PROJECT COMPLETION REPORT

# DEMONSTRATION FOR SELECTED FOOD PROCESSES OF A POLLUTION REDUCTION SYSTEM UTILIZING OZONATION, PHASE II

SUBMITTED BY

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# INTRODUCTION

Whenever food stuffs are processed, there will always be an inherent generation of wastewater. The quantity of this food processing wastewater generated and its general quality has both economic and environmental consequences with respect to its treatability and disposal. The food industries in North Carolina discharge about 27.5 billion gallons of wastewater each year. North Carolina food plant wastewaters such as those generated by poultry, dairy, seafood, sweet potato and apple processing industries typically contain high organic and inorganic waste loads which often place enormous economic and environmental burdens on publically owned treatment works (POTWs) as well as taxing available potable water supplies.

Poultry processors are one of the largest water consumers of all the food processing industries. The United States Department of Agriculture's Food Safety and Inspection Service (FSIS) enforces a number of regulations that address the concern for proper sanitation of poultry products. Several of these regulations mandate the use of significant amounts of water to achieve proper sanitation levels, particularly from a microbiological standpoint. The poultry industry in the United States withdraws an estimated 5.5 to 10 gallons of fresh water for processing each broiler and 11 to 23 gallons for turkey carcasses. In 1986, the total number of broilers and turkeys processed was approximately 4.5 billion broilers and 208 million turkeys. This equates to an annual water consumption rate of 25 to 45 billion gallons of water for broilers and 2.3 to 4.8 million gallons for turkeys.

The average cost of water and sewer use service has been steadily increasing over the last several decades and will probably continue this upward trend. Together these costs greatly influence the average market price per carcass since they are directly proportional to water use and amount of wastewater generated. Therefore, individual poultry processors may eventually need to recycle process waters and reduce waste loads in order to retain their competitive edge in the marketplace. Additional incentives for examining this issue of recycling process water was recently provided by the United States Department of Agriculture. A final ruling was enacted by the Food Safety and Inspection Service of the USDA (1984) to allow recycling of chiller water. As stated in the Federal Register, the ruling amends the Federal poultry products inspection regulations to permit operators of poultry processing establishments the option, if specific controls are maintained, of reducing the amount of fresh water intake required for continuous poultry chillers by supplementing the reduced intake with larger amounts of reconditioned water. Implementation of this regulation would help to conserve fresh water and energy while reducing the waste loads generated without resulting in increased costs or threatening the wholesomeness of the product. Furthermore, this rule would reduce the burden on private and municipal effluent treatment facilities (POTWs), while maintaining sanitary conditions that are at least as effective as those provided under current practices. The type of water conditioning treatment is not specified.

The ruling requires that the reconditioning treatment attain a minimum of at least 60% reduction of total microorganisms including coliforms, E.coli and Salmonella and the maintenance of light transmission of no less than 60% of fresh water (Table 1).

Table 1. USDA Criteria for Recycling Chiller Water

| Minimum percent reduction of microorganisms in treated water[1] | Minimum percent light transmission in treated water (500 nm) | Gallons of reconditioned water to replace 1 gallon of fresh water |
|---|---|---|
| 60 . . . . . . . . | 60 | 1.75 |
| 70 . . . . . . . . | 70 | 1.50 |
| 80 . . . . . . . . | 80 | 1.35 |
| 90 . . . . . . . . | 80 | 1.25 |
| 98 . . . . . . . . | 80 | 1.10 |

[1] Total microorganisms, coliforms, _E. coli_, Salmonellae.

Over the past twenty years a number of government regulations at the Federal, State and local levels have been adopted to control the quality of wastewater that can be discharged into municipal water systems or directly into streams, estuaries or oceans. Most municipalities in North Carolina with the guidance of the state and Region IV offices have passed sewer use and pretreatment ordinances which severely restrict or prohibit what can be discharged into the municipal sewer system, The sewer use ordinance usually contains surcharges which are the proposed solution to equitable recovery of costs. Some municipalities have even required dairies and other food industries to pretreat their wastewaters with the equivalent of secondary treatment before discharge to the municipal system. Individual food plants are often faced with wastewater treatment costs exceeding one hundred thousand dollars per year and these costs have been rapidly increasing with more stringent regulations.

The results of Phase I of this overall project (Project No. 86-502) which examined the effects of ozonation alone and in combination with different physical wastewater treatments including slow sand filtration, dissolved air flotation, rapid sand filtration, and diatomaceous earth (DE) filtration, identified several water treatments that were effective in reconditioning overflow prechiller water to a quality level suitable for recycling back to the chiller. In addition, the treatments were effective in significantly reducing the effluent pollutant load including BOD, solids and fat, oil, and greases (FOG). Of all the treatments tested, a combination of prescreening, DE filtration and ozonation yielded the highest quality water in the shortest treatment time. Significant reductions in chemical oxygen demand (COD), total solids (TS), FOG, total aerobic microorganisms, coliforms and Salmonellae of 87%, 65%, 95%, 99.9%, 99.8%, and 99.9% respectively, were achieved with this water treatment. Furthermore, the water would qualify for recycling back to the chiller at a rate of 1.1 gallons of reconditioned water to replace 1.0 gallon of fresh water. The potential economic impact of these recycling opportunities was calculated for a 200,000 broiler per day processing plant to be approximately $93,000 per year with an estimated payback period of one year for implementing such a treatment system. The calculations did not take into account operating costs. In addition to these findings, the quality of broiler carcasses chilled in reconditioned chiller water was equivalent to broilers chilled in fresh water,

The objective of phase I of this overall project was to identify, by bench-top laboratory studies, an economical and effective water treatment system that would reduce the overall effluent waste loads and water demand in a broiler processing facility. The focus of these preliminary studies was on treating overflow chiller water, whole bird rinse water, and neck chiller water. With these preliminary studies completed, the objective of phase II of this project was to choose a successful water treatment identified in phase I, refine and optimize the treatment system, and conduct a series of on-site, pilot-scale feasibility and demonstration trials at a selected broiler processing plant.

