewater, (b) the extended periods of downtime as a result of intermittent and varying supplies of raw products, and (c) the readily putrescible nature of wastewater which made immediate, thorough, and frequent cleanup mandatory.

The startup and shutdown of the cannery could possibly be a source of problems for effective DAF system operation. It was noted in the pilot study that during days when a short plant operation occurred (several hours), much of the operational time was spent filling the tankage before treatment could begin. This was also noted in plant scale operation. Some potential difficulties also resulted from draining the system after the cannery ceased operation. The contents of all tanks were removed; this resulted in a discharge of only partially treated wastewater and septic bottom deposits which had collected in all tanks. Also, the manufacturer recommended, and it was found to be desirable, the "blow down" of the flotation cell main drain for a short period (at least 30 seconds) each shift, resulting in a strong discharge. Although pollutants in this drainage were not included in the treatment data, the totals discharged must be considered in the operation of a treatment system and are discussed later in this section. For example, on those days when only a 4-hour processing operation occurs, the amount of partially treated wastewater dumped would equal about 28% of the total cannery flow for that day, including washdown. This chemically treated but unseparated wastewater adds to the total cannery pollutant discharge.

An alternate method of wastewater treatment system cleanup and shut down which may be advantageous has been suggested. This method would be the continued operation of the treatment system for two or three, or more, hours beyond the cannery operations and washdown by pumping clean water (well water, at Violet) through the system until all wastewater is displaced. This fresh water would be kept in the tanks until the next run. This procedure was not used during the study, but it has been theorized that it could reduce the volume of partially treated wastewater and the total pollutants discharged. While it is estimated that the pollutant discharge could be as much as 5 to 8% less than by draining the system daily (or less frequently), such a procedure would require the use of additional pumped water, power, and labor and may not be cost effective. Since no specific data are available, this alternate shut down procedure is merely suggested as a possibility and all data presented herein are based on the actual project operation.

The project results (Table 16, page 68) show that somewhat better removals were obtained in the recycle mode of operation. However, in evaluating the numerical data, other factors should be considered. Recycle and partial modes both require a special flocculation tank and a recycle tank with pump and controls. This added equipment causes additional capital and O & M costs not experienced with the full flow mode. Also, there is a longer retention time in the flocculation tank. While there are advantages to both the recycle and full flow modes and overall treatment results would probably be comparable, it has been concluded for this report that the recycle mode is to be preferred for shrimp wastewater treatment.

Evaluation of the performance of the installed DAF wastewater treatment system is based on the project data which is tabulated in Appendix C and summarized in Table 16. Comparing the screened influent and DAF effluent during 1977, the best average removals achieved in the recycle mode were:

Parameter	% Removed	Effluent (lbs/1000 lbs. raw shrimp)
BOD_5	65	15
TSS	65	8.9
O & G	84	0.8

The above listed best numerical achievements are based on several atypical operating conditions which would not exist in normal installations. Demonstration project conditions which contributed to these high removals were: (a) constantly monitored operation with technically trained project personnel, (b) a system operated at 71% of design flow rate, and (c) short duration runs maintaining near constant flows and operating conditions. Therefore, in determining the best average levels of treatment achievable in day-to-day DAF treatment of shrimp cannery wastewater, the atypical, high removal, project attainments would be reduced somewhat. Special, unattended runs were made to try to simulate average, day-to-day operations. The data from these runs were weighed with the data from the short, optimization runs. For calculation purposes, it was assumed there would be an average nine hour processing period and a one and a half hour clean-up, and the tankage would be drained and washed down at the end of the day. Calculated pollutants from blowdown and tank drainage were deducted from averaged performance values and estimated achievable levels were determined. The average levels of shrimp wastewater treatment attainable by recycle dissolved air flotation are estimated to be:

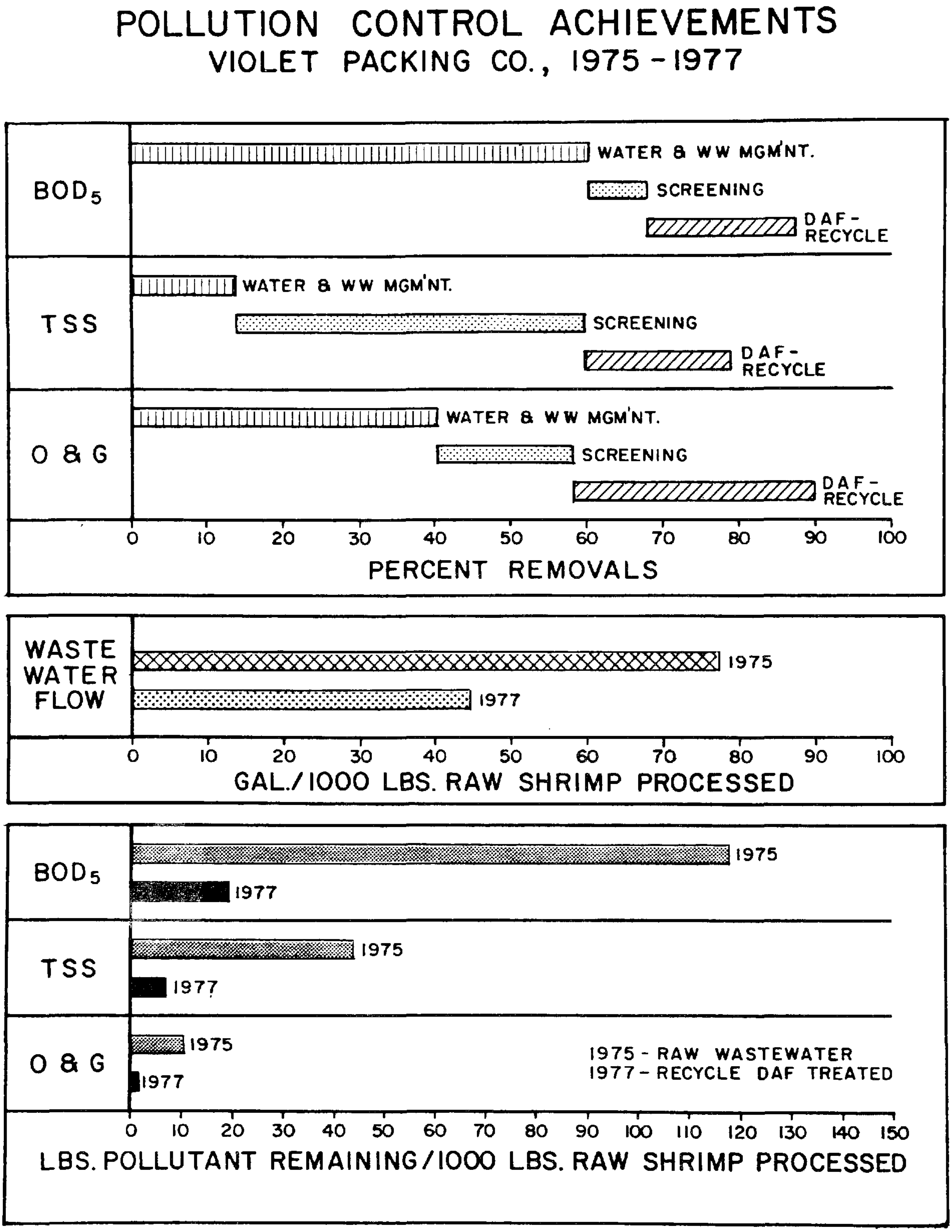
Parameter	% Removal	Average Discharge (lbs/1000 lbs raw shrimp)
BOD_5	53	20
TSS	44	10
O & G	72	1.4

Although these percentage removals may not seem to be particularly impressive, one should review the characterizations of the raw cannery wastewater to observe the overall pollution abatement achievement at Violet Packing Company. Using the 1975 unscreened wastewater composite sample characterization (Table 3, page 24), project pollutant removals by various abatement procedures are tabulated in Table 29 and are shown in Figure 28.

TABLE 29. POLLUTION ABATEMENT ACHIEVEMENTS VIOLET PACKING COMPANY 1975-1977

Abatement Measure	REMOVALS - %		
	BOD_5	TSS	O&G
Water and Wastewater Management (1)	60.1	12.9	39.8
Screening (2)	7.1	45.4	17.5
DAF-FFP	14.8	18.4	32.2
DAF-Recycle (3)	18.3	18.3	30.8
DAF-No Chemicals	1.0	28.9	4.5
Accumulative Total (Sum of 1,2, and 3)	85.5	76.7	88.1

The percent removals tabulated in Table 29 were calculated by starting



POLLUTION CONTROL ACHIEVEMENTS
VIOLET PACKING CO., 1975 - 1977
BOD5
WATER & WW MGM'NT.
SCREENING
DAF-RECYCLE
TSS
WATER & WW MGM'NT.
SCREENING
DAF-RECYCLE
O & G
WATER & WW MGM'NT.
SCREENING
DAF-RECYCLE
0 10 20 30 40 50 60 70 80 90 100
PERCENT REMOVALS
WASTE WATER FLOW
1975
1977
0 10 20 30 40 50 60 70 80 90 100
GAL./1000 LBS. RAW SHRIMP PROCESSED
BOD5
1975
1977
TSS
1975
1977
O & G
1975
1977
1975 - RAW WASTEWATER
1977 - RECYCLE DAF TREATED
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
LBS. POLLUTANT REMAINING/1000 LBS. RAW SHRIMP PROCESSED

FIGURE 28

with the analyses of the raw, unscreened wastewater in 1975. Reductions achieved by water and wastewater management were calculated by comparing the raw, unscreened wastewater in 1975 to the screened wastewater in 1977 and deducting the demonstrated removals by screening. Removals by screening are from Table 11, page 59. Percentage removals by various modes of DAF treatment were calculated by applying the project degree of treatment attained in the particular instance to the remaining percentage of the original (1975) pollutant load on which this removal comparison is based. It should be noted that these removals are based on optimized achievements, not adjusted for average operational conditions.

Using cost data from Appendix D and achievements tabulated in Table 29, an evaluation of the cost effectiveness of various project pollution abatement procedures was prepared. This analysis is given in Table 30 based on BOD removal. Table 31 is a similar comparison for removal of TSS and O & G. It can be seen that the most cost effective BOD abatement method is water management at about 1.3 cents per pound removed, followed by screening at 65 cents per pound and DAF treatment at 83 cents per pound.

TABLE 30. COST EFFECTIVENESS OF VARIOUS POLLUTION ABATEMENT MEASURES FOR BOD REMOVAL

Treatment Component	Approximate Daily Cost ***	Removal %	Approximate lbs. Removed /1000#	Approximate lbs. Removed /Day	Cost per lb. Removed
Water and Wastewater Management	$ 51.70	60.1	70.8	4130	$0.013
Screening*	$ 318.00	7.1	8.4	490	$0.65
DAF-FFP**	$1,006.00	14.8	17.4	1070	$0.94
DAF-Recycle**	$1,096.00	18.3	21.6	1320	$0.83
DAF - No Chemicals	$ 516.00	1.1	1.3	76	$7.18

* Based on estimated cost of screening and contract wet hauling of screenings to a landfill.

** Based on influent concentrations before water management began and on screen effluent in 1977.

*** Based on 8 peeler cannery operating 9 hrs/day, 130 days/year.

E. DAF Treatment of Oyster Processing Wastewater

The treatment of oyster processing wastewater was conducted using the DAF

TABLE 31. COST EFFECTIVENESS COMPARISONS FOR REMOVAL OF TSS and O&G

Treatment Component	TSS REMOVALS %	lbs/ 1000 lbs	lbs/ Day	Cost/ lb.	O&G REMOVALS %	lbs/ 1000 lbs.	lbs/ Day	Cost/ lb.
Water & Wastewater Management	12.9	5.6	327	$0.16	39.8	4.1	239	$ 0.22
Screening	45.4	19.7	1150	0.28	17.5	1.8	105	3.03
DAF-FFP	18.4	8.0	467	2.15	32.2	3.3	192	5.24
DAF-Recycle	17.4	7.6	443	2.47	30.8	3.2	187	5.86
DAF-No Chemicals	28.9	12.5	729	0.75	4.5	0.5	29	18.83

Notes: Daily costs same as in Table 30. Calculations similar.

system which was designed, sized, and installed for the treatment of shrimp cannery wastewater. Oyster processing wastewaters differed from shrimp processing wastewater in several parameters i.e., flow rate, suspended solids and COD to BOD ratios. The rate of the oyster wastewater discharge was only about 20% that of shrimp wastewater. The suspended solids level was 4 to 5 times higher than that of shrimp wastewaters and the COD: BOD_5 ratio was 3 to 10 times higher than that of shrimp wastewater.

Since the oyster raw flow rate of 100gpm was considerably smaller than the 700 gpm design flow rate for the system, detention times in each component of the system were correspondingly longer. While the wastewater volumes are dependent on the amount of raw material processed, there was a large difference between the average daily rate of wastewater flow for oyster processing and that for shrimp processing. This study found total average daily flows of approximately 70,000 gallons of oyster processing wastewater and 300,000 gallons during average shrimp processing (9 hour day).

Due to the 100 gpm average rate of the oyster wastewater flow in relation to the system pumping rates, at least 50% of the liquid wastewater which was treated was composed of clarified equalization flow. Attempts were made to keep return flow to a minimum by raising the process pump discharge pressure to decrease the rate of pumpage. Regardless, recirculation flow comprised a major portion of the treated flow. The returned flow was evidenced by the long period of time required for the pH of the effluent to stabilize when alum addition was discontinued in the influent. The lag time was longer than the nominal retention period.

Wallace and Tiernan Series 44 pumps were employed as chemical feeders in both the oyster and shrimp wastewater treatment studies. As with the remainder of the system, these pumps were sized for shrimp wastewater flows, rates much higher than those encountered in oyster canning. At extremely low rates of flow, the automatic dosage control on the pumps did not function. For this reason, all chemical pumps were operated on manual rather than automatic control during oyster operations, providing for no automatic proportioning of chemical dosage with variation in the raw influent flow. Frequent overdosing was thus probably occurring in the system although efforts were made to control the effect of this condition. Frequent checks and adjustments were made and dosage rates are reported as an average value. Similarly, composite influent and effluent samples were used, rather than grab samples, to produce results representative of the average treatment.

It can be seen from Table 29 that the treatment system operated during oyster wastewater treatment at less than design loadings. One exception was the air to solids ratio. The average A/S ratio for the oyster treatment was approximately 0.032. One particular run was carried out at an A/S level almost twice the average, however, and no significant increase in treatment efficiency was noted.

The high settleable solids content of the wastewater and the higher specific gravity of these silty muds would require a much larger dissolved air content to increase this ratio. A better solution would be to design for more effective removals of the heavier suspended (settleable) solids prior to wastewater treatment by DAF. Such pre-treatment removals would also reduce the observed DAF settled sludge problem. After five days of DAF operation it was noted that as much as one foot of settled material (mostly mud from raw oysters) had accumulated in the bottom of the flotation cell.

Skimmings during oyster processing from the DAF cell were generally more concentrated (higher solids content) than during shrimp canning. The long detention, high recirculation, and lower surface loading rates probably contributed to this but the higher specific gravity of coagulated and floated silty materials may also be a factor. Sludge volumes produced during oyster operations were also about 2% of raw wastewater. Although project data indicated significant pollutant removals while operating the oversized treatment system on a once-through sedimentation only basis, this is not concluded to be an effective treatment method. Settled sludge handling facilities would have to be provided, increasing capital costs. DAF operation without chemical addition produced results comparable to treatment with coagulants. The high recirculation rate, long detention time, continuous air saturation and natural steady pH are conducive to and may have resulted in some degree of biological treatment. Further investigation of DAF with the recirculation of a part of the float sludge may indicate whether such an operating technique would be effective.

It is to be noted that the percent soluble BOD is somewhat lower in processing wastewaters from oysters than from shrimp. Basic processing differences and the seafood itself contribute to this. Oysters are steamed and at least partially "cooked" as the whole animal before it is immersed in water, and the oyster meat is in contact with processing water for only a short time period. Much of the pollutant load in shrimp processing wastewaters comes from the long contact time of raw shrimp, shrimp peelings and raw peeled shrimp meat in the processing and transporting waters. Much of the oyster processing wastewater pollutant load is contributed in the initial plant cleaning of the raw oyster shell on the outside. It is very important, therefore, that raw oysters be received as clean as possible and that the wastewater from the initial operation be effectively settled to remove grit and silt with as short a water contact time as possible. Re-use of water in this washing process, possibly on a counter-current flow basis, may be worthy of investigation.

The same mass balance of effluent pollutants to include the draining and filling of treatment system tanks is applicable to the oyster wastewater discharge as was applied to the shrimp wastewater treatment. Since settled sludges experienced during oyster processing were greater, it would be necessary to drain or blow-off these sludges more frequently, adding to the total pollutant discharge. However, since oysters are processed at shrimp canneries during the cooler winter months and the wastewaters are not as odorous, it is probable that the DAF system could be operated continuously with recirculation for several days, perhaps five or six, without draining the tanks and adding to the total daily pollutant load discharge.

In comparing oil and grease removals of the DAF system operating on shrimp and oyster wastewater, it appears that initial concentrations are a factor. The higher the initial content, the higher the percentage removal. The lower the initial content, the lower the efficiency and the percentage removal achieved. Establishment of an average based on a concentration of 25 mg/l of O&G for treated oyster processing wastewater would therefore appear to be more practicable than using a mass limitation.

Recognizing that the project treatment system was designed for shrimp cannery wastewaters without specific consideration for oyster processing wastewater, it is believed that the limited project study did establish that a DAF system can be effective in treating oyster processing wastewater. Based on results obtained in this study, the overall wastewater treatment by grit removal and screening and DAF system treatment with effective coagulant and polymer additions may be expected to achieve removals of pollutants as shown in the following tabulation for oyster processing:

Parameter	BATEA lbs/1000 lb. finished product	ACHIEVABLE lbs/1000 lbs. finished product	ACHIEVABLE % Removal
BOD_5	17	20	55
TSS	39	20	85
O & G	0.42	1.0	60

F. Skimmings Sludge

The production of skimmings sludge in the DAF wastewater treatment system is the result of the coagulation and flotation separation of the removable solids from the screened cannery wastewater. The volume of skimmings produced amounted to about 2% of the total wastewater flow. Based on an average 9 hours processing day, the sludge volume would be about 5,400 gallons, or 28 cu. yds. A large quantity of this volume was air, so a specific weight much below that of water existed. The dry solids concentration was found to average about 5% by weight.

The skimmings consist of concentrated odor causing highly putrescible solids from the wastewater. Collecting and handling this material requires continuous attention to control odors and flies. Disposal of skimmings is probably the most serious problem to be solved in installing and operating a DAF system to treat shrimp processing wastewater, or for that matter, any seafood wastewater. Only limited skimmings sludge handling considerations were included as a part of this project work plan. An effort was made to seek a practicable method of handling the solids, but there was no attempt to find the satisfactory solution of the ultimate disposal problem. Known sludge handling techniques reviewed were:

Gravity Thickening *	Flotation
Centrifugation *	Chemical Conditioning *
Freezing	Vacuum Filtration
Filter Pressurization	Drying beds*
Lagooning	Land Application*
Composting	Incineration
Flash Drying *	Fludized bed oxidation
Aerobic Digestion	Anaerobic Digestion
Ocean Dumpings *	Elutriation
Pressure Filtration	Heat Drying *
Vibration	Wet Oxidation
Dumping *	Landfilling *

Those marked by asterisk (*) above were given more consideration in this study. Ocean dumping, for example, may be feasible from some shrimp processors which have docks and frequent arrivals and departures of boats. Even then, chemical conditioning would probably be required prior to storage for such shipment. The necessity of a dumping permit must also be considered. In both the pilot study and in this plant scale investigation, it was shown that gravity dewatering does not appear to be a practical solution for volume reduction due to the method by which separation occurs. In gravity settling of the shrimp DAF sludge, there are essentially three distinct layers: a layer of solids on the top, then a layer of liquid, and then a layer of solids on the bottom. The separation is not uniform from sample to sample, and thus prediction of this separation is difficult. It was found that this separation occurred more rapidly if the sludge was heated slightly, but separation was still in an unorderly 3-layer sequence and offered little practical potential for establishing an effective system under project conditions.

Centrifugation of the DAF skimmings was evaluated for both a perforate and solid bowl basket centrifuge. Neither showed promise. Bench scale testing showed that the sludge had properties which might make it treatable by a high speed centrifuge or a decanter type-conveyor bowl centrifuge. During the pilot study, some intermittent success was observed with centrifuging the skimmings in a bench scale test.

In terms of the effect of the evaporation dryer unit, the results were encouraging. Principal investigators of this DAF project had the task of operation and evaluation of the scraped surface evaporator dryer, since no trained operator was available. The unit seemed relatively operation intense and complicated, and most data was obtained on a trial and error basis. By these methods, an increase of 100% solids content was obtained. With more expertise in operation, it is believed that better results could be attained and reduction to one fourth the starting volume is probably achievable.

The chemical oxidation system tested on a bench scale was shown to be capable of producing a stable sludge. While this system was not a volume reduction measure, it rendered the material adaptable to storage and handling as a liquid and, probably, to subsequent dewatering since the physical nature of the material was altered. Even with these measures the same volume must be dealt with, although it would then be in a better condition. The chemical oxidizing system shows promise in that respect.

Concern in recent years over the existence of chlorinated organics has prompted previous investigation into the creation of compounds such as chlorinated phenols, chlorinated hydrocarbons, PCB's, etc. A report [13] to BIF indicated the results of testing performed on sludges treated by the chemical oxidizing process. The report concludes: "Based on the analyses of five samples of raw and treated sludge from five plants treating sludges of widely differing character, we find no significant evidence to indicate that the amounts of chlorinated phenols, chlorinated hydrocarbons, or PCB's were increased by the Purifax system of treatment. Rather, the evidence was quite convincing that marked destruction of such compounds does occur during treatment. Further, there was no evidence to indicate that new chloro compounds were formed." It should be noted however that the sludges investigated were primarily biological in nature (waste activated sludge, primary sludge, septic tank sludge, and anaerobic digestor supernatant), and thus may not contain the large amounts of long-chain hydrocarbon materials in a physical-chemical system employing organic polymers.

To a limited extent fine screens were tested to determine whether solids in the skimmings could be effectively separated from the liquid-air phases, but results were in no way encouraging. It is believed that the nature of the skimmings is such that screening is not practical as a dewatering measure.

Gravity belt and pressure belt dewatering systems were explored via manufacturers literature and conversations with factory representatives. These devices may hold promise for properly conditioned sludge (chemically oxidized or coagulated), but the sizes now offered are much larger than required to handle the sludge generated. These units are presently operated primarily on industrial wastes, activated sludges, and municipal primary sludges.

Gulf shrimp canneries are now separating hulls, heads and other solids by screening the wastewater. These solids must be disposed of. Present practice is either (a) hauling to a landfill with or without prior compaction, or (b) kiln drying and marketing as an inexpensive protein source. Volumes of screenings produced are somewhat comparable to wet sludge volumes to be expected. Land disposal or kiln drying of skimmings sludge should, therefore, be considered.

It was hoped that there would be an opportunity to kiln dry DAF skimmings with the screenings, or separately, at the project cannery. This was not accomplished, however.

Land application of sludge may be a possibility. Such a method is complicated on the Gulf Coast by the high average annual rainfall and the problems of land application under such conditions. Also, land in the immediate area of the Gulf canneries is just not available for such purposes. Some canneries are located in highly developed rural marginal wet lands along bayous, bays or estuaries; some are in urban communities; and all are essentially land starved. Large tracts of land for lagooning or spreading sludges (and hulls) and subsequently plowing into the soil could only be obtained at some distance, perhaps 25 to 50 miles. Even then, the odor and insect problems may be insurmountable.

Land filling is current practice for hull (screenings) disposal and, therefore, this may be a possibility for disposing of sludge. Some now haul to public sites and some to private operations. Canners are finding that present arrangements for land disposal are very difficult to maintain. None have long term arrangements, and most feel that their present procedures are temporary at best. This method of disposal has been used for developing cost data given in Appendix D. However, this is done to give relative cost comparisons and is not intended to suggest that this is the preferred option.

Skimmings, and screenings, must be handled and disposed of in an effective way. The problem is complicated by the putrescible, odorous, wet nature of the material, its large volume, its present low value (if any) as a by-product, the unavailability of suitable disposal sites and the ever rising costs of handling. It is important that satisfactory methods of volume reduction and conditioning be developed.

Based on current information, landfilling is the only available alternative for disposal of the sludge. However, the most feasible method of ultimate disposal into the environment has not been determined. If there is no change in the current regulations for the removal of conventional pollutants from shrimp cannery wastewater prior to discharge into marine waters, further study will be urgently needed to develop practicable methods to solve the tremendous problem of sludge treatment and disposal.

G. Conclusions

The findings of this study lead to certain conclusions on pollution abatement procedures for a shrimp and oyster processor. While certain achievements have been reached at the study site, it is to be recognized that each processing installation, whether existing or new, will have certain inherent conditions which may make it impracticable or impossible to exactly duplicate the project results. For instance, reduction in cleanup effort and thus in water use and pollutant discharge which resulted from canning room floor reconstruction and drainage system improvements at the project cannery would not be possible or be necessary at a plant which already has these improvements.

The study did show that substantial pollution abatement would be accomplished by more effective water use and wastewater management. Such techniques are well established and are comparatively less costly than other abatement measures. The cost effectiveness of this source reduction pollution control measure is compared in Tables 30-31 to wastewater treatment costs, including screening and a DAF system.

The variability of the raw product, both shrimp and oysters, and the resulting variations in processing wastewater characteristics were confirmed during this study. It is necessary during processing to vary the water supply to the peelers, for example, as the raw shrimp vary due to species, size, age or other characteristics. Also, water flow to other processing units varied from time to time. Such variations have an adverse effect on the wastewater. The variability of the wastewater produced is demonstrated by the reported wide ranges of values and deviations from mean values. Non-uniform, unsteady flow causes wastewater treatment to be less effective in most instances. Operation and control of treatment facilities for shrimp and oyster wastewaters, therefore, is more difficult and may be expected to require more constant attention and knowledgeable, trained operators. In addition to the sensitivity of chemical dosages, the sophisticated control equipment and instrumentation will require careful maintenance. Another condition which necessitates constant attention, particularly during shrimp processing, is the highly putrescible and odorous nature of the wastewater and the solids produced.

The DAF method of wastewater treatment can be expected to remove significant quantities of conventional pollutants from screened shrimp and oyster processing wastewaters. The recycle mode of operation was found to give better BOD_5 removals and to be more cost effective. Changes in design of future treatment facilities from the project system should include the following considerations:

(1) Provide sloped, hopper bottoms in all vessels for ease of cleaning and draining, and provide bottom sweeps where practicable,
(2) Pre-screening efficiency and reliability should be maximized,
(3) Provide an alternate, positive source of compressed air in order to assure an adequate, reliable dissolved air supply,
(4) Provide a more flexible flocculation system with adequate mixing capabilities and hydraulic controls for the varying rates of flow and

chemical requirements to be expected in order to adequately mix and to prevent sedimentation, and

(5) For systems which will also treat oyster processing wastewater, effective settleable solids removal by grit and/or settling pre-treatment should be included and the system design should take into account the different flow rates between shrimp and oyster wastewaters.

Effective operation of a DAF system will reduce the pollutants in the discharged wastewaters. Cost of the reductions are estimated and should be evaluated to determine whether the reductions are truly economically achievable. Of several abatement procedures discussed, the cost per pound of BOD_5 removed is greatest in the DAF system, partly due to the cost of handling the sludge produced in the DAF wastewater treatment process.

Sludge handling, storage and disposal is a new problem created as a result of the DAF system installation. Because of the volume and putrescible nature of the sludge, this problem needs to be solved if DAF systems are to be installed and operated at shrimp processing plants.

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APPENDIX A

LABORATORY PROCEDURES

A consistent effort was made throughout this project to conduct all laboratory methods according to accepted procedures. The 14th Edition of Standard Methods 12 was followed in all cases with the exceptions which are noted in this section.

All samples were stored on ice while being composited at the treatment site. Upon transportation to the laboratory, BOD_5 and pH were immediately performed, with subsequent acidification with concentrated H_2SO_4 and storage at approximately 4°C. Neutralization was affected prior to running most analyses. Acidification was conducted on a portion of each sample since Suspended, Volatile and Settleable solids were very dependent on the pH in relation to the precipitation point of the soluble material.

The following are modifications to the Standard Methods procedures for performing each test and/or additional notes.

BIOCHEMICAL OXYGEN DEMAND

Sample measurement for dilution with nutrient water were as specified in Standard Methods; all samples were diluted, and then this diluted amount was measured as sample. No samples were neutralized prior to dilution, since the concentration of sample in a given BOD bottle seldom exceeded 0.5%, and thus a pH as low as 5.0 would have no effect. Samples were not blended prior to BOD testing, because it was experimentally found that generally only 5% increase in BOD_5 was noted with blending.

Initially in the 1977 shrimp season, 5 dilutions were used for all samples since the range of expected values was quite broad. At all other times during the study, a minimum of 2, but almost always 3 dilutions were used for all samples.

Soluble BOD was determined in a manner similar to total BOD except that filtrate through a 0.45 micron glass fiber filter was used as sample.

No seeding of dilution water was performed due to the high biodegradability of the wastewater, and the fact that there was no conditions in either the shrimp or oyster processing and canning operations which would have eliminated any microbial growth. During the 1975 season, a seeded dilution water for raw wastewater was used and no significant variations were noted.

When PRA was used as a coagulant in the system, all effluent samples employed dilution water seeded with 2 ml/gallon of an acclimated culture. This culture consisted of aerated wastewater that was fed settled influent (approx. 200 ml/day) and PRA (approx. 3 ml/day). A portion of the culture approximately equal to the volume of feed added was wasted each day. The seed material was obtained after allowing the mixture to settle. It was experimentally found that PRA had a COD of 0.74 mg/mg of PRA (S.G. equaled approximately 1.2). It was also found that the material exerted a BOD_5 of 0.038 mg/mg PRA. This represents COD and BOD_5 values of 888,000 mg/l and 45,600 mg/l, respectively. In order to adequately define the chemical, a BOD curve was performed as shown in Figure A-1. As can be seen, the BOD_{ult} is being approached in 12 days, which would indicate a relatively high "K" rate. The PRA acclimated culture was used as a seeded material for this analysis, and the proper seed correction was applied to all values.

CHEMICAL OXYGEN DEMAND

As recommended by Standard Methods, COD determinations were performed employing Silver Sulfate as a catalyst and 0.4g Mercuric Sulfate as a chemical agent to complex chlorides. It was experimentally found during the project that this amount of $HgSO_4$ was sufficient. In an effort to allow more analyses, a 1 1/2 hour reflux time was used, which was shown to give 90% of the COD yield produced by a 2-hour reflux period. Soluble COD was performed on filtrate of a 0.45 micron filtered wastewater sample.

CHLORIDES

Chlorides were determined according to Standard Methods, Method 408A (1975 - 15th Edition). This is the Argentometric Method that relies upon the formation of silver chloride for depletion of the chloride, and the formation of silver chromate for endpoint detection.

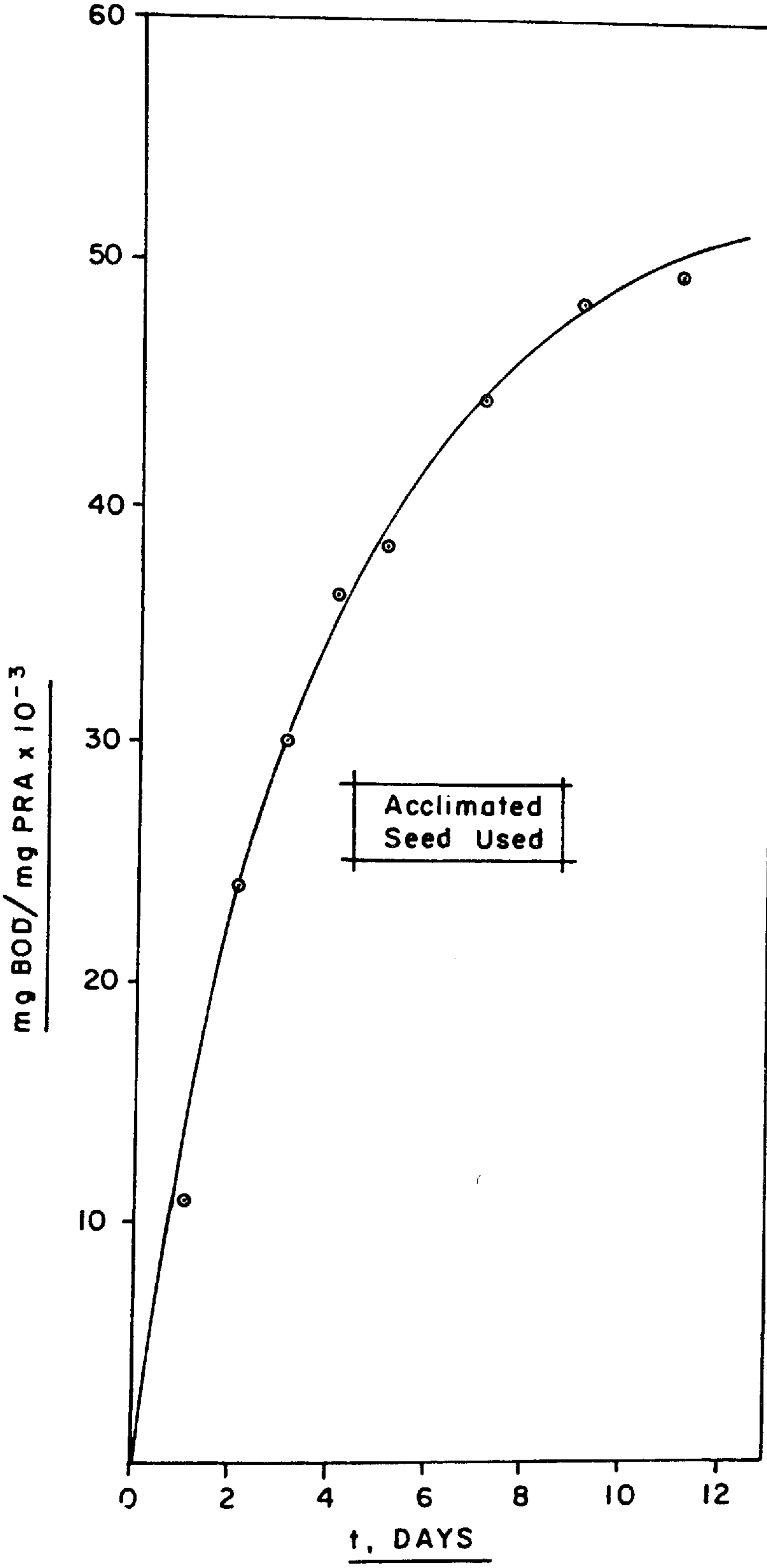
TURBIDITY

No turbidity apparatus was available during the course of this project, so a spectrophotometer was used to simulate one. For this reason, all turbidity values in this report should be viewed as reference numbers, and not as absolute values. The optimum wavelength was determined each time turbidity was run, by searching for the wavelength exhibiting maximum sensitivity. Turbidity standards were prepared and used according to Standard Methods 214A , which gives turbidity values in NTU. By reading % Transmittance, a linear response was observed.

OIL AND GREASE

The Soxhlet Extraction Method (502C) was followed for the determination of Oil and Grease. Prior to mid-May 1975 (Fall shrimp season 1974), Petroleum ether was used for the solvent, as called for in the 11th edition of Standard Methods. After that time, Freon was used as the solvent as is specified in the 14th Edition of Standard Methods. The primary difference in the two solvents is that Petroleum ether is described as leaving less than 0.1 mg residue per 100 ml, upon evaporation while Freon is said to leave no

FIGURE A-1
*PRA BOD CURVE



*PRA-I (Lignosulfonate) As Manufactured By American Can Co.

t	y
1	11×10^{-3}
2	24×10^{-3}
3	30×10^{-3}
4	36×10^{-3}
5	38×10^{-3}
7	44×10^{-3}
9	48×10^{-3}
11	49×10^{-3}
13	60×10^{-3}

measurable residue upon evaporation. This is an unnoticeable difference, so no detectable difference in oil and grease values should be produced from the use of these different solvents. Method 502D of Standard Methods (14th Edition) was used for the determination of oil and grease in all sludge samples.

% Solids (Sludge Samples)

The solids content of the DAF sludge was determined in a manner similar to the determination of % moisture in soil samples. The % solids was determined on a weight basis, rather than on a weight per volume basis, to minimize the variability produced by the quanity of air present, and the fact that the specific gravity of the sludge was much less than 1.0. Wet weight, dry weight, and tare measurements yielded a percent solids which was based on dry weight divided by wet weight multiplied by 100. Note that the percentage was based on the weight of the liquid-solid complex rather than on the weight of either liquid or of solid.

Jar Testing Procedures

Jar tests conducted during the early portions of this study employed rapid mix and slow mix speeds of 100 rpm and 20 rpm, respectively. The rapid mix period lasted 3 minutes, while the flocculation period lasted 20 minutes. pH adjustment was conducted prior to beginning the jar testing procedure, and prior to any other chemical addition. Polymer was added approximately 10 seconds before the end of the rapid mix period for even distribution. All analyses were performed on a sample siphoned from 1" below the water surface of each sample after 15 minutes of settling. Care was taken to obtain only clarified liquid.

During the 1977 season, jar testing was conducted on a more informal basis to allow more testing, primarily as an operational aid. Mixing times and speeds were similar for this jar testing, except a shorter flocculation period was used. Also, settling time was an uncontrolled parameter, since only visual observations were noted. A Phipps & Bird gang stirrer employing up to 1 liter samples was used for all jar testing.

APPENDIX B

WATER AND WASTEWATER MANAGEMENT AT A SHRIMP CANNERY

The use of water and the discharge of wastewater, like any other industrial operation, can become excessive and costly unless properly controlled. Water is a raw product which has a real cost. Wastewaters can be even more costly, requiring treatment and monitoring prior to discharge into a waterway, or into a public sewer with its user charges and other costs. Also, water and wastewaters are resources which should be conserved. Conservation and control requires good management. Management must follow a plan.

This is a proposed, preliminary plan for water conservation and water and waterwater management at a shrimp processing cannery. It is expected that further refinements, additions and/or deletions can be made as the management plan is implemented and the individual canner experience is available.

Water use purposes have been categorized into:

(a) Domestic sanitary (drinking, handwashing, water closets, etc.)
(b) Cooling (non-contact)
(c) Finished product (incorporated into cans)
(d) Washdown (cleaning and sanitizing equipment, etc.)
(e) Conveying (water fluming)
(f) Processing Operations (Raw product washing, peelers, agitators, or cleaners, graders, deveiners, product blanching and cooling)
(g) Miscellaneous (boiler feed, other)

In a shrimp plant the larger demands are for processing operations, washdown and conveying. Emphasis on water management should therefore be directed to these uses, although all water demands must be considered. Each category of use is discussed below:

A. Domestic Sanitary Uses

Water used for domestic, sanitary purposes must be from a portable water system. A convenient method of monitoring this water usage is needed. An easily accessible meter is recommended. Daily consumption and use rates should be determined, monitored and recorded. Variations in flow should be noted for investigating leaking plumbing, piping or other abnormal uses.

B. Cooling Water (Non-Contact)

In a shrimp cannery, this water is used to cool cans after retorting. Such water normally does not contain pollutants and does not constitute a thermal pollutant. It may generally be discharged without treatment. Conservation of this re-useable resource may be accomplished by recirculating through an atmospheric cooling tower with only evaporation make-up and sufficient displacement to control solids concentration. An alternative conservation measure is to re-use the once-through cooling water in some other plant process on a counterflow principal, such as in the peelers, agitators (cleaners), graders or in the recieving tank. A storage tank and pressure pump system will facilitate re-use potential.

C. Finished Product Water

Some water is incorporated into the finished canned product from a shrimp cannery. This is potable water with salt and citric acid added. The added chemicals make this a costly material which should not be wasted. Proper control of chemical additions and control of the can filling water to prevent spillage or waste should receive proper attention.

D. Washdown Water

Adequate water use for washdown and cleaning purposes is essential for general good housekeeping and cleanliness and for sanitation. Cleaning by washing or flushing with large quantities of water is a first impulse. Refined techniques of "washdowns" by "dry" solids removal (sweeping, or vacuum), chemical or detergent cleaning and high pressure - low volume rinsing can appreciably reduce water use if an optimum program is planned and properly managed. Washdown water use requires much effort for good conservation and control.

E. Conveying Water

Historically, seafood and other food processord have used water to transport or convey product through the plant. Not only does such use increase the water consumption but it adds to the wastewater pollutant strength, as well. The total weight of shrimp protein dissolved into water during processing will increase with the time of contact. Therefore, conveying by other than water flumes will reduce water use and wastewater volumes and will result in a reduction in the pounds of product dissolved in the wastewater. Alternate methods of conveying include belt or screen conveyors, vibrating conveyors, screw conveyors, bucket conveyers, and vacuum systems. Possible substitution of waterless conveying systems should be considered in all plant re-arrangement, repairs, improvements, etc. This is an important management function.

F. Processing Operations

Water is an essential ingredient in the present shrimp picking, cleaning and processing techniques. However, optimization and control can be improved with experimental and developmental effort and continued monitoring and supervision. Processors should call on equipment suppliers to expend the necessary developmental effort. Alert supervision will be needed to implement optimization on a continuing basis.

G. Miscellaneous Water Uses

Water is used for boiler feed to generate steam for retorting the canned product and for heating water for blanching and other heated water uses. This use should be optimized to conserve energy as well as water. Consideration of heating water for blanching and other uses by other than steam may be indicated.

Other types of water use should be monitored for elimination or reduction, or for optimization of use rates. Water use consciousness must be a prime consideration of management and operating personnel.

The following is an outline for a management program which is recommended to each cannery for consideration and implementation:

A Proposed Water-Wastewater Management For A Shrimp Cannery

I. Objectives

The objectives of the water and wastewater management program are to:

1. Acquaint shrimp plant personnel with water and wastewater terminology,

2. Relate shrimp product or by-product losses to wastewater characteristics and the environment,

3. Relate shrimp and by-product waste to financial losses at a shrimp plant,

4. Relate available data on other plants and compare to the specific cannery, and

5. Develop and initiate action program to reduce water and waste within the plant.

II. The Educational Program

The water and waste management education program for shrimp processing plant personnel follows:

a. Management Phase: Describe federal, state and local regulatory involvement; discuss waste terminology, research, and survey findings; relate cost and product losses; discuss wastewater and the cost of waste treatment; and describe the duties of supervisors in the water and waste management program .

b. Supervisors Phase: Instruct supervisors in respect to recent research findings, plan activities that need to be carried out in the employee phase of the program and other details of a water and waste management program.

c. Employee Phase: This program should illustrage good and bad wastewater practices, explain good water and waste management, relate product losses to cost and familiarize the employees with waste terminology and current techniques in controlling water and waste in a shrimp processing plant. The activation and involvement of the employees is critical for they will often suggest needed solutions within their areas of responsibility in the overall attack on the plant water-waste program. Special efforts should be made during these sessions to relate the effects of a shrimp processing wastes on "Our Environment."

d. Follow up phase - A tour and evaluation session conducted with management and the supervisors will help determine progress made within the plant after an initial time period of effort. This should be repeated periodically.

III. Duties of Supervisors in Water-Wastewater Management

Since a supervisor is management's representative with regard to the water-waste program, the responsibilities of each supervisor are:

1. Each supervisor should be completely aware of the need for and the planned activities in the water and waste program. He should have an attitude of personal interest and involvement in each phase of the program and should report suggestions for improvement directly to the plant Manager. He shall see that the established procedures are followed and shall see that required equipment is available.

2. Using the results of sponsored studies, the major water using and waste contributing areas in the plant should be attacked. Nozzels should be installed on all hoses. Level controllers might be used to control overflow of tanks without positive controls. Leaking water or product valves should be replaced. The machine maintenance program should be checked to see that it is sufficient to prevent product and/or water losses.

3. Simultaneously, a water and waste savings educational program should be instituted. Employees should be informed and involved in the program or it will not work. The supervisors must be responsible for the program, but it is the operating personnel who will assure that the program will be a success.

4. Management should remember the program must be emphasized or it will die. Mention of the program must be frequent. The supervisors must follow the operations assuring that proper water and waste procedures are followed each operating day.

IV. Specific Recommendations

The supervisors should be familiar with the process and equipment changes evaluated and proven technically and economically feasible. Successful implementation of these and other needed changes are a part of a broad program of water and waste management. An adequate program for control of water and waste must including the following:

1. Continual records that will assure knowledge of changes in the operating procedures of the plant. This should include water use, wastewater characteristics, and production.

2. The supervisory personnel must see that competent, designated personnel maintain all operating flow records and wastewater information. This includes determining the effectiveness of the day's cleanup. This should be reviewed with the responsible foreman. Any divergencies from good practices should be corrected.

3. Employee awareness of the cost of poor water and waste management should be maintained. Employees should be encouraged to be careful with water use and product or by-product wasteful practices. They should also be encouraged to suggest possible conservation/re-use measures.

4. Eliminate the cause of spillage, rather than just wash it away after it has occurred. Scoop up or vacuum up foam overflow.

5. Water hoses should be turned off when not in use. Do not use a constantly running water hose in any room. Hoses equipped with automatic shut-off valves should be utilized to avoid excessive usage.

6. Adequate weir, flume or meter and sampling equipment should be provided at the discharge of the shrimp processing plant for monitoring wastewater strength and volume.

7. Pipes for steam, well water, city water, and wastewater should be properly identified by color or other suitable marking.

V. Sanitation and the Water-Wastewater Program

A. Large water savings during washdown and clean-up are possible if an adequate sanitation program is developed and adhered to. An adequate sanitation program is one in which conscientious combined efforts are made by both management and employees to maintain the plant in a clean and wholesome atmosphere. However, no sanitation program should place undue burden on the plant personnel or management. A well-planned sanitation program should become an integral part of the operation. Thus will management and employee enjoy an efficient and smooth operating daily schedule. Sanitation is not necessarily expensive, but the lack of it may prove very costly.

Personnel training and education are integral parts of a sanitation program. Education of the employee is best accomplished by on-the-job training which permits the learning of a practical and sound sanitation program through experience. Training includes not only instruction on how to clean equipment properly, but must also include why it should be done. An employee must understand why it is important. He should never get the impression that all management wants is to get the job done in any manner.

If sanitation is to become a reality, it is necessary that management and employees work as a team. Because the shrimp processor deals primarily with a highly perishable raw product which can easily become contaminated, it is obvious that training and sanitation will secure beneficial results for both the industry and consumer.

B. General Sanitation and Good Housekeeping

In general, sanitation involves a four-step process. When these four steps are taken, in the proper order, a consistent, safe sanitation program will result. Attempts to shortcut one or two of these steps can result in serious shortcomings in any sanitation program. These steps include:

(1) Pre-rinsing
(2) Washing
(3) Post-rinsing
(4) Sanitizing

1. Step #1 - Pre-rinsing

The pre-rinsing or preparation of equipment fcr actual washing is the one area which is often overlooked in a good sanitation program. This step eliminates the majority of the soil before the detergent solutions are used. It is recommended that methods other than the high volume water hose be used to remove large scraps from the production area prior to washing. The following steps are to be taken in pre-rinsing of equipment for clean-ups:

a. Immediately after production, remove all products from the processing area into approved storage area.

b. Remove all scraps by using appropriate methods:
   (1) Shovel large piles of scraps into disposal area.
   (2) Sweep or squeegee remaining scraps into disposal area.

c. Disassemble or open all equipment with such provisions for cleaning.

d. Disconnect or protect any electrical devices so that water may be used safely.

e. Rinse all equipment with warm water to remove remaining scraps.

NOTE: High pressure, low volume rinsing techniques are especially useful in this step.

2. Step #2 - Washing

In any sanitation program the results obtained are based directly upon the degree with which the detergent fulfills the requirements of removing the soil encountered and the method of application. Only after the proper detergent has been selected, can the true value of a sanitation program be realized. These detergents are selected for the type of soil conditions found, and the degree of soil and construction of equipment being cleaned.

There are many methods of application of detergent to soiled equipment. The various methods of application of detergent solution to equipment are designed to provide correct combination of time, temperature, concentration and mechanical force. These four factors, along with the proper detergent, are the key to a clean piece of equipment.

The particular method of application used in any plant is dependent upon the plant design, equipment design and construction, general availability for clean-up. Following are two of the various methods of application which are available and should provide an effective sanitation program.

Hand Cleaning

A concentrated cleaning solution is prepared in a plastic pail using a concentration of approximately 1 ounce of cleaner to each gallon of hot water. Water temperature here should be at least 145°F.

The equipment to be cleaned is thoroughly scrubbed, using a properly designed brush working directly from the pail. This method may be abandoned in favor of others listed below.

Spray Cleaning

The use of a high pressure, low volume spray cleaning system, provides an added benefit in the area of mechanical force. When using high pressure, low volume cleaning systems, all surfaces are sprayed from a distance of approximately two feet. The purpose here is to thoroughly coat all of the surface to allow the chemicals to react with the soils. After a brief period, the equipment is thoroughly rinsed using the high pressure wand at a distance of 6 inches with hot water 140°F to remove the loosened soil and rinse the detergent solution from the equipment. Central high pressure, low volume cleaning systems can be designed with manifolds for the cleaning of conveyor systems such as inspection line belts.

3. Step #3 - Post-rinsing

After the detergent solutions have been applied and the equipment thoroughly cleaned, a fresh water rinse, as in spray cleaning above, is used to remove the loosened soils and detergent residues. In this step a thorough inspection of the results of the cleaning should be made. Where equipment is not thoroughly cleaned, appropriate measures are taken to correct the situation. After equipment has been thoroughly rinsed, it is drained and allowed to air dry.

4. Step #4 - Sanitize

There are several methods of sanitizing equipment. Flushing the surface of the equipment with hot 180°F water for approximately five minutes will effectively kill microorganisms. Steam may also be used. However, total contact with live steam is difficult because many people mistake water vapor for live steam. There are several dangers involved when hot water or steam is employed for sanitizing.

a. The obvious possibility of burns incurred from hot water or steam.

b. Equipment must be heated to 180°F for five minutes for effective kill. This requires large volumes of hot water or steam for just spraying of the hot water or steam on a cold surface will not effectively kill microorganisms.

Chemical sanitizers, such as chlorine, iodine and quaternary ammonium chloride compounds, have the advantage of being economical to use when one considers the cost of heating water. They are harmless to the equipment when used properly. They are easy to apply and very effective in killing microorganisms.

C. Implementation of an effective sanitation program, utilizing the above principles, will bring benefits to plant maintenance and operation and should reduce wastewater volumes. The ingenuity and imagination of management can investigate, adopt, adapt and operate the type of sanitation program needed in the cannery.

APPENDIX C

PROJECT DATA

SHRIMP CANNERY WASTEWATER TREATMENT

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION - Receiving Tank

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
12/4/75	3,980	2,460	7,390	4,930	968	772	6.7			2,140	810		6	7,390	6050
5/28/75	6,950		6,930			1,020	7.0	11,200	5,180	2,030	1,280	7.5	6		
6/10/75	3,780		7,600			482	6.9	7,360	2,750	1,410	1,020	14	7	15,400	
6/27/75			6,900		657	503	7.0	8,200	3,060	1,810	1,330	46	6	14,800	4110
11/27/74						820	7.3	11,400	6,070	1,420	1,070	20			
12/3/74	3,680		7,420			218	7.2	12,000	5,750	2,080	1,160	18			
12/12/74	3,010		6,560			660	6.6	9,100	3,910	1,530	1,140	40			
7/11/77			6,500		560	719	7.6			1,280	1,120				3500
Mean	4,280	2,460	7,040	4,930	728	650	7.0	9,870	4,450	1,710	1,120	24	6		4550
St. Dev.	1,540		434		213	246	0.3	1,900	1,410	341	159	15	0.5		1330
No. of ob	5	1	7	1	3	8	8	6	6	8	8	6	4		3

All values in mg/l unless noted otherwise.
All Protein values are calculated, 6.25 X TKN.

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION - All Peelers

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
11/13/75			3,450		430	146	7.1			790	670		22	92,800	2690
5/28/75	2,990		4,180			171	7.2	8,250	2,280	1,050	780	175	25		
6/10/75	3,130		6,160			113	7.1	10,500	2,620	1,280	900	135	20	239,000	
6/18/75	1,690		2,580			176	6.9	7,820	1,970	1,010	860	80	20	156,000	
6/27/75			5,080		610	271	7.2	8,520	2,410	930	660	110	20	350,000	2810
11/27/74						147	6.7	8,350	2,500	1,120	840	40			
12/3/74		1,660	5,250			208	7.4	8,600	2,790	1,040	815				
7/11/77	1,690	1,660	3,420		298	254	7.8			480	430				1860
Mean	2,380	1,660	4,300		446	257	7.2	8,670	2,420	963	744	108	21		2790
St. Dev.	793		1,250		157	148	0.3	920	300	241	153	52	2		981
No. of ob	4	2	7		3	11	8	6	6	8	8	5	5		3

All values in mg/l unless noted otherwise.

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION - Peeler #1

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
5/28/75	2,910		7,680			298	7.2	11,400	4,210	2,090	1,270	200	25		
6/18/75	1,730		3,190			218	6.9	7,940	1,860	1,210	994	75	21		
Mean	2,320		5,430			258	7.1	9,660	3,030	1,650	1,130	138	23		
No. of ob	2		2			2	2	2	2	2	2	2	2		

All values in mg/l unless noted otherwise.

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION - Peeler - Start of Flume

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
12/10/75		530		512	109	23							24		681
12/4/75		235		507	98	14							24		613
Mean		383		510	104	19							24		650
No. of ob		2		2	2	2							2		2
LOCATION - Peeler - End of Flume															
12/10/75		615		672	129	24							24		806
12/4/75		305		436	137	16							24		856
Mean		460		554	133	20							24		831
No. of ob		2		2	2	2							2		2

All values in mg/l unless noted otherwise.

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION - Agitators

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
11/10/75	375		725		129	35	7.4			214	178		22		806
6/10/75	1,770		9,460			36	7.3	7,310	1,830	732	628	1.2	21		
6/18/75			1,440			5	7.2	8,890	8,380	498	422	8	22		
7/2/75			1,980		142	40	7.0	5,970	572	390	314	1.3	26		888
Mean	1,070		3,400		136	29	7.2	7,390	3,590	459	386	3.5	23		850
St. Dev.			4,070			16	0.1	1,460	4,190	217	190	3.9	2		
No. of ob	2		4		2	4	3	3	3	4	4	3	4		2

All values in mg/l unless noted otherwise.

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION - Separators

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
11/10/75	660		1,220		195	59	7.3			478	402		23		1220
6/10/75	1,250	1,560				30	7.2	6,300	1,030	296	246	25	21	44,600	
6/18/75		760				23	7.1	6,300	958	352	282	15	21	32,300	
6/27/75		2,600			292	37	7.1	6,200	776	320	238	14	21	61,300	1820
11/27/74						41	7.5	6,910	1,170	376	362	14			
12/3/74	693		825			28	7.4	6,230	850	216	202	15			
7/11/77	994	720	2,630		241	17	7.9			768	722				1510
Mean	899	1,410	1,560		243	34	7.4	6,410	957	401	351	17	22		1520
St. Dev.	278	883	951		49	14	0.3	288	155	180	178	5	1		306
No. of ob	4	4	3		3	7	7	5	5	7	7	5	4		3

All values in mg/l unless noted otherwise.

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION - Graders

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
11/10/75	174		314		72	13	7.3			114	83		22	5,600	450
6/18/75			1,480			4.4	7.2	5,700	3,880	264	170	1.2	22	7,500	
7/2/75			1,520		110	15	6.8	5,480	202	138	124	10	26		688
7/11/77	615	574	1,240		132	14	7.9			245	221				825
Mean	935	574	1,140		105	12	7.3	5,590	2,040	190	151	6	23		656
St. Dev.			564		30	5	0.5			75	58		2		188
No. of ob	2	1	4		3	4	4	2	2	4	4	2	3		3
LOCATION - Grader - Start of Flume															
12/10/75		1,050		840	104	27							25		650
12/4/75		375		810	157	7							26		981
Mean		713		825	131	17							26		819
No. of ob		2		2	2	2							2		2
LOCATION - Grader - End of Flume															
12/10/75		1,130		1,120	100	30							25		625
12/4/75		385		915	134	8							26		838
Mean		755		1,020	117	19							26		731
No. of ob		2		2	2	2							2		2

All values in mg/l unless noted otherwise.

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION - Deveiner - Start of Flume

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
12/10/75		336		544	29	15							25	90,000	181
12/ 4/75		90		328	21	1.0							26		131
6/18/75			1,220			6	7.2	5,580	1,020	180	126	7.5	23	83,100	
6/27/75			1,640		177	34	7.3	6,530	1,010	306	236	6.5	21	154,000	1110
11/27/74						22	7.8	6,010	830	258	258	7			
12/3/74	240		834			2.8	7.6	5,620	386	130	128	8			
7/11/77	492	356	1,130		130	15	7.8			180	168				813
Mean	366	261	1,200	436	89	14	7.5	5,940	810	211	183	7.3	24		556
St. Dev.		148	333		77	12	0.3	444	295	70	61	0.6	2		481
No. of ob	2	3	4	2	4	7	5	4	4	5	5	4	4		4
LOCATION - Deveiner - End of Flume															
12/10/75		396		672	14	12							25		88
12/4/75		135		264	32	0.2							26		200
Mean		266		468	23	6.1							26		144
No. of ob		2		2	2	2							2		2

All values in mg/l unless noted otherwise.

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION - Blanch Tank

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
11/13/75			11,000		1,690	14	4.5			6,730	4,650		98		10,600
6/12/75	9,780		23,600			6	6.0	113,000	110,000	6,300	3,920		98		
7/2/75			14,700		1,310	7	5.9	81,500	7,740	7,250	2,600		97		8,210
11/27/74						18	5.3	111,000	19,300	4,200	4,160				
12/3/74			12,800			60	5.5	96,800	16,000	3,640	3,640				
12/12/74	13,900		28,300			26	6.6	103,000		8,740	5,040				
Mean	11,800		18,100		1,500	22	5.6	101,000	38,400	6,140	4,000		98		9,390
St. Dev.			7,490			20	0.7	12,700	48,300	1,920	852		0.6		
No. of ob	2		5		2	6	6	5	4	6	6		3		2

All values in mg/l unless noted otherwise.

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION - Blanch Cooling Tank

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
11/13/75			78		47	5	6.5			58	34		30		294
6/12/75	1,170		1,480			5	7.1			508	348	0	45		
7/2/75			1,370		49	1	7.2	7,520	52	64	22	0.5	32		306
11/27/74						18	5.9	9,010	438	78	78	0.1			
12/3/74	204		768			9	7.4	10,100	736	120	120	1.7			
12/12/74	181		217			19	6.9	7,970		82	40	0.1			
Mean	518		783		48	10	6.8	8,650	409	152	107	0.5	36		300
St. Dev.	564		642			7	0.6	1,150	343	176	123	0.7	8		
No. of ob	3		5		2	6	6	4	3	6	6	5	3		2

All values in mg/l unless noted otherwise.

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION - Canning Room Discharge

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
6/4/75	1,170		1,710			7	6.5	26,700	910	378	266	1.2	36		
6/10/75	904		1,330			11	7.2	17,200	866	226	100	1.1	21		
6/27/75			4,760		294	19	6.9	18,900	876	792	448	1.1	30		1,840
12/3/74	635		857			32	7.1	16,300	936	186	176	0.2			
11/27/74						10	7.4	9,400	496	150	150	0.2			
12/12/74	416		752			20	7.7	14,100		240	158	0.1			
Mean	781		1,880		294	17	7.1	17,100	817	329	216	0.7	29		1,840
St. Dev.	327		1,650			9	0.4	5,750	181	240	126	0.5	8		
No. of ob	4		5		1	6	6	6	5	6	6	6	3		1

All values in mg/l unless noted otherwise.

INDIVIDUAL PROCESS CHARACTERIZATION
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

LOCATION Retort Cooling Water

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
11/10/75	5		24		5	1.0	9.2			14	0		41		31
6/4/75							9.3	274	12	14		0	42		
6/10/75	8		30			2	9.3	370	122	24	10	0	45		
6/27/75			2			12	9.2	340	112	6		0	42		
11/27/74						6.6	10.2	2,600	220	32	32	0			
12/3/74	16		6.4			6.6	10.2	2,130	72	12	12	0			
12/12/74	20		32			4.3	7.9			20	20	0			
Mean	12		19		5	5	9	1,140	108	17	15	0	43		31
St. Dev.	7		14			4	0.8	1,130	76	9	12	0	1		
No. of ob	4		5		1	6	7	5	5	7	5	6	4		1

All values in mg/l unless noted otherwise

CHARACTERIZATIONS OF SCREENED WASTEWATER
GULF SHRIMP CANNERY

Violet Packing Co.

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
FALL 1974															
Dec. 12	1,440		2,580			124		7,160		456	370	5			
SUMMER 1975															
May 21	1,570		2,400				7.3	9,300	1,120	318	242	4			
May 26	2,170		3,080			34	6.9	10,800	1,430	120	48	10			1270
May 28	1,740		2,050			140	6.9	10,500	1,000	518	404	12			
June 4	1,880		2,890			223	6.9	10,900	1,250	490	374	5.5			
June 5			1,900			127	7.4	8,280	1,920	640	525	4			
June 10	1,900		2,580			247	7.3	8,890		340	270	5			
June 18	1,270		2,050			62	7.5	9,720	1,050	518	394	9			
June 27			2,120		236	264	7.4	6,460	2,060	646	535	8			1480
July 10	950	683	2,360		203	107	7.5	9,200	810	476	370	11			1270
SUMMER 1976															
June 1	2,040	1,468	6,160	3,280		124				918				554,000	
June 24	1,680		3,360			44				228				229,000	
June 24	1,460		2,720			126				310					
June 30	1,720		3,120			29				308				647,000	
June 30	1,920		2,960			90				200					
July 2	1,440		2,800			82				232				545,000	
July 3			3,360							562				356,000	
July 6			3,840							360				251,000	

All values in mg/l unless noted otherwise.

CHARACTERIZATIONS OF SCREENED WASTEWATER
GULF SHRIMP CANNERY

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
July 7	1,320		2,640			190				254					
July 12			3,600							352					
July 19			3,200			26				454					
July 21			2,800							292					
FALL 1976															
Oct. 11	2,240									208					
Oct. 21	1,350	1,150	3,800	2,800	342	196				322					2140
Oct. 22			2,280							264					
Oct. 22			4,340							298					
Oct. 25			2,840												
Oct. 27			3,720							264					
Oct. 28	1,160	1,020	4,400	3,150		150				356					
Oct. 28	1,330	1,160	4,000	2,880		178				410					
Oct. 30			3,160							212					
Nov. 3	1,530	1,240	3,600	3,060		151				256					
Nov. 5	1,010	810	2,740	2,190	227	75				189					1420
Nov. 8				4,460											
Nov. 9	995 *	750*	3,230	2,500						340					
Nov. 10	1,130	932		2,580						350					
Nov. 11				2,350						408					
Nov. 17	1,230	1,090	4,500	2,740						321					
*Nov. 17	378	251	2,500	1,180						490					
Nov. 23	1,460	1,250	3,060	1,800	216	107				240					1350
Nov. 29	1,010	825	2,380	2,110	224	138				260					1400
*Nov. 29	262	150	392		28	125				268					175

* Not included in Totals or Averages.
All values in mg/l unless noted otherwise.

CHARACTERIZATIONS OF SCREENED WASTEWATER
GULF SHRIMP CANNERY

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
1976 Continued															
*Nov. 30	825	675	2,450	2,020	197	138				262					1230
*Nov. 30	825	675	712	472		30									
*Nov. 30	150	150	1,020	1,100	78					98					488
Nov. 30	300*	150		632	90					135					563
Dec. 1	937	600	2,770	2,060	235	134				552					1470
Dec. 1	1,240	900	4,110	1,900	265	136				556					1660
*Dec. 1	300	187	1,900	864		64				268					
*Dec. 1	562	262				42				456					
*Dec. 2	1,200	1,030	3,480			84				376					
*Dec. 2	945	798	2,930							316					
SPRING 1977 (Oysters)															
Feb. 8			1,560							4,500		49			
Feb. 10			662							902		9.0		82,000	
Feb. 17	743	585	3,900							1,830		13		78,000	
March 2			1,320		59	21				704	320	40		109,000	369
March 3	377	240	2,580		77					3,510	1,080	42		53,000	481
March 7			4,080		150	121	7.0			2,960	1,080			48,000	938
March 9			4,780		128	26	7.8			2,810	996	40		40,000	800
March 10	405	293	2,120		89	3.0	7.9			1,670	556	19		37,000	556

*Not Included in Totals or Averages

All values in mg/l unless noted otherwise.

CHARACTERIZATIONS OF SCREENED WASTEWATER
GULF SHRIMP CANNERY

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
1976 Continued															
March 11			3,920		159	16				1,610	726	24		132,000	994
SUMMER 1977															
May 17	1,370	1,100	3,360		241	150	8.1			758	592	20			1510
May 18	1,500	1,100	3,080	1,920	283	156				600	540	20			1770
May 19	1,260	750	3,150		297	151	7.7			860		15			1860
May 20	531		2,470	1,080	213	88	8.0			492	452				1330
May 21	733		2,320	1,240	238	82	8.1			648	608				1490
May 22	997	628	2,470	1,830	283	94	7.9			552	470	14			1770
May 23	885	645	2,550	1,470	258	91	7.9			408	332	9			1610
May 24	912	602	2,390	1,470	207	119				508	460	17			1290
May 26	1,390	734	2,950	1,860	274	109	7.9			516	436	13		554,000	1710
May 27	783	615	3,450	2,040	272	130	7.9			432	340	25		702,000	1700
May 28	450	328	2,120	1,490	224		8.2			356	316			645,000	1400
May 30	1,190	750	3,250	1,920	277	138	7.1			544	508	30		678,000	730
May 31	1,120	750	2,840	1,540	283	128	7.8			580	544	12		840,000	1770
June 1	1,060	453	2,460	1,490	283	109				996	892	130		663,000	1770
June 2	1,280	980			314	162				388	352	15		618,000	1960
June 3	978	778	2,630		221	148				312	274	11		683,000	1380
June 4	992	742	2,240		239	162				318	280			623,000	1490
June 6	863	619	2,180		246	98				340	298	12		574,000	1540
June 7	1,400	921	3,050		321	162				436	364	15		434,000	2010
June 13	885	672	2,240	1,510	224	131				368	328	11		600,000	1400
June 14	1,580	1,120	3,920	2,960	344	116	7.5			896	764	14		700,000	2150

All values in mg/l unless noted otherwise.

CHARACTERIZATIONS OF SCREENED WASTEWATER
GULF SHRIMP CANNERY

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
1977 Continued															
June 16	1,290	971	3,440	2,840	316	129	7.4			240	188	4.5		600,000	1980
June 17	1,070	732	2,880	2,200	272	98	7.4			292	260	15		554,000	1700
June 18	1,150	764	3,280	1,800	286	106	7.6			300	272	12		584,000	1790
June 20	1,060	667	3,360	2,600	297	147	7.4			344	328	11		649,000	1860
June 21	971	516	2,920	2,040	253	168	7.5			450	412			440,000	1580
June 22	1,620	932	3,360	2,320	325	74	7.5			408	346	12		401,000	2030
June 24	963	623	2,640	1,920	252	97	7.5			272	240	5.5		942,000	1580
June 25	933	619	2,360	1,760	218	92	6.9			272	268	6.5		328,000	1360
June 27	1,340	823	2,670	1,880	280	124	7.2			420	388	7.0		452,000	1750
June 28	1,180	416	3,250	1,180	210	122	6.9			1,020	808	12			1310
Aug.17	630	265	1,390	1,030											
Aug.18	642	408	1,590	1,270	167	28	7.4	8,280		430	380			226,000	1040
Aug.19	972	550	2,260	1,550	228	73	7.4	7,970		566	496	9.0			1420
Aug.22	945	710	2,460	1,350	156	79	7.6	7,110		590	496	7.8			975
FALL 1977															
Oct. 26	883	460	2,560	1,760	236	67	6.8	8,600		428	324	31			1480
Oct. 27	1,230	585	3,380	2,560	298	67	6.4	10,200		920	760				1860
Oct. 28	1,380	1,050	3,140	2,560	298	86	7.2	9,700		332	288	11			1860
Oct. 31	1,400	965	3,650	2,330	335	120	6.8	10,300		908	792	58			2090
Nov. 1	1,450	1,070	3,780	2,520	304	80	7.2	13,300		540	504				1900
Nov. 2	930	689	2,600	2,170	253	59	6.7	10,900		412	384	26			1580

Additional Data - Summer 1977

	Conductivity (µmhos)	Chlorides (mg/l)	Turbidity (NTU)	BOD_{20} (mg/l)
Aug. 18		4,000	385	937
Aug. 19	7,400	3,650	360	1,480
Aug. 22	6,200	3,250	330	

All values in mg/l unless noted otherwise.

GULF SHRIMP CANNERY
TREATMENT RESULTS BY SCREENING

Violet Packing Co.

Date		BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids (ml/l)	Temp. °C	Flow/day (Gal.)	Protein
12/10/75	I												45			
	E	2,100	1,190	2,920	2,280	292	168	7.0			414	76	7.5	23		1830
12/4/75	I												30			
	E	1,300	706	1,620	1,160	193	73	7.2			254	60	6.0	22		1210
11/10/75	I												30			
	E												3.5			
11/13/75	I												24			
	E												8			
11/4/75	I												20			
	E												7.5			
11/15/75	I												22			
	E												9			
12/5/75	I												27			
	E												5.5			
12/11/75	I												33			
	E												8.5			
5/21/75	I										348	286	23			
	E										294	258	5.5			
5/28/75	I	1,900									594	448	32			
	E	1,600									308	205	7			
6/4/75	I	1,750									704	522	40			
	E	1,730									430	340	6			
6/18/75	I										802	544	30			
	E							7.3	10,500	5,130	302	212	10	22		
6/27/75	I			2,920		460	160	7.2	9,420	1,380	916	670	33	23		2880
	E			2,200		299	154	7.2	9,300	1,100	568	412	10	23		1870
I Mean		1,830		2,920		460	160	7.2	9,420	1,380	673	494	30	23		2880
St. Dev.											217	141	7			
No. of ob		2		1		1	1	1	1	1	5	5	13	1		1

GULF SHRIMP CANNERY
TREATMENT RESULTS BY SCREENING

Date	BOD_5	BOD_5 Sol.	COD	COD Sol.	TKN	O & G	pH Units	TS	TVS	TSS	TVSS	Sett. Solids	Temp. °C	Flow/day (Gal.)	Protein
E Mean	1,700	948	2,250	1,720	261	132	7.2	9,890	3,110	367	223	7	23		1630
St. Dev.	328		652		59	51	0.1			110	129	2	1		369
No.of ob	4	2	3	2	3	3	3	2	2	7	7	13	4		3

All values in mg/l unless noted otherwise.

DAF TREATMENT RESULTS - 1976 SHRIMP SEASON
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

Run No. & Date	Mode	Alum (mg/l)	Polymer (mg/l)	pH	BOD_5 Tot	BOD_5 Sol	COD Tot.	COD Sol	TKN	Oil & Grease	TSS	Protein
#C Oct.11	F	258	2.2	5.2			2,240 1,280 43%				208 266	
#1 Oct. 21	F	0	0	7.3	1,350 1,360	1,140 1,320	3,800 2,120 44%	2,800 960 66%	342 347	196 184 6%	322 166 48%	2140 2170
#1 Oct. 22	F	0	0	5.5			2,280				264 412	
#2 Oct. 22	F	0	0	5.0			4,340 2,830 35%				298 356	
#3 Oct. 22	F	0	0	4.5			4,340 4,140 5%				298 1,130	
#1 Oct. 25	F	75	2.2	4.5			2,840 840 70%	705			96	
#1 Oct. 27	R	78	3.0	4.5			3,720 2,890 22%	338			264 474	
#1 Oct. 28	R	187	3.1	4.8	1,160 367 68%	1,020 327 68%	4,400 66%	3,150 1,320 58%		150 17 89%	356 210 41%	
#2 Oct. 28	R	223	3.1	4.8	1,330 403 70%	1,160 345 70%	4,000 66%	2,880 1,240 57%		178 10 95%	410 84 80%	
#1 Oct. 30	R	217	6.6	5.0			3,160 1,320 58%				212 218	
#2 Nov. 3	F	198	5.2	4.8	1,530 470 69%	1,240 466 62%	3,600 1,408 61%	3,060 1,330 57%		151 21 86%	256 122 52%	
#3 Nov. 3	R	198	5.2	4.8	1,530 510 67%	1,240 439 64%	3,600 1,570 56%	3,060 1,060 65%		151	256 101 61%	

Coagulant - aluminum sulfate, unless otherwise noted.
Coagulant Acid - polymer 835 A, unless otherwise noted.
*Values shown are Influent/Effluent and Removal Percent (%).
Influent and Effluent values are in mg/l unless noted otherwise.

DAF TREATMENT RESULTS - 1976 SHRIMP SEASON

SHRIMP CANNERY WASTEWATER

Violet Packing Co.

Run No. & Date	Mode	Alum (mg/l)	Polymer (mg/l)	pH	BOD_5 Tot	BOD_5 Sol	COD Tot.	COD Sol	TKN	Oil & Grease	TSS	Protein
#1 Nov. 5	F	0	0	4.5	1,010 569	813 382 53%	2,740 2,030 26%	2,190 1,290 41%	227 151 33%	75 99	189 536 --	1420 944 33%
#1 Nov. 8	F	75	0	4.5			4,460 3,640 18%				-- 1,360 --	
#2 Nov. 8	F	100	0	4.5			4,460 3,920 12%	1,360				
#3 Nov. 8	F	150^{V}	0	4.5			4,460 3,680 18%				-- 1,010 --	
#4 Nov. 8	F	200^{V}	0	4.5			4,460 3,140 30%				-- 1,040 --	
#5 Nov. 8	F	75^{V}	0	4.5	1,080 375 65%	952 320 66%	4,460 3,170 29%				-- 612 --	
#1 Nov. 9	F	200	4.1	4.5	995 432 57%	750 347 54%	3,230 936 71%	2,500 -- --			340 216 36%	
#3 Nov. 10	F	300	7.0	4.5	1,130 567 59%	932 282 70%		2,580 1,020 61%			350 118 66%	
#1 Nov. 11	F	150	4.0	4.5				2,350 1,210 48%			408 490 --	
#C Nov. 17	F	92	2.3	4.5	1,230 478 61%	1,090 392 64%	4,500 1,800 60%	2,740 1,130 59%			321 133 59%	
#5 VV Nov. 17	F	92	2.3	4.5	378 666 --	251 521 --	2,500 2,350 6%	1,180 1,960 --			490 324 34%	

V Alum added @ Screen Discharge.

VV Problems: pH or washdown intrusion, etc.

Influent and Effluent values are in mg/l unless noted otherwise.

DAF TREATMENT RESULTS - 1976 SHRIMP SEASON

SHRIMP CANNERY WASTEWATER

Violet Packing Co.
Page 3 of 4

Run No. & Date	Mode	Alum (mg/l)	Polymer (mg/l)	pH	BOD_5 Tot	BOD_5 Sol	COD Tot.	COD Sol	TKN	Oil & Grease	TSS	Protein
#1 Nov. 23	F	95	2.1	4.5	1,460 655 55%	1,250 560 55%	3,060 1,250 59%	1,800 784 56%	216 176 19%	107 23 79%	240 112 53%	1350 1100 19%
#1 Nov. 29	F	118	2.6	4.5	1,010 187 82%	825 75 91%	2,380 504 79%	2,110 1,330 37%	224 75 67%	138 38 72%	260 174 33%	1400 469 67%
#2 VV Nov. 29	F	199	4.4	4.5	262 300 --	150 262 --	392 624 --	-- 192 --	28 97 --	125 20 83%	268 142 47%	175 606 --
#1 VV Nov. 30	F	142	2.7	4.5	825 112 86%	675 75 89%	2,450 544 78%	2,020 432 79%	197 26 87%	138 34 75%	262 82 69%	1230 87 87%
#2 VV Nov. 30	F	142	2.7	4.5	825 150 82%	675 150 78%	712 552 22%	472 712 --	-- 70 --	30 24 20%	-- 164 --	-- 438 --
#3 Nov. 30	F	142	2.7	4.5	825 187 73%	675 150 78%	712 864 --		-- 160 --		-- 172	-- 1000 --
#4 Nov.30	F	142	2.7	4.5	150 262 --	150 225 --	1,020 1,420 --	1,100 1,260	78 26 67%		98 124 --	488 163 67%
#5 VV Nov. 30	F	199	3.8	4.5	300 150 50%	150 37 75%	-- 1,260 --	632 864 --	90 28 69%		135 64 53%	563 173 69%
#1 VV Dec. 1	F	113^V	2.3	4.5	937 450 52%	600 337 44%	2,770 1,100 60%	2,060 1,020 50%	235 128 46%	134 43 68%	552 328 41%	1470 800 46%
#2 Dec. 1	F	113^V	2.3	4.5	1,240 412 67%	900 262 71%	4,110 1,500 63%	1,900 712 62%	265 112 58%	136 14 90%	556 162 71%	1660 700 58%

[V] Alum added @ Screen Discharge.
[VV] Problems: pH or washdown intrusion, etc.
Influent and Effluent values are in mg/l unless noted otherwise.

DAF TREATMENT RESULTS - 1976 SHRIMP SEASON

SHRIMP CANNERY WASTEWATER

Violet Packing Co.

Run No. & Date	Mode	Alum (mg/l)	Polymer (mg/l)	pH	BOD_5 Tot	BOD_5 Sol	COD Tot.	COD Sol	TKN	Oil & Grease	TSS	Protein
#3 Dec. 1	F	113[V]	2.3	4.5	-- 487 --	-- 375 --	-- 1,100 --	-- 792	-- 112	-- 18	-- 134 --	-- 700 --
#4 Dec. 1	F	113[V]	2.3	4.5	-- 412 --	-- 450 --	-- 1,100 --	-- 944 --	-- 104 --	-- 30 --	-- 162 --	-- 650 --
#5 Dec. 1	F	190[V]	3.8	4.5	300 487 --	187 525 --	1,900 1,020 46%	864 712 17%		64 13 80%	268 148 45%	
#6 VV Dec. 1	F	532[V]	10.6	4.5	562 375 33%	262 375 --				42 11 74%	456 110 76%	
#1 VV Dec. 2		86[V]	1.7	5.2	1,200 416 65%	1,030 367 64%	3,480 864 75%			84 18 79%	376 130 65%	
#2 VV Dec. 2		86[V]	1.7	5.2	945 416 56%	798 382 52%	2,930 1,420 51%				316 178 44%	

[V] Alum added @ Screen Discharge

[VV] Problems: pH or washdown intrusion, etc.

Influent and Effluent values are in mg/l unless noted otherwise.

DAF TREATMENT RESULTS - 1977 SHRIMP SEASON
SHRIMP CANNERY WASTEWATER

Run No. & Date	Mode	Alum (mg/l)	Polymer (mg/l)	pH Units	BOD_5 Tot		BOD_5 Sol		COD Tot		COD Sol		TKN		Oil & Grease		TSS		VSS		Settleable Soilds (ml/l)	
#100 May 17	F	none	none	N	1,360* 1,420*	--	1,110 1,370	--	3,360 3,900	--			241* 297*	--	150 149	0.7%	758 149	80%	592 112	81%	20 0.0	100%
#101 May 17	F	none	none	N	1,360 1,260	7%			3,360 3,010	10%			241 278	--	150 123	18%	758 358	53%	592 308	48%	20 0.0	100%
#102 May 18	F	none	none	N	1,500 1,550	--	1,100		3,080* 4,110	--	1,920		283* 297	--	156 178	--	600 178	70%	540 122	77%	20 0.1	99%
#103 May 19	F	none	none	N	1,260 1,060	16%	750 900	--	3,150 2,010	4%			297 297	0%	151 94	38%	860 176	80%			15	
#104 May 20	F	none	none	5	531 552	--			2,470 2,130	14%	1,080		213 199	7%	88 68	23%	492* 496*	--	452			
#105 May 21	F	none	none	3.8	733 367	50%			2,320 1,780	23%	1,240 695	44%	238 165	31%	82 58	29%	648 688	--	608 576	5%		
#106 May 22	F	none	none	4.4	997 564	43%	628		2,470 2,080	16%	1,830 926	49%	283 218	23%	94 62	34%	552 596	--	470 540	--	14 6	57%
#107 May 23	F	none	none	5	885 682	23%	645 547	15%	2,500 2,010	21%	1,470		258 224	13%	91 85	7%	408 508	--	332 448	--	9 7	22%
#108 May 23	F	100	none	5	885 699	21%	645		2,550 2,550	0%	1,470		258 216	16%	91 85	7%	408 784	--	332 576	--	9 30	--
#109 May 24	F	100	none	5	912 566	38%	602		2,390 1,930	19%	1,470		207 185	11%	119 74	38%	508 488	4%	460 384	17%	17 24	--

*Values shown are Influent/Effluent and Removal Percent (%)
Influent and Effluent values are in mg/l unless noted otherwise.

Coagulant - aluminum sulfate, unless otherwise noted.
Coagulant Acid - polymer 835 A, unless otherwise noted.

DAF TREATMENT RESULTS - 1977 SHRIMP SEASON
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

Run No. & Date	Mode	Alum (mg/l)	Polymer (mg/l)	pH Units	BOD_5 Tot		BOD_5 Sol		COD Tot		COD Sol		TKN		Oil & Grease		TSS		VSS		Settleable Soilds (ml/l)	
#110 May 24	F	140	none	5	912 712	22%	602 512	15%	2,390 2,470	--	1,470 1,240	16%	207 213	--	119 76	36%	508 632	--	460 564	--	17 2.6	85%
#111 May 26	F	150	2.5	5	1,390		734*		2,950 1,710	42%	1,860 1,400	25%	274 168	39%	109 12	89%	516 248	52%	436 112	74%	13 0.4	97%
#112 May 27	F	130	2.5	5	783 522	33%	615 497	19%	3,450 1,650	52%	2,040 1,180	42%	272 176	35%	130 24	82%	432 208	52%	340 36	89%	25 0.4	98%
#113 May 27	F	130	1.4	5	783 613	22%	615 545	11%	3,450 1,730	50%	2,040 1,410	31%	272 168	38%	130 13	90%	432 348	19%	340 204	40%	25 0.3	99%
#114 May 28	--	--	--	--	450		328		2,120		1,490		224				356		316			
#115 May 30	--	--	--	--	1,190		750		3,250		1,920		227		138		544		508		30	
#116 May 31	F	175	4.0	5	1,120 756	33%	750 652	13%	2,840 1,690	40%	1,540 1,380	10%	283 193	32%	128 30	77%	580 148	74%	544 124	77%	12 0.5	96%
#401 June 1	F	250	4.2	5	1,060 550	48%	453 395	13%	2,460 998	59%	1,490 768	48%	283 144	49%	109* 18*	83%	996 82	92%	892 35	96%	130 0.1	99%
#402 June 2	F	260	4.2	5	1,280 430	67%	980 390	60%	-- 1,130		--		314 126	60%	162* 13	92%	388 88	77%	352 66	77%	15 0.3	98%
#403 June 3	P	279	5.2	5	978 545	44%	778 438	44%	2,630 1,460	45%			221 146	34%	148* 22	85%	312 134	57%	274 120	56%	11 7	36%
#404 June 4	P	280	7.6	5	992 422	57%	742 372	50%	2,240 1,170	48%			239 146	39%	162 23	86%	318 160	50%	280 139	50%	-- 0.6	

Influent and Effluent values are in mg/l unless noted otherwise.

DAF TREATMENT RESULTS - 1977 SHRIMP SEASON
SHRIMP CANNERY WASTEWATER

Run No. & Date	Mode	Alum (mg/l)	Polymer (mg/l)	pH Units	BOD_5 Tot	BOD_5 Sol	COD Tot	COD Sol	TKN	Oil & Grease	TSS	VSS	Settleable Soilds (ml/l)
#405 June 6	R	400	10	5	863 368 57%	619 325 57%	2,180 752 66%		246 143 42%	98 26 73%	340* 215 37%	298 202 32%	12 7.5 38%
#406 June 6	P	366	7.4	5	931 422 55%	682 363 47%	2,070 865 58%		231 123 47%	111 33 70%	508 72 86%	384 60 84%	8.5 0.6 93%
#407 June 6	R	287	7.0	5	1,030 355 65%	784 298 62%	2,930 1,130 62%		283 139 51%	169 25 85%	312 90 71%	288 74 74%	12 0.3 98%
#408 June 7	R	326	6.9	5	1,400 612 56%	921 530 42%	3,050 1,090 64%		321 188 41%	162 10 94%	436 136 69%	364 82 77%	15 0.3 98%
#409 June 7	F	296	6.7	5	1,180 541 54%	925 475 49%	2,860 1,330 53%		277 160 42%	182 6 97%	360 96 93%	280 52 81%	14 0.5 96%
#410 June 7	R	210	6.0	5	731 230 69%	473 212 55%	2,200 811 63%		217 90 59%	91 30 67%	328 90 73%	292 40 86%	9.5 0.6 94%
#122 June 13	--	--	--	--	885	672	2,240	1,500	224	131	368	328	10.5
#121 June 14	--	--	--	--	1,580	1,120	3,920	2,960	344	116	896	764	14
#123 June 16	--	--	--	--	1,290	971	3,440	2,840	316	129	240	188	4.5
#124 June 17	--	--	--	--	1,070	732	2,880	2,200	272	98	292	260	15
#125 June 18	F	290	5.1	5	1,150 368 68%	764 311 59%	3,280 1,260 62%	1,800 1,100 39%	286 137 52%	106 17 84%	300 156 48%	272 100 63%	12 1.5 88%

*Duplicate Analyses
Influent and Effluent values are in mg/l unless noted otherwise.

DAF TREATMENT RESULTS - 1977 SHRIMP SEASON
SHRIMP CANNERY WASTEWATER

Run No. & Date	Mode	Alum (mg/l)	Polymer (mg/l)	pH Units	BOD_5 Tot		BOD_5 Sol		COD Tot		COD Sol		TKN		Oil & Grease		TSS		VSS		Settleable Soilds (ml/l)	
#126 June 20	F	290	4.1	5	1,060 395	63%	667 368	45%	3,360 1,840	45%	2,600 1,600	38%	297 190	36%	147 12	97%	344 78	77%	328 76	77%	10.5 1.9	82%
#127 June 21	R	95	5.8	5	971 272	72%	516 222	57%	2,920 960	67%	2,040 880	57%	253 95	62%	168 2.4	99%	450 28*	94%	412 23*	94%		
#128 June 22	R	130	6.8	4.8	1,620 475	71%	932 396	58%	3,360 1,300	64%	2,320 920	60%	325 132	59%	74 16	78%	408 62	85%	346 53	85%	12 1.8	85%
#129 June 24	R	300	7.3	5	963 316	67%	623 288	54%	2,640 1,100	58%	1,920 840	56%	252 106	58%	97 3.2	97%	272 103	62%	240 93	61%	5.5 4	27%
#130 June 25	R	400	7.3	5	933 438	53%	619 398	36%	2,360 1,060	55%	1,760 1,020	42%	218 119	45%	92 24	74%	272 146*	46%	268 145*	46%	6.5 4.3	34%
#131 June 27	R	400	10.8	5	1,340 382	71%	823 302	63%	2,670 1,240	54%	1,880 902	52%	280 104	63%	124 18	85%	420 225	46%	388 188	52%	7.0 15	--
#U132 June 28	F	400	2.5	5	1,100 580	47%	750		2,800 1,650	59%	1,850		265 160	40%	125 21	83%	473 466	1%	409 298	3%	13 63	--
#133 June 28	P	400	2.5	5	1,180 494	58%	416 354	15%	3,250 1,300	60%	1,180 1,090	7%	210 146	30%	122 16	87%	1,020 144	86%	808 131	84%	12 8.5	29%
#134 June 28	P	400	7.6	5	1,180 461	61%	416 353	15%	3,250 1,270	61%	1,180 1,070	13%	210 87	59%	122 14	89%	1,020 164	84%	808 130	84%	12 1.0	92%
#U135 June 29	F	400	3.3	5	1,100 484	56%	750 343	54%	2,800 1,220	57%	1,850 823	56%	265 112	58%	125 23	82%	473 398	16%	409 330	19%	13	

*Duplicate Analyses

Influent and Effluent values are in mg/l unless noted otherwise.

DAF TREATMENT RESULTS - 1977 SHRIMP SEASON
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

Run No. & Date	Mode	Alum (mg/1)	Polymer (mg/1)	pH Units	BOD_5 Tot		BOD_5 Sol		COD Tot		COD Sol		TKN		Oil & Grease		TSS		VSS		Settleable Soilds (ml/1)	
#136 June 30	F	240	12.7	5	1,100 618	44%	750 382	49%	2,800 1,764	37%	1,850 1,058	43%	265 196	26%	125 30	76%	473 432	9%	409 392	4%	13 25	--
#U137 July 6	F	185	3.9	5	1,100 413	62%	750 381	49%	2,800 1,215	57%	1,850 941	49%	265 129	51%	125 28	78%	473 164	65%	409 150	63%	13 --	
#U139 July 11	F	225	4.9	5	1,100 518	53%	750 417	44%	2,800 1,429	49%	1,850 1,015	45%	265 134	49%	125 8.8	93%	473 212	55%	409 184	56%	13 1.5	88%
#142 Aug. 18	F	PRA 60	2.5	5	642 189	71%	408 180	56%	1,590 794	50%	1,270 675	47%	167 63	62%	28 11	61%	430 70	84%	380 65	83%		
#143 Aug. 19	F	PRA[1] 60	2.5	5	972 363	63%	550 267	51%	2,260 794	65%	1,550 675	56%	228 98	57%	73 11	85%	566 70	88%	496 65	87%	9.0	
#144 Aug 22	F	PRA[1] 60	2.5	4.5	945 603	36%	710 463	35%	2,460 1,230	50%	1,350 833	38%	156 90	42%	79 34	57%	590 266	55%	496 248	50%	7.8 4.5	42%

1 Applied Polymer @ pressure release valve.
* Duplicate Analyses

Influent and Effluent values are in mg/l unless noted otherwise.

DAF TREATMENT RESULTS - FALL 1977 SHRIMP SEASON
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

Run No. & Date	Mode	Alum (mg/l)	Polymer (mg/l)	pH Units	BOD_5 Tot		BOD_5 Sol		COD Tot		COD Sol		TKN		Oil & Grease		TSS		VSS		Settleable Soilds (ml/l)	
#151 Oct. 26	F	Alum	none	N	883 921	--	460 429	7%	2,560 2,870	--	1,760 1,570	11%	236 243	--	67 52	22%	428 1,184	--	324 880	--	31 127	--
#152 Oct. 27	F	Alum	none	N	1,230 857	30%	585 599	--	3,370 2,210	34%	2,560 1,670	35%	298 211	29%	67 58	13%	920 508	45%	760 380	50%		
#153 Oct. 28	F	Alum 450	none	N	1,380 644	53%	1,050 350	67%	3,140 1,590	49%	2,560 930	64%	298 160	46%	86 31	64%	332 704	--	288 556	--	11 72	--
#154 Oct. 31	F				1,400		965		3,650		2,330		335		120		908		792		58	
#155 Nov. 1	F	520C 300	5.0	5.0	1,450 380	74%	1,070 350	67%	3,780 1,030	73%	2,520 990	61%	304 116	62%	80 15	81%	540 37	93%	504 33	93%	1.5	
#156 Nov. 2	F	520C 300	5.0	5.0	930 342	63%	690 307	56%	2,600 1,145	56%	2,170 737	66%	253 132	48%	59 23	61%	412 328	20%	384 312	19%	26 40	--

Influent and Effluent values are in mg/l unless noted otherwise.

DAF TREATMENT RESULTS - 1977 OYSTER SEASON
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

Run No & Date	Mode	Alum (mg/l)	Polymer (mg/l)	pH Units	BOD_5 Tot	BOD_5 Sol	COD Tot	COD Sol	TKN	Oil & Grease	TSS	VSS	Settleable Soilds (ml/l)
#9 A Mar. 3	R	--	--	--	377 154 50%	240 119 50%	2,580 2,280 12%		77 19 24%	16.2	3,510 170 95%	1,080 70 93%	
#5A Feb. 16	R	70	4								1,590 182 89%		15 0.1 99+%
#10A Mar. 7	F	--	--	--			4,080 1,100 73%		150 47 69%	121 19 84%	2,960 348 88%	1,080 174 84%	
#1 Feb. 8	F	100	2i	--			1,560 570 57%				4,510 208 95%		49 0.1 99+%
#11 Mar. 7	F	130	3.1i	--			4,080 2,740 33%		150 79 47%	121 23 81%	2,960 444 85%	1,080 284 74%	
#2 Feb. 10	F	110	2i	--			662 442 33%				902 116 37%		9 0.1 99+%
#3 Feb. 10	F	110	4i	--			662 118 82%				902 84 91%		
#8 Mar. 3	P	142	8.4	--	377 187 50%	240 171 29%	2,580 1,250 52%		77 33 60%		3,510 316 91%	1,080 154 86%	42 0.1 99+%
#6 Fe b 17	R	70**	4i	--	585 299 49%	743 329 56%	3,970 1,400 65%				1,830 376 79%		13 0.2 98%
#7 Mar. 2	R	107	2.2ii	--			1,320 220 83%		59 18 69%	21 12 41%	704 144 80%	320 100 69%	40 0.3 99+%
#4 Fe b. 15	R	110**	4ii	--			2,210 736 67%				3,900 160 96%		39 0.2 99%

Influent and Effluent values are in mg/l unless noted otherwise.

DAF TREATMENT RESULTS - 1977 OYSTER SEASON
SHRIMP CANNERY WASTEWATER

Violet Packing Co.

Run No. & Date	Mode	Alum (mg/l)	Polymer (mg/l)	pH Units	BOD_5 Tot	BOD_5 Sol	COD Tot	COD Sol	TKN	Oil & Grease	TSS	VSS	Settleable Soilds (ml/l)
#16 Mar. 11	R	165**	5.5[ii]				3,920 1,410 64%		159 54 66%	16 9 45%			24 0.1 99+%
#12 Mar. 9	R	194**	6.4[ii]	--			4,780 2,200 54%		128 56 56%	26 12 54%	2,810 220 92%	996 172 83%	40 0.2 99+%
#15 Mar. 10	R	200**	4.6[ii]	--	405 260 36%	293 243 17%	2.120 940 56%		89 40 56%	3.0 9.6 --	1,700 184 89%	556 84 85%	19 0.1 99%
#13 Mar. 9	R	240	6[iii]	--			4,780 2,430 49%				2,810 240 93%	996 182 82%	40 0.2 99+%
#14 Mar. 9	R	240	6[iii]	--			4,780 2,120 56%		128 58 55%	26 15 42%			40 0.1 99+%

A - No Air Flow   Polymer applied @ i - Pressure Valve
ii - Bottom of flocculation chamber
iii- Both
Alum applied @: **- Static Mixer

Influent and Effluent values are in mg/l unless noted otherwise.

American Shrimp Canners Association — Fall 1974

JAR TEST SUMMARY

Coagulant (mg/l)	Polymer & Dose (mg/l)	pH (adjusted)	Remaining Concentration (mg/l) & Percent Removal: COD	TSS	Turbidity (JTU)
Alum 50 mg/l	845 A 3 mg/l	4.0	1,630 37%	66 86.6%	350 65%
Alum 75 mg/l	845 A 3 mg/l	4.0	1,710 34.3%	52 89.4%	23 98%
Alum 75 mg/l	845 A 4 mg/l	4.0	1,670 36%	40 91.9%	37.5 96%
Alum 50 mg/l	845 A 4 mg/l	4.0	1,630 37.3%	100 79.7%	220 78%
509 C 150 mg/l	845 A 2 mg/l	4.0	1,440 45%	42 91.5%	76 92.4%
509 C 500 mg/l	845 A 3 mg/l	4.0	1,360 48%	56 88.6%	60 94%
Alum 100 mg/l	845 A 2 mg/l	4.0			
509 C 200 mg/l	845 A 3 mg/l	4.0	1,440 45%	76 85%	48 95%
PRA 50 mg/l		3.0	1,320 49.2%	22 95.5%	40 96%
PRA 50 mg/l		3.5	1,360 47.7%	52 89%	370 66%

Jar Test Notes: 1. All pH values given are as adjusted by chemical dosages.
2. % Removals are based on analyses of untreated waste water samples on which jar tests were run.

American Shrimp Canners Association Fall 1974

JAR TEST SUMMARY

Coagulant (mg/l)	Polymer & Dose (mg/l)	pH (adjusted)	Remaining Concentration (mg/l) & Percent Removal		
			COD	TSS	Turbidity (JTU)
GTS Solution 6 ml		4.0	1,400 35%	224 57%	240 78%
GTS Solution 8 ml		4.0	1,940 9%	78 85%	17.5 98%
GTS Solution 10 ml		4.0	2,100 2%	40 92%	20 98%
Acid only		4.0	1,630 24%	86 83%	260 76%
Acid only		5.0	1,440 33%	158 70%	370 66%
Alum 75 mg/l		4.0	1,670 22%	254 51%	370 66%
Alum 75 mg/l		5.0	1,750 18%	322 38%	350 68%
Chitosan 18 mg/l		4.0	1,470 31%	44 91.5%	50 95.5%

AMERICAN SHRIMP CANNERS ASSOCIATION
SHRIMP CANNERY WASTEWATER TREATMENT

SUMMER 1975

SUMMARY
JAR TEST
TREATABILITY STUDY

Coagulant and Dose mg/l	Polymer and Dose mg/l	pH (adjusted)	Remaining Concentration (mg/l) And Percent Removal		
			COD	TSS	Turbidity JTU
Alum 27 mg/l	-	4.0	1040 56%	108 86%	175 65%
Alum 72 mg/l	-	4.0	1050 56%	82 90%	175 65%
Alum 108 mg/l	-	4.0	1070 55%	52 95%	50 90%
Alum 180 mg/l	-	4.0	1150 52%	92 88%	250 50%
Alum 270 mg/l	-	4.0	1050 56%	72 91%	220 56%
Alum 30 mg/l	-	7.0	-	-	-
Alum 80 mg/l	-	7.0	-	-	-
Alum 120 mg/l	-	7.0	-	-	-
Alum 200 mg/l	-	7.0	1520 36%	504 36%	500 0
Alum 300 mg/l	-	7.0	1430 40%	272 65%	200 60%
Alum 30 mg/l	835A 2 mg/l	4.0	1740 49%	104 81%	350 49%
Alum 30 mg/l	835A 4 mg/l	4.0	1880 45%	132 75%	300 57%
Alum 30 mg/l	835A 6 mg/l	4.0	1880 45%	64 88%	200 71%
Alum 30 mg/l	835A 8 mg/l	4.0	1840 46%	110 80%	170 75%
Alum 30 mg/l	835A 10 mg/l	4.0	1780 48%	124 77%	150 78%

AMERICAN SHRIMP CANNERS ASSOCIATION
SHRIMP CANNERY WASTEWATER TREATMENT — SUMMER 1975

SUMMARY
JAR TEST
TREATABILITY STUDY

Coagulant and Dose mg/l	Polymer and Dose mg/l	pH (adjusted)	Remaining Concentration (mg/l) And Percent Removal		
			COD	TSS	Turbidity JTU
-	-	3.0	-	-	-
-	-	4.0	1170 41%	170 71%	175 80%
-	-	5.0	1330 33%	256 56%	220 74%
-	-	6.0	-	-	-
-	-	7.0	-	-	-
-	-	-	-	-	-
Alum 200 mg/l	-	3.0	-	268 54%	500 41%
Alum 200 mg/l	-	4.0	1140 42%	132 77%	300 65%
Alum 200 mg/l	-	5.0	1190 40%	240 59%	200 76%
Alum 200 mg/l	-	6.0	1120 44%	192 67%	175 80%
Alum 200 mg/l	-	7.0	1250 37%	248 57%	160 81%
Alum 200 mg/l	-	8.0	1220 38%	216 63%	200 77%
Chitosan 135 mg/l	-	3.0	1410 29%	266 54%	400 53%
Chitosan 135 mg/l	-	4.0	1370 31%	82 86%	250 71%
Chitosan 135 mg/l	-	5.0	1050 47%	218 63%	375 56%
Chitosan 135 mg/l	-	6.0	1260 37%	276 53%	350 59%
Chitosan 135 mg/l	-	7.0	1360 32%	308 47%	425 50%
Chitosan 135 mg/l	-	8.0	-	398 32%	375 56%

AMERICAN SHRIMP CANNERS ASSOCIATION
SHRIMP CANNERY WASTEWATER TREATMENT

SUMMER 1975

SUMMARY
JAR TEST
TREATABILITY STUDY

Coagulant and Dose mg/l	Polymer and Dose mg/l	pH (adjusted)	Remaining Concentration (mg/l) And Percent Removal		
			COD	TSS	Turbidity JTU
Alum 80 mg/l	835A 6 mg/l	7.0	-	186 76%	600 30%
Alum 300 mg/l	835A 2 mg/l	7.0	1450 18%	76 91%	375 57%
Alum 300 mg/l	835A 4 mg/l	7.0	1540 12%	166 79%	350 59%
Alum 300 mg/l	835A 6 mg/l	7.0	1480 16%	60 93%	400 53%
Alum 300 mg/l	835A 8 mg/l	7.0	1500 15%	112 86%	370 57%
Alum 300 mg/l	835A 10 mg/l	7.0	1660 6%	120 85%	-
Chitosan 5 mg/l	-	4.0	1480 39%	84 80%	100 85%
Chitosan 15 mg/l	-	4.0	1270 48%	80 81%	100 85%
Chitosan 30 mg/l	-	4.0	1330 45%	78 81%	120 83%
Chitosan 60 mg/l	-	4.0	1520 37%	85 80%	70 90%
Chitosan 120 mg/l	-	4.0	1520 35%	90 78%	125 82%
Chitosan 200 mg/l	-	4.0	1700 30%	75 82%	100 85%
Chitosan 5 mg/l	-	7.0	-	-	-
Chitosan 15 mg/l	-	7.0	-	-	-
Chitosan 30 mg/l	-	7.0	1190 51%	63 63%	400 41%
Chitosan 60 mg/l	-	7.0	1210 50%	60 86%	370 45%
Chitosan 120 mg/l	-	7.0	1530 37%	300 28%	370 45%
Chitosan 200 mg/l	-	7.0	1270 48%	92 78%	370 45%

AMERICAN SHRIMP CANNERS ASSOCIATION
SHRIMP CANNERY WASTEWATER TREATMENT — SUMMER 1975

SUMMARY
JAR TEST
TREATABILITY STUDY

Coagulant and Dose mg/l	Polymer and Dose mg/l	pH (adjusted)	Remaining Concentration (mg/l) And Percent Removal		
			COD	TSS	Turbidity JTU
PRA-1 5 ml of .1% by Vol.	-	3.0	-	105 68%	125 50%
PRA-1 10 ml of .1% by Vol.	-	3.0	-	95 71%	75 70%
PRA-1 30 ml of .1% by Vol.	-	3.0	1290 11%	22 93%	170 32%
PRA-1 5 ml of 1% by Vol.	-	3.0	-	134 58%	170 32%
PRA-1 8 ml of 1% by Vol.	-	3.0	1390 4%	100 69%	-
PRA-1 10 ml of 1% by Vol.	-	3.0	1430 1%	124 61%	-
-	835A 3 mg/l	3.0	1410 40%	178 72%	70 92%
-	835A 3 mg/l	4.0	1640 30%	220 66%	250 71%
-	835A 3 mg/l	5.0	1680 28%	316 51%	425 50%
-	835A 3 mg/l	6.0	1920 11%	382 41%	600 30%
-	835A 3 mg/l	7.0	2020 13%	394 39%	625 27%
-	835A 3 mg/l	8.0	1980 15%	436 32%	600 30%

AMERICAN SHRIMP CANNERS ASSOC.
SHRIMP CANNERY WASTEWATER TREATMENT — SUMMER 1975

SUMMARY
PRESSURIZED FLOTATION
TREATABILITY STUDY

Coagulant & Dose, mg/l	Polymer & Dose, mg/l	pH (adjusted) Units	PSI	Mode of Operation	REMAINING CONCENTRATION (mg/l) AND PERCENT REMOVAL COD	TSS	Turbidity JTU
Chitosan 15 mg/l	-	4.0	42	50:50 recycle	1010 55%	208 68%	300 63%
Chitosan 15 mg/l	835A 3 mg/l	4.0	45	50:50 recycle	644 71%	190 70%	100 87%
Chitosan 15 mg/l	-	4.0	43	Direct	1600 28%	358 45%	440 45%
Chitosan 30 mg/l	-	7.0	45	50:50 recycle	772 65%	90 86%	120 85%
Chitosan 30 mg/l	-	7.0	45	Direct	1740 22%	370 46%	550 31%
PRA 1 5 ml of .1%	-	3.0	45	50:50 recycle	1200 46%	234 65%	270 66%
PRA 1 10 ml of 1%	-	3.0	44	50:50 recycle	871 61%	-	250 69%
Alum 55 mg/l	835A 3 mg/l	4.0	45	50:50 recycle	1110 68%	200 62%	170 75%
Alum 30 mg/l (Added in Cylinder)	835A 6 mg/l (Added in Cylinder)	4.0	45	Direct	2360 31%	414 21%	500 26%
Alum 30 mg/l	835A 6 mg/l	4.0	42	50:50 recycle	990 71%	48 91%	70 90%
Alum 30 mg/l	835A 2 mg/l	4.0	45	50:50 Recycle	1070 69%	110 80%	125 82%
Alum 30 mg/l	835A 10 mg/l	4.0	45	50:50 recycle	1050 70%	82 85%	125 82%
Alum 30 mg/l (Added in Cylinder)	835A 10 mg/l (Added in Cylinder)	4.0	44	Direct	2340 32%	366 31%	500 26%
Alum 30 mg/l (Added in Bomb)	835A 10 mg/l (Added in Cylinder)	4.0	45	Direct	1950 43%	78 85%	240 65%

SHRIMP CANNERY WASTEWATER
FLOW DATA

Gallons Per Day
(Gallons Per Thousand Lbs.)

Date	Rec. Tank	Peelers	Separators	Graders	Deveiners	Total Screen
6/2/75	6,250 (135)	99,500 (2,140)	27,330 (589)	18,700 (403)	18,600 (401)	284,000 (6,120)
6/3/75	4,300 (192)	82,770 (3,680)	16,200 (720)	9,220 (410)	36,800 (1,640)	
6/4/75	8,120 (121)	156,000 (2,330)	30,500 (456)	17,400 (260)	69,400 (1,040)	429,000 (6,400)
6/5/75	12,300 (127)	237,000 (2,450)	46,300 (479)	26,400 (273)	105,000 (1,090)	647,000 (6,690)
6/6/75	13,200 (137)	253,000 (2,640)	49,500 (516)	28,200 (294)	113,000 (1,170)	739,000 (7,700)
6/7/75	10,100 (124)	195,000 (2,380)	38,200 (464)	21,700 (265)	86,700 (1,060)	614,000 (7,480)
6/9/75	16,200 (139)	312,000 (2,670)	61,100 (522)	34,800 (297)	139,000 (1,190)	782,000 (6,680)
6/10/75	15,400 (174)	239,000 (2,710)	44,600 (505)	19,200 (217)	172,000 (1,940)	724,000 (8,210)
6/11/75	10,500 (134)	160,000 (2,060)	29,810 (383)	12,500 (160)	118,000 (1,520)	724,000 (9,320)
6/12/75	7,060 (170)	108,000 (2,610)	20,100 (486)	8,430 (203)	79,800 (1,930)	
6/13/75	9,340 (126)	198,000 (2,530)	44,200 (565)	19,300 (246)	49,300 (631)	

SHRIMP CANNERY WASTEWATER
FLOW DATA

Gallons Per Day
(Gallons Per Thousand Lbs.)

Date	Rec. Tank	Peelers	Separators	Graders	Deveiners	Total Screen
6/14/75	10,800 (165)	226,000 (3,450)	59,000 (901)	13,300 (202)	66,200 (1,010)	479,000 (7,310)
6/16/75	15,800 (172)	276,000 (3,020)	66,300 (724)	10,700 (116)	102,000 (1,120)	574,000 (6,270)
6/17/75	3,670 (161)	62,600 (1,760)	13,700 (604)	1,810 (79)	28,700 (1,260)	
6/18/75	7,180 (3,240)	156,000 (3,240)	32,300 (669)	7,510 (155)	83,100 (1,720)	272,000 (5,630)
6/19/75	5,500 (187)	111,000 (3,750)	20,400 (687)	7,750 (261)	56,900 (1,920)	229,100 (7,740)
6/20/75	5,880	118,000	21,600	8,220	60,300	208,000
6/23/75	14,500	322,000	70,200	13,300	180,000	724,000
6/24/75	13,500 (110)	309,000 (2,530)	70,400 (576)	13,510 (110)	107,000 (877)	705,000 (5,780)
6/25/75	11,900 (133)	280,000 (3,140)	59,300 (666)	12,100 (135)	95,800 (1,080)	822,000 (9,230)
6/26/75	6,780 (107)	169,000 (2,660)	33,700 (530)	7,260 (114)	81,700 (1,280)	556,000 (8,740)
6/27/75	14,770 (122)	350,000 (2,900)	61,300 (507)	23,300 (192)	154,000 (1,280)	845,000 (8,230)

SHRIMP CANNERY WASTEWATER
FLOW DATA

Gallons per day
(Gallons per Thousand lbs.)

Date	Rec. Tank	Peelers	Separators	Graders	Deveiners	Total Screen
6/28/75	13,700 (123)	372,000 (3,350)	63,300 (570)	15,200 (136)	171,000 (1,540)	847,000 (7,630)
6/30/75	10,300 (109)	247,000 (2,640)	43,600 (465)	14,000 (149)	145,000 (1,540)	771,000 (8,230)
7/2/75	24,100 (191)	335,000 (2,660)	61,600 (490)	16,800 (133)	191,000 (1,520)	884,000 (7,030)
7/3/75	8,840 (127)	194,000 (2,790)	34,300 (494)	11,600 (166)	70,500 (1,020)	451,000 (6,520)
7/5/75	6,970 (146)	153,000 (3,200)	27,000 (566)	9,110 (191)	63,500 (1,330)	35,600 (7,470)
7/7/75	6,700 (155)	147,000 (3,390)	26,000 (600)	8,750 (202)	61,100 (1,410)	342,000 (7,910)
7/8/75	3,424 (103)	73,700 (2,220)	15,700 (472)	34,760 (1,050)	6,120 (184)	238,000 (7,160)
7/10/78	6,680 164	131,000 3,220	29,000 716	9,380 230	97,800 2,400	369,000 9,060
11/10/75	2,620	75,500		5,600	2,890	221,000
11/13/75	92,800	92,800		5,300	42,200	243,000

SHRIMP CANNERY WASTEWATER

FLOW DATA

Gallons Per Day
(Gallons Per Thousand Lbs.)

Date	Rec. Tank	Peelers	Separators	Graders	Deveiners	Total Screen
11/14/75	6,030	164,000		11,500	61,400	327,000
11/15/75		186,000		3,710	34,900	371,000
12/4/75	7,390	221,000		11,400	162,000	553,000
12/5/75	7,050	181,000		12,400	433,000	424,000
12/10/75	21,700	234,000			90,000	263,000
Avg Gallons Per 1000#	(143)	(2,830)	(572)	(237)	(1,290)	(7,440)

APPENDIX D

COST DATA

General

Cost study data include estimated cost (December 1977) of the following:

1. Basic DAF wastewater treatment plant
2. Solid Waste disposal alternatives
3. Operation and Maintenance Costs.

The cost estimates given herein reflect costs applicable to the wastewater treatment system after a water conservation program has been implemented. Cost estimates reported here assume 15 years service life and 9% interest. Cost are reported in 1977 dollars. As discussed earlier, the water conservation program at the project plant has reduced the wastewater flow from an average of 700 gpm in 1975 to an average of 500 gpm in 1977. It is estimated that a similar water conservation program would cost almost $50,000 in 1977 dollars.

Table D-1,Estimated Annual Costs,shows DAF system costs in Columns A, B, and C, while Columns D and E show the total cost of wastewater treatment, including sludge disposal. The capital cost of the DAF plant shown in Column A reflects the actual cost of the project plant, Engineering News Record Construction Cost Index adjusted to December 1977. The estimated total cost of equipment for an 8 peeler plant (Column B) reflects 85% of the capital cost in Column A to allow for size reduction due to water management.Sizing of DAF system tankage for a particular flow rate is not always feasible since a non-standard size could be required. Therefore, the DAF systems used for analysis are taken to be 500 gpm and 250 gpm sizes for the 8 peeler and 4 peeler plants, respectively. The project study plant now has nine peelers, therefore, a 6% further reduction is used to calculate the eight peeler variable costs based on flow. Column C, 4 peeler plant costs, reflect 75% of the capital cost in Column B (8 peelers). A straight line interpolation for shrimp processing plants of intermediate sizes will give a reasonable estimate of costs.

An attempt has been made to analyze sludge or skimmings disposal costs. This developed cost-disposal relationship is summarized in Table D-2, Estimated Solid Waste Handling and Disposal Costs for DAF Skimmings Disposal. The costs are based on hauling of the sludge, with no conditioning or treatment, to disposal on the owners approved landfill site. Due to the restrictions on land fill operations and the nature of the DAF sludge, it is doubtful that landfilling of the material at a public or private site would be reliable, or a permanent arrangement. Even though these alternatives,Columns N and O in Table D-2, are shown to be lower in cost than hauling to the owner operated land fill, these alternatives are by no means a certainty. If disposal to a landfill not operated by the shrimp processor is available, any savings advantage could be taken. The only controlled disposal alternative is to the shrimp processors land. Suitable land near these plants probably is not available regardless of monetary considerations. The Gulf shrimp processors land disposal is further complicated by being in a high annual rainfall area. Frequent rains and wet soil conditions are not conducive to successful land applications operations. Therefore, it has been assumed suitable land would be acquired 25 to 50 miles from the cannery.

Annual Wastewater Treatment and Sludge Disposal Costs in terms of Canned Shrimp Production, Table D-3, reflects the cost of treatment and disposal per case of canned product , based on average production rates and 9 hours per day, 120 days of production. Costs are taken from Table D-1, Columns D and E. Table D-4 shows typical costs for different production ranges. Calculations, data and assumptions used in computing tables D-1 and D-2 are given on pages D-6 through D-29.

TABLE D-1

ESTIMATED ANNUAL COSTS
DAF WASTEWATER TREATMENT
GULF SHRIMP CANNERY WASTEWATER

		A Project DAF System Cost	B DAF Treatment Costs	C	D Treatment and Land Disposal Costs (B)+(P)	E (C)+(R)
	Fixed Costs		8-Peeler	4-Peeler	8-Peeler	4-Peeler
1	Capital Costs	$282,900	$227,500	$172,400	-	-
2	Salvage (PW)	- 6,900	- 5,500	- 4,100	-	-
3	Land Cost	5,000	5,000	5,000	-	-
4	Present Worth	281,000	227,000	173,300	-	-
5	Annual Equivalent Costs Total	34,900	28,200	21,500	45,100	32,300
	Variable Costs					
6	Energy	1,500	1,400	700	-	-
7	Chemicals	8,300	7,800	3,900	-	-
8	Maintenance & Repairs	9,300	7,800	6,300	-	-
9	Labor	46,200	46,200	38,800	-	-
10	Total annual Variable Costs	65,300	63,200	49,700	86,400	71,800
11	Total Annual Average Equivalent Costs	$ 100,200	$ 91,400	$ 71,200	$ 131,500	$ 104,100

DAF Capital Costs are based on Recycle mode system.
For Full Flow Pressurization Mode, reduce capital costs by 11%.
Costs presented are end of year 1977 dollars, 15 year amortization and 9% interest.
Capital and variable costs must be adjusted to reflect estimated costs at a specific time.

TABLE D-2
ESTIMATED SOLID WASTE HANDLING AND DISPOSAL COSTS
FOR DAF SKIMMINGS SLUDGE DISPOSAL

	COLUMN	L	M	N	O	P	Q	R
	Treatment or Disposal	Chemical Conditioning (1)	Evaporator-Dryer (2)	Contract Hauling-Wet (3)	Wet Disposal to Private Landfill (3)	Wet Disposal to Owner's Landfill (4) (5)	Haul to Owners Fill After M (5)	Wet Disposal to Owner's Fill (5)
	FIXED COST	8 Peelers	8 Peelers	8 Peelers	8 Peelers	8 Peelers	8 Peelers	4 Peelers
1	Capital Cost	$130,800	$167,300	-	(6)	(6)	(6)	(6)
2	Present worth Salvage Value	5,400	9,200	-	(6)	(6)	(6)	(6)
3	Land Cost	0	0	-	0	60,000	15,000	30,000
4	Present Worth	125,400	158,100	-	-	60,000	15,000	30,000
5	Equivalent Annual Costs	15,600	19,600	-	0	7,400	1,900	3,700
6	Equivalent Annual Vehicle Purchases and Salvage	0	0	-	5,900	9,500	7,100	7,100
7	Annual Cost	15,600	19,600	-	5,900	16,900	9,000	10,800
	ANNUAL VARIABLE COST							
8	Energy	500	6,400	-	2,400	2,300	600	1,200
9	Chemicals	1,400	0	-	100	100	100	100
10	Maintenance or Vehicle Costs	1,300	1,700	-	3,500	5,000	5,000	5,000
11	Labor	0	0	-	10,400	15,800	15,800	15,800
12	Dumping Fees	0	0	$ 24,000	7,500	0	0	0
13	Total Annual Variable Costs	3,200	8,100	24,000	23,900	23,200	21,500	22,100
14	Total Annual Average Equivalent Cost	18,800	27,700	24,000	29,800	40,100	30,500	32,900

(1) Bif Purifax Unit

(2) De Laval Convap Unit

(3) Assumes Contractor Accepts Sludges

(4) Assumes Land is Available

(5) Processor owned land to assure continued availability.

(6) Multiple Vehicles involved, See line item.

TABLE D-3

WASTEWATER TREATMENT COSTS
IN TERMS OF
CANNED SHRIMP PRODUCTION

	8-Peeler	4-Peeler
(1) Total Average Annual Cost	$131,500	$ 104,100
(2) Cost/day/peeler (120 Days)	$ 136.98	$ 216.88
(3) Cost/peeler/hr. (9-hour day)	$ 15.22	$ 24.10
(4) Raw shrimp processed/hour/ peeler	810 lbs	810 lbs
(5) Finished Product/hr./ peeler (32% yield)	259.2 lbs	259.2 lbs
(6) Cases/hour/peeler	38.4 cases	38.4 cases
(7) Total Annual Cases	331,776	165,888
(8) Avg. Cost/case	$ 0.396	$ 0.628

TABLE D-4

TYPICAL COST RANGES*

Production	Annual Cost	Cost Per Case
Four Peeler Cannery		
100,000 cases	$ 101,800	$ 1.023
150,000 cases	103,500	0.687
200,000 cases	104,900	0.523
Eight Peeler Cannery		
200,000 cases	$ 119,500	0.600
300,000 cases	130,400	0.433
350,000 cases	132,100	0.376

* NOTE: Considers cost variation due to variable energy, chemical, fuel and other costs with varying processing and wastewater flows.

TABLE D-1; DAF Wastewater Treatment Costs

COLUMN A: Project DAF System Cost

A1) Capital Cost of Project DAF System -

Equipment Costs:

a) November 1975 Bid Price = $165,872 (ENR Index = 2293.6) December, 1977 ENR Index= 2672.4

% increase = 16.52%

ENR Corrected Capital Cost = ($165,872)(1.1652) = $193,300

b) Erection Cost (March 1976) = $50,141 (ENR Index = 2327.4) December 1977 ENR Index = 2672.4

% increase = 14.82%

ENR Corrected Erection Cost = ($50,141)(1.1482) = $57,600

c) Other Capital Costs

Engineering and Inspection = (193,300 + 57600) X (0.10)	$25,000
Soil Data =	$ 2,000
Laboratory Equipment	$ 5,000
	$32,000

Total Capital Cost = $ 282,900

A2) Salvage Value

Salvage Value = (10%) ($193,300 + $57,600) = $25,090
PW = $25,090 (P/F, 15 yrs, 9%)= ($25,090) (0.2745)= $6900

Total Salvage Value $ 6,900

A3) Land Cost - Assume 1 acre required at $5000/acre

Land Cost= $5,000

A4) Present Worth = Capital Cost - Salvage Value + Land Cost
= $282,900 - 6900 + 5000
= $ 281,000

PW = $ 281,000

A5) Annual Equivalent Cost
($281,000) (A/P, 15yrs, 9%) = (281,100)(0.12406)
= $34,900

Annual Equivalent Cost= $ 34,900

A6) Energy Costs - Energy Costs for the DAF system are based on KWH and flow meter readings. Electrical cost is assumed to be 2.5¢/KWH including demand charges. Due to variations in use of pumps, etc., costs were 3¢/1000 gallons to 6.6¢/1000 gallons, and 4.5¢/1000 gallons is assumed to be average. From data, it has been assumed 120 9-hour processing days is typical/year.

Total Flow = (120 operating days/yr) (9 hrs/day) (500 gpm)(60)
= 32.4×10^6 gallons/year

Power Cost = (32.4×10^6 gal/yr)($0.045/1000 gal)
= $1500/yr

Energy Cost = $ 1500/yr

A7) Chemical costs are based on the wastewater volume calculated in A5 and typical chemical additions of 200 mg/l Alum, 4 mg/l 835A polymer, 0.236 ml 95% H_2SO_4/l, and caustic addition of 25% of acid addition. Based on actual chemical costs during 1977, this is a total cost of $0.257/1000 gallons.

Chemical Cost = (32.4×10^6 gal/yr) ($0.257/1000 gal) = $8300

Chemical Cost = $8300/yr

A8) Maintenance & Repairs

Estimate @ 3% of Capital Cost
(0.03) ($193,300 + $57,600) = $7500

This figure does not include contract services for pH meter, and chemical feed systems. This service is estimated to cost about $1800/year.

Total Maintenance & Repairs=$ 9300/yr

A9) Labor costs are inclusive of a full-time operator, one full-time assistant, and one part time assistant. Labor costs are based on current New Orleans area cannery estimates.

Operator: $20,000/yr + 25% benefits = $25,000/yr

Asst. Operator: $11,000/yr + 25% benefits =$13,750/yr

Asst. Operator: (1080 hrs/yr) ($5.50/hr.) +(25% benefits)= $7425/yr

Total Labor = $ 46,200/yr

A10) Total Annual Variable Cost

$$A10 = A6 + A7 + A8 + A9$$
$$= \$1500 + \$8300 + \$9300 + \$46,200$$
$$= \$65,300$$

Total Annual Variable Cost=$ 65,300

A11) Total Annual Average Equivalent Costs

$$A11 = A5 + A10$$
$$= \$34,900 + \$65,300 = \$100,200$$

Total Annual Average
Equivalent Cost = $ 100,200

COLUMN B: 8-Peeler DAF Treatment Costs

B1) Capital Cost of A1 are reduced 15% to allow for water conservation and 6% to allow for an 8-peeler operation. This 6% reduction also allows for one of the 8 peelers to have a partial down time.

a) Equipment Costs:
($193,300) (0.85) (0.94) = $ 154,447

b) Erection Costs:
($57,600) (0.85) (0.94) = $ 46,022

c) Other Capital Costs

Engineering & Inspection = ($154,447 + $46,022)(0.10)	$ 20,046
Soils data =	$ 2,000
Laboratory Equipment =	$ 5,000
Total Capital Cost =	$ 227,500

B2) Salvage Value

(10%) (B1a + B1b)
(10%) ($154,447 + $46,022) = $20,047

PW = $20,047 (P/F, 15 yrs 9%)
= $20,047 (0.2745) = $5500

PW Salvage Value = $ 5500

B3) Land Cost based on 1 acre @ $5000/acre

Land Cost = $ 5000

B4) Present Worth

= B1 - B2 + B3
= $227,500 - $5500 + $ 5000
= $227,000

PW = $227,000

B5) Annual Equivalent Cost

= (B4) (A/P, 15 yrs, 9%)
= $227,000 (0.12406) = $28,200

Annual Equivalent Cost= $ 28,200

B6) Energy Cost:

Reduce A6 by 6% for 8-peeler operation
($1500) (0.94) = $1400

Energy Cost = $ 1400/yr

B7) Chemical Cost:
Reduce A7 by 6% for 8-peeler operation

($8300) (0.94) = $7800/yr

Chemical Cost = $ 7800/yr

B8) Maintenance and Repairs

3% of Capital Cost for equipment and installation

(0.03) ($154,447 + $46,022) = $6014

Add also contract costs shown in A8, $1800

Maintenance & Repairs= $ 7800/yr

B9) Labor

Same as A9

Labor = $ 46,200/yr

B10) Total Annual Variable Costs

B10 = B6 + B7 + B8 + B9
= $1400 + $7800 + $7800 + $46,200
= $63,200

Total Annual Variable Costs = $ 63,200

B11) Total Annual Average Equivalent Cost

B11 = B5 + B10
= $28,200 + $63,200
= $ 91,400

Total Annual Average Equivalent Cost = $ 91,400

Column C: 4-Peeler DAF Treatment Costs

C1) Capital Cost of B1 are reduced by 25% due to flow decrease

a) Equipment Costs

($154,447) (0.75) — $115,835

b) Erection Costs

($46,022) (0.75) — $ 34,517

c) Other Capital Costs

Engineering & Inspection = 10% ($115,835 + $34,517)=	$ 15,035
Soils data	2,000
Laboratory Equipment	5,000
TOTAL CAPITAL COST =	$172,400

C2) Salvage Value

(10%) (C1a + C1b)

(10%) ($115,835 + $34,517) = 15,035

PW Salvage Value = $ 15,035 (P/F, 15 yrs, 9%)

= $ 15,035 (0.2745)

= $ 4,100

PW SALVAGE VALUE = $ 4,100

C3) Land Cost

1 acre @ $5,000/acre

LAND COST $ 5,000

C4) Present Worth

C4 = C1 - C2 + C3

= $172,400 - $4,100 + $5,000

= $173,300

PW = $173,300

C5) Annual Equivalent Cost

$ 173,300 (A/P, 15 yrs, 9%)

$ 173,300 (0.12406) = $21,500

ANNUAL EQ. COST = $21,500

C6) Energy Cost

Based on 50% of B6

($1400) (0.5) = $700 — $ 700/yr

C7) Chemical Cost

Based on 50% of B7

(\$7800) (0.5) = \$3900

CHEMICAL COST= $\underline{\underline{\$\ 3900/yr}}$

C8) Maintenance and Repairs

Based on 3% of Capital Cost

(0.03) (\$115,835 + \$34,517) = \$4500

Add Contract Services Cost = \$1800

MAINTENANCE & REPAIRS= $\underline{\underline{\$6300/yr}}$

C9) Labor - Allow elimination of Part time Assistance from A9

46,200 - 7425 = 38,800

LABOR $\underline{\underline{\$38,800/yr}}$

C10) Total Annual Average Equivalent Costs

C10 = C6 + C7 + C8 + C9

= \$700 + \$3900 + \$6300 + 38,800

= \$ 49,700

TOTAL ANNUAL VARIABLE COST = $\underline{\underline{\$49,700/yr}}$

C11) Total Annual Average Equivalent Costs

C11 = C5 + C10

= \$21,500 + \$49,700

= \$ 71,200

TOTAL ANNUAL AVERAGE EQ. COST= $\underline{\underline{\$71,200/yr}}$

COLUMN D: Treatment and Land Disposal Costs (8-peeler Plant)

D5)

B5 = B5 + P7
= $28,200 + 16,900
= $45,100

D10)

D10 = B10 + P13
= $63,200 + 23,200
= $86,400

D11)

D11 = D5 + D10
= $131,500

COLUMN E: Treatment and Land Disposal Costs

E5)

E5 = C5 + R7
= $21,500 + $10,800
= $32,300

E10)

E10 = C10 + R13
= $49,700 + $22,100
= $71,800

E11)

E11 = E5 + E10
= $104,100

TABLE D-2; Solid Wastes Handling and Disposal Costs
COLUMN L: Sludge Conditioning by Chlorine Oxidation

L1) Capital Cost - estimated by supplier

Capital Cost = $130,800

Capital Cost = $ 130,800

L2) Salvage Value - estimate at 15% of Capital Cost

($130,800) (0.15) (P/F, 15 yrs, 9%)
= $19,620 (0.2745)
= $ 5,400

PW Salvage Value = $ 5,400

L3) Land Cost

There is no land cost for the oxidizing equipment

Land Cost = $ -0-

L4) Present Worth

L4 = L1 - L2 + L3
= $130,800 - $5,400 + 0
= $125,400

PW = $ 125,400

L5) Equivalent Annual Cost

PW (A/P, 9%, 15yrs) = ($125,400) (0.12406)
= $15,600

Eq. Annual Cost $ 15,600

L6) Equivalent Annual Vehicle Purchases and Salvage

There are no vehicle costs associated with the chemical oxidizer other than the disposal costs which are addressed in the disposal alternatives.

Vehicle Purchases and Salvage $ -0-

L7) Fixed Annual Cost

L7= L5 + L6
= $15,600 + 0 = $15,600 $ 15,600/yr

L8) Energy Costs for the Chemical Oxidizing system are based on the power requirements estimated for the system by the manufacturer.

($0.48/hr) (9hrs/day) (120 days/yr.) = $500/yr.

Energy Cost = $ 500

L9) Chemical Costs are estimated in the same fashion as L8.

($1.31/hr) (9 hrs/day) (120 days/yr) = $1400/yr.

Chemical Cost = $ 1400

L10) Maintenance or Vehicle Costs -
No Vehicle is required for this sludge treatment method;

Maintenance estimated at 1% of Capital Cost per year.

($130,800) (0.01) = $1300/yr

Maintenance or Vehicle Costs=$ 1300/yr

L11) Labor - It is assumed that the DAF operator will also take care of the chemical oxidizing system.

Labor = $ -0-

L12) Dumping Fees - No dumping is required for chemical oxidation: These costs appear in the wet hauling columns.

Dumping Fees = $ -0-

L13) Total Annual Variable Costs

L13= L8 + L9 + L10 + L11 + L12
= $500 + $1400 + $1300 + 0 + 0
= $3200/yr

Total Annual Variable Cost = $3200/yr

L14) Total Annual Average Equivalent Cost
L14= L7 + 113= $15,600 +$3200 = $18,800/yr.

Total Annual Average Equivalent Cost = $18,800/yr

COLUMN M: Sludge Volume Reduction by Evaporator - Dryer (convap)

M1) Capital Cost estimated by manufacturer

Capital Cost = $ 167,300

M2) Present Worth Salvage Value - 20% of Capital

M2 = (M1) (0.2) (P/F, 9%, 15 yrs.)
= ($167,300) (0.2) (0.2745)
= $9200

PW Salvage Value $ 9,200

M3) Land Cost - No additional land requirement for the evaporator-dryer

Land Cost = $ -0-

M4) Present Worth

M4= M1 - M2 + M3
= $167,300 - $9,200 + 0
= $158,100

Present Worth = $ 158,100

M5) Equivalent Annual Cost

M5 = M4 (A/P, 9%, 15yrs)
= $158,100 (0.12406) = $19,600

Equivalent Annual Cost= $19,600/yr

M6) Equivalent Annual Vehicle Purchases and Salvage

No vehicles required for the Evaporator-Dryer itself.

Equivalent Annual Vehicle Purchases and Salvage = $ -0-

M7) Fixed Annual Cost

M7 = M5 +M6
= $19,600 + 0 = $19,600

Fixed Annual Cost = $ 19,600/yr

M8) Energy - Energy costs for the scraped surface evaporator are based on the power requirements for the 68 hp total required for the unit at 2.5 ¢ per KWH and steam costs associated with evaporating 75% of the moisture in the sludge at 0.4 cents per pound of steam.

Energy Cost = Power Cost + Energy Cost
= $1787 + 4633
= $6400

Energy Costs = $ 6400/yr

M9) Chemical Costs - There is no chemical cost associated with the scraped surface evaporator.

Chemical Cost = $ -0-

M10) Maintenance or Vehicle Costs -

No Vehicle Costs

Maintenance Costs = 1% of Capital Cost
= (0.01) (M1)
= (0.01) ($167,300) = $1700

Maintenance or Vehicle Costs = $1700/yr

M11) Labor - The DAF operator will also take care of the scraped surface evaporator, so no additional labor costs will be incurred.

Labor Costs = $ -0-

M12) Dumping Fees - Dumping is not included in operation of the sludge dryer.

Dumping Fees= $ -0-

M13) Total Annual Variable Costs

M13 = M8 + M9 + M10 + M11 + M12
= $6400 + 0 + $1700 + 0 + 0
= $8100/yr

Total Annual Variable Costs = $8100/yr

M14) Total Annual Average Equivalent Cost

M14 = M7 + M13
= $19,600 + $8,100 = $27,700/yr $ 27,700/yr

COLUMN N: Contract Wet Hauling

Past experience with wet hauling of screenings and conversations with ASCA members indicate that when contract hauling is available to contractors landfill, a charge of up to $200/day is assessed for a volume similar to the volume of sludge. Discussions with contract haulers indicate that some landfills do not accept liquid sludges.

The Contract hauler,if he accepts liquid sludges, is assumed to provide all containers, vehicles, labor, etc., for collecting and disposing of the waste; therefore, there are no Capital Costs involved with contract hauling.

The only variable costs that could be associated with contract hauling might be tied to the actual volume of material to be handled. Since it is assumed that a typical 9-hour processing day exists 120 days/year, daily costs can be extrapolated to yearly costs. The $200/day figure includes container rental, dumping fees, insecticide, chemicals, hauling charges, etc., borne by the contractor.

Cost will be $200/day, 1977 figures. Assume no increase due to inflation.

Annual Cost = ($200) (120) = $24,000

C-12) Avg. Annual Equivalent Dumping Fee = $24,000

C-13) = C12

C-14) = $24,000

COLUMN O : Wet Disposal to Private Landfill

Wet disposal to private landfill assuming shrimp processor owns, operates, and maintains truck and two tank trailers and dumps at a private landfill on a fee basis. Costs could be expected to be at some level which would pay the landfill operator enough to give the waste the special, immediate attention it requires in order to keep vectors under control.

01) through 05) - Only vehicles are involved, so these costs will come under vehicle columns.

06) Equivalent Annual Vehicle Purchases & Salvage

Two Trucks; year 1 (Truck and 2 trailers)
year 8 (Truck only)

Truck 1 (Truck and Trailer)

Capital Cost = \$30,000
Salvage Value of Truck = 15% of Truck cost of \$20,000 @ year 8
Salvage Value of Trailer = 0 @ year 15

PW Salvage Value = (\$20,000) (0.15) (P/F, 9%, 7yrs)
= (\$3000) (0.54703)
= \$ 1641

Total PW Truck 1 = \$30,000 - \$1641 = \$28,359

Additional Trailer:
Capital Cost = \$10,000
PW Salvage = 0

Total PW = \$10,000

Truck 2 (Truck Only)

Capital Cost @ year 8 = \$20,000
PW = \$20,000 (P/F, 9%, 8yrs)
= \$20,000 (0.50186)
= \$10,037

Salvage Value @ year 15 = 10%
PW Salvage = (\$20,000) (0.10) (P/F,9%, 15yrs)
= \$2000 (0.274538)
= \$ 549

Total PW Truck 2 = \$10,037 - \$549 = \$9,488

Total PW = \$28,359 + \$10,000 + \$9,488 = \$47,849

Equivalent Annual Cost = (\$47,849) (0.12406) = \$5900 \$5900/yr

07) Fixed Annual Cost

07 = 05 + 06
= 0 + $5900 = $5900

Fixed Annual Cost= $ 5900/yr

08) Energy Costs - include gasoline for trucks only

$$\frac{120 \text{ days}}{\text{yr}} \times \frac{5 \text{ trips}}{\text{day}} \times \frac{40 \text{ miles}}{\text{day}} \times \frac{1 \text{ gallon}}{6 \text{ miles}} \times \frac{\$0.60}{1 \text{ gall.}} = \$2400/\text{yr}$$

Energy Costs = $ 2400/yr

09) Chemical Cost - Assume that approximately $100/yr will be needed-cleaning, etc.

Chemical Costs = $ 100/yr

010) Maintenance or Vehicle Costs-
Assume the following costs for each truck, with each truck having about a 7 1/2 year life.

Brakes, hydraulic system, etc.	$ 2,500
2 sets of tires @ $200/tire @ 8 tires/set	$ 3,200
Tire repairs	$ 350
Batteries (2 @ $75 per)	$ 150
Insurance, fees @ $2500/yr	$ 18,750
Tune ups (4 @ $100 per)	$ 400
Water Pump, msc. repairs	$ 1,000
	$ 26,350

$26,350/ 7 1/2 years = $3500/yr

Maintenance or Vehicle Costs = $ 3500/yr

011) Labor

One full time truck driver is required.

($4/hr) (1.25) (2080 hrs/yr) = $10,400

Labor = $ 10,400/yr

012) Dumping Fees

Assume $10/Ton Fee

$$\frac{27 \text{ ft}^3}{\text{yd}^3} \times \frac{7.48 \text{ gall.}}{\text{ft.}^3} \times \frac{2.5 \text{ lb}}{\text{gallon}} = \$2.50/\text{yd}^3$$

012) continued

($2.50/yd^3$) (25 yd^3/day) (120 days/yr) = $7500/yr

Dumping Fees = $ 7500/yr

013) Total Annual Variable Cost

013 = 08 + 09 +010 + 012
= $2400 + $100 + $3500 + $10,400 + $7500
= $23,900

Total Annual Variable Cost = $ 23,900/yr

014) Total Annual Average Equivalent Cost

014 = 07 + 013 = $5900 + $23,900 = $29,800

Total Annual Average Equivalent Cost = $ 29,800/yr

COLUMN P: Wet Disposal to Owner's Landfill

P1, P2) Vehicles are included in Line 6

P3) Land Cost

Based on disposal of all sludge at 0.5 ft^3/Ft^2. It is generally agreed that no land is available for any purpose at any cost in the vicinity of the shrimp plants, much less, land for disposal of shrimp solids.

Assume that land can be purchased 50 miles away at $1000/acre in sufficient quantity to serve as a landfill to be operated by the owner.

$$500 \text{ gpm} \times \frac{60 \text{ min.}}{\text{hr}} \times \frac{9 \text{ hrs.}}{\text{day}} \times \frac{120 \text{ days}}{\text{year}} \times \frac{1 \text{ ft}^3}{7.48 \text{ gal.}} \times 2\% \text{ Sludge Flow}$$

$$= 88631 \text{ ft}^3\text{/year}$$
$$= 27.4 \text{ yd}^3\text{/day } (738 \text{ ft}^3\text{/day})$$

$$\frac{86631 \text{ ft}^3}{\text{year}} \times \frac{1 \text{ ft}^2}{0.5 \text{ ft}^3} \times \frac{1 \text{ acre}}{43560} = 4 \text{ acres/year}$$

4 acres/year X 15 years X 1000/acre =$60,000

Land Cost = $ 60,000

P4) Present Worth

P4 = P1 - P2 + P3 = $60,000

Present Worth $ $60,000

P5) Equivalent Annual Cost

PW (A/P, 9%, 15 yrs) = $60,000 (0.12406)
= $7400/yr

Equivalent Annual Cost = $ 7400/yr

P6) Equivalent Annual Vehicle Purchases & Salvage -
Costs are the same as O6 except 2-70hp farm tractors, implements are required. Assume the tractors are at year 1 and 8, 15% Salvage of 1st tractor, 10% Salvage of 2nd tractor with no salvage for implements.

Tractor 1

Capital Cost = $18,000
PW Salvage Value @ yr 8 = ($18,000) (0.15) (0.54703) = $1477

PW = $18,000 - 1477 = $16,523

P6) Continued

Implements

2 @ \$2000 each = \$4,000
Salvage = 0

Tractor 2

Capital Cost @ yr 8 = \$18,000
PW = \$18,000 (P/F, 9%, 8 yrs)
= \$18,000 (0.50186) = \$9,034

Salvage Value @ yr. 15 = (\$18,000) (0.10) = \$1800
PW = (1800) (0.274538) = \$494

Total PW Tractor 2 - 9034 - 494 = \$8540

Total PW = \$16,523 + \$4000 + \$8540
= \$29,063

Annual Cost = (\$29063) (0.12406) = \$3,600

Total Annual Cost = \$3600 + 06
= \$3600 + 5900
= \$9500

Equivalent Annual Vehicle
Purchases and Salvage = \$ 9500/yr.

P7) Fixed Annual Cost

P7 = P5 + P6
= \$7400 + \$9500 = \$16,900

Fixed Annual Cost = \$ 16,900/yr

P8) Energy Cost
Gasoline for Truck

120 days X 1 trip/day X 100 miles/trip $\div \frac{6 \text{ miles}}{\text{gal.}}$ X $\frac{\$0.6}{\text{gal.}}$ = \$1200/year

Fuel for Tractor @ 0.5 #/hp-hr, assume use 40 hp constantly
for 6 hrs/day, 120 day/year.

Assume fuel oil @ 60 lbs/Ft^3

0.5#/hp hr X 40 hp-hr. X $\frac{6 \text{ hrs}}{\text{day}}$ X $\frac{120 \text{ days}}{\text{year}}$ = 14,400 lbs fuel/ yr

$\div$ 60 lbs = 240 ft^3

$\frac{240\ ft^3\ fuel}{year} \times \frac{7.48\ gal}{ft^3}$ = 1800 gal/year X$0.6/gal = $1080/year

Round to $1100/yr.

Energy Cost = $1200 (truck) + $1100 (tractor) = $2300/year

Energy Cost = $ 2300/yr

P9) Chemical Cost - Same as 09

Chemical Cost = $100/yr

P10) Maintenance or Vehicle Costs

Truck Cost (from 010) = $3500/yr
Tractor Cost (estimated) = $1500/yr
$ 5000

Maintenance or Vehicle Cost = $ 5,000/yr

P11) Labor

Tractor driver:

($4.00)(1.25) (9hrs) (120 days) = $ 5400/yr
011 = $10,400/yr

Labor Costs = $15,800/yr

P12) Dumping Fees - None

Dumping Fees = $ -0-

P13) Total Annual Variable Cost

P-13 = P8 + P9 + P10 + P11 + P12
= $2300 + $100 + $5000 + $15,800 + 0
= $23,200/yr

Total Annual Variable Cost = $23,200/yr

P14) Total Annual Average Equivalent Cost

P7 + P13 = $16,900 + 23,200 = $40,100/yr

Total Annual Average Equivalent Cost = $ 40,100/yr

COLUMN Q: Haul to Owner's Landfill after M (Evaporator-Dryer) Treatment

Q1) Capital Cost - Covered in Vehicle Costs

Q2) Slavage Value - Covered in Vehicle Costs

Q3) Land Cost - Since the evaporator - dryer is assumed to reduce sludge volume by a factor of 4, only 25% of the land area with wet hauling would be required.

Land Cost = ($60,000) (0.25) =

Land Cost = $ 15,000

Q4) Present Worth

PW = Q1 - Q2 + Q3
= 0 - 0 + $15,000
= $15,000

Present Worth = $15,000

Q5) Equivalent Annual Cost

($15,000) (0.12406) = $1900

Equivalent Annual Cost= $1900/yr

Q6) Equivalent Annual Vehicle Purchases & Salvage

Assume Q6 = 75% of P6
= (0.75) (9500) = $7100

Equivalent Annual Vehicle Purchases and Salvages = $ 7100/yr

Q7) Fixed Annual Cost

Q7 = Q5 + Q6 = $1900 + $1700
= $9000

Fixed Annual Cost = $ 9000/yr

Q8) Energy - Assume 1/4 of P8

(0.25) ($2300) = $600

Energy = $ 600/yr

Q9) Chemicals - Same as P9

Chemical Cost = $ 100/yr

Q10) Maintenance or Vehicle Costs

Same as P10

Mainentance or Vehicle Costs = $5000/yr

Q11) Labor - Use Full Cost of Truck driver and full cost of tractor driver

Truck = $10,400
Tractor = $ 5,400
$15,800

Labor = $15,800/yr

Q12) Dumping Fees - None

Dumping Fees = $ -0-

Q13) Total Annual Variable Cost

Q13 = Q8 + Q9 + Q10 + Q11 + Q12
= $600 + $100 + $5,000 + 0 + $15,800
= $21,500

Total Annual Variable Cost = $21,500/yr

Q14) Total Annual Average Equivalent Cost

Q14 = Q7 + Q13
= $9,000 + $21,500
= $30,500

Total Annual Average Equivalent Cost = $ 30,500/yr

COLUMN R: Wet Disposal to Owner's Landfill (4 peelers)

R1) Capital Cost - Covered in Vehicle Cost

R2) Salvage Value - Covered in Vehicle Cost

R3) Land Cost - same as P3 but reduced by 1/2

Land Cost = ($60,000) (0.5) = $30,000

Land Cost = $ 30,000

R4) Present Worth

PW = R1 - R2 + R3 =$30,000

Present Worth = $30,000

R5) Equivalent Annual Cost

R5 = ($30,000) (0.12406) = $3700

Equivalent Annual Cost = $ 3700

R6) Equivalent Annual Vehicle Purchases and Salvage

Reduce P6 by 25% :

($9500) (0.75) = $7100

Equivalent Annual Vehicle Purchases and Salvage = $ 7100/yr

R7) Fixed Annual Cost

R7 = R5 + R6
= $3700 + $7100 = $10,800

Fixed Annual Cost = $ 10,800/yr

R8) Energy

It is assumed that a 4-peeler plant will incurre 1/2 the sludge energy costs of an 8-peeler plant.

1/2 (P8) = 1/2 (2300) = $1200

Energy Cost = $ 1200/yr

R9) Chemicals Same as 09, $100 Chemical Cost = $100/yr

R10) Maintenance or Vehicle Costs

Same as Q10

Maintenance or Vehicle Costs = $5,000

R11) Labor

Same as Q11

Labor = $ 15,800/yr

R12) Dumping Fees-

None

Dumping Fees = $ -0-/yr

R13) Total Annual Variable Costs

R13 = R8 + R9 + R10 + R11 + R12
= $1200 + 100 + $5000 + 15,800 + 0
= $22,100

Total Annual Variable Costs = $ 22,100/yr

R14) Total Annual Average Equivalent Cost

R14= R7 + R13
= $10,800 + $22,100
= $25,100

Total Annual Average Equivalent Cost = $ 25,100/yr

Sponsor of this Dissolved Air Flotation Treatment study of shrimp cannery wastewater was the American Shrimp Canners Association, P. O. Box 50774, New Orleans, Louisiana 70150. Member canners are listed below:

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Weems Brothers Seafood Company 1124 East Bay View Biloxi, Mississippi 39530	Mr. Charles Weems

List of Project Equipment and Manufacturers or Suppliers

SUPPLIER	EQUIPMENT
1. Acco Bristol-Division Waterbury, Connecticut 06720	Strip Chart Recorder
2. Allen Bradley 1201 South 2nd Street Milwaukee, Wisconsin 53204	Automatic Float Switches
3. Badger Meter, Inc. 6116 East 15th Street Tulsa, Oklahoma 74115	Flow Meter-Controller
4. Beach Precision Parts Company R D#1 Glen Rock, Pennsylvania 17327	Acid Tank Breather
5. BIF 1600 Division Road W. Warwick, Rhode Island 02893	BIF Purifax Sludge Conditioner
6. Carborundum Environmental Systems, Inc. Pollution Control Division P.O. Box 1269 Knoxville, Tennessee 37901	Dissolved Air Flotation System
7. Contherm Corporation Route #1 Newburyport, Massachusetts 01950	Con-Vap Dryer
8. Crane Company, Deming Division 884 South Broadway Salem, Ohio 44460	Process Pumps
9. Eagle Signal 736 Federal Davenport, Iowa 52803	Automatic Pump Timers

Supplier	Equipment
10. ITT-Marlow Fluid Handling Division ITT Corporation Midland Park, New Jersey	Sludge Pump
11. Kenics Corporation One Southside Road Danvers, Massachusetts 01923	Static Mixer
12. Lightnin Mixing Equipment Co., Inc. Rochester, New York	Mixers-Stirrers
13. The Metraflex Company 2323 W. Hubbard Street Chicago, Illinois 60612	Rate-of-Flow Meters
14. Rotex, Inc. 1230 Knowlton Street Cincinnati, Ohio 45223	Liquatex-Rotex Screens
15. Uni-Loc, Inc. 17401 Armstrong Avenue Santa Ana, California 92705	pH Controllers & Meters
16. Wallace & Tiernan Division Pennwalt Corporation 25 Main Street Belleville, New Jersey 07109	Chemical Feed Pumps
17. N-Con Systems Company 308 Main Street New Rochelle, N.Y. 10801	Automatic Sampler
18. DeLaval Corporation 1415 Hyde Park Avenue Hyde Park, Massassuchetts 02136	Bench Centrifuge

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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4. TITLE AND SUBTITLE Dissolved Air Flotation Treatment of Gulf Shrimp Cannery Wastewater		5. REPORT DATE March 1979 issuing date
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15. SUPPLEMENTARY NOTES

Co-sponsor was the American Shrimp Canners Association (ASCA) New Orleans, Louisiana

16. ABSTRACT

This study reports on the operation of a plant scale dissolved air flotation system installed to define and evaluate attainable shrimp cannery wastewater treatment levels. The system was operated in all three modes of DAF pressurization. Destabilizing coagulants investigation included alum, lignosulfonate(PRA-1)and cationic polymer(507-C). Using alum and anionic polymer 835A as a coagulant aid, significant removals of BOD, TSS and Oil and Grease were achieved. Operating data are presented which characterize the Gulf shrimp cannery wastewaters and show the removals attained. Data on oyster processing wastewaters are also presented.

In conjunction with the project, water use reduction and wastewater management practices were instituted at the study cannery resulting in large overall reductions of pollutants. Costs of the wastewater treatment system installation, opreation and maintenance are presented. Average annual wastewater treatment equivalent costs and costs per case of finished product are estimated.

Oyster canning wastewater can be treated and pollutant discharge can be reduced using the DAF shrimp wastewater treatment system. The problem of the handling and disposal of the DAF skimmings sludge (and screenings solids) has not been solved. Preliminary dewatering investigations are reported in this study.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Capitalized costs, Cost effectiveness, Dewatering, Effluents, Management, Operating costs, pH, Selection, Skimming, Sludge, Sludge drying	Dissolved air flotation, pressurization modes, chemical optimization, water management, plant scale reduction and treatment of Gulf shrimp and oyster cannery wastewaters	13/B

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