## LITERATURE REVIEW

### Water Use in The Poultry Industry

Water has many uses in poultry processing including scalding, product preparation, cooling whole carcasses and parts, transporting products and wastes and cleanup (Carawan, 1974). The concern of poultry processors in providing clean, good tasting poultry products coupled with the government's legal authority to insure the sanitary processing of broilers has further increased the use of water in the processing plant. Federal poultry inspection regulations call for a water supply that is ample, clean and potable. To prevent product adulteration, water that is to be used in direct contact with carcasses and equipment must originate from a potable supply. Previously, the only exception to this regulation is the use of chiller overflow water in the scalder (Houston, 1985). The USDA Food Safety and Inspection Service (FSIS) enforces a number of regulations to address the sanitation level of poultry products and these measures rely on the use of significant volumes of water. The luxury of having unlimited supplies of inexpensive quality water is quickly declining across the United States. The large volumes of water used in poultry processing and equally large waste loads generated have become an important problem for many municipalities. The disposal of large amounts of wastewater raises both economic and environmental concerns. The average costs of water and sewer service have been steadily increasing over the last several decades and will probably continue this upward trend. These costs greatly influence the average cost to process each carcass and ultimately the market value of each carcass since they are directly proportional to water use and wastewater generated. With regional water shortages, pollution problems and new policies on pricing which recognize the economic value of water, daily water conservation practices by all poultry plants will become a necessity. Water conservation and reuse is an issue that goes far beyond the immediate concerns of the USDA or poultry industry. The use of water by the public or any industry has raised important environmental and public health questions that cannot be ignored by any group (Houston, 1985).

Currently the USDA allows some process water to be reused under strict user guidelines. Guidelines for using reconditioned chiller water in poultry chillers are outlined in the code of Federal Regulations (USDA, 1984). This regulation specifies that reconditioned chiller water must have at least a 60% reduction in microorganisms including total coliforms, E. coli and Salmonellae and the maintenance of light transmission of the treated water to be at no less than 60% of that of fresh potable water.

Several studies have been conducted to evaluate the effect of reusing poultry process water. Processors must carefully consider a number of aspects prior to initiating any recycling or reuse program such as the following: health effects; regulations; product quality; feasibility; reliability (Russell, 1980). Carawan (1974) demonstrated that the use of chiller water and final bird wash water for flushing in gizzard splitting machines had no detrimental effects on either the wholesomeness of the gizzards or of the whole carcasses. Effluents from the final bird washer and chiller water were initially screened before using. The total bacterial and coliform counts of the gizzards collected at the splitter exit were not statistically different between the two treatments (Carawan, 1974).

Poultry processing plants can reduce their waste discharges by several treatments including rotary screening, chemical flocculation, dissolved air flotation and low-load biological aeration. Diatomaceous earth filtration has also been utilized for purification of process waters from the prechiller and wash tanks (Litchfield, 1984; Sheldon and Chang, 1987; Sheldon and Carawan, 1988).

## Chilling Poultry

Poultry products are chilled to reduce the carcass temperature as well as to reduce the rate of microbial growth in order to extend shelf life. The most common method for chilling carcasses is direct immersion in water vats chilled by ice or mechanical means. Normally two or three tanks in series are used employing in most cases a countercurrent flow pattern of water and ice in one direction and the carcasses in the opposite direction (Stadelman, 1974). The internal carcass temperature must be reduced to 40°F(4.4°C) or less within a specified time period: that is, within 4 hr for carcasses under 4 lb; 6 hr for carcasses 4 to 8 lb; and 8 hr for those over 8 lb. Most immersion chillers reduce breast muscle temperature to less than 40°F in about 30 to 50 minutes. During chilling carcasses absorb between 6 and 12% moisture by weight (Carawan, 1974). To maintain the required overflow of chiller water which prevents the excessive buildup of microbial contaminants, the following volumes of fresh water must be added per carcass: for frying chickens, 0.5 gal(1.89 L); for turkey, 1 gal(3.78 L). There are several styles of chillers including drag chillers, parallel-flow tumble chillers, counter-flow tumble chillers and oscillation vat chillers (Houston, 1985).

Important factors contributing to the microbial loads of immersion chilled poultry are the bacterial contamination levels of carcasses before chilling, the volume of water overflow per carcass and the ratio of birds to water in the chiller (Stadelman, 1974). In evaluating the effect of continuous immersion chillers, Kotula et al. (1962) found that total microbial counts of carcasses were reduced during chilling. In contrast, Clark et a1.(1969) found that continuous immersion chilling was related to an increase in carcass microbial counts. Chilling may also allow for cross-contamination between carcasses.

## Diatomaceous Earth Filtration

Diatomaceous earth (Celite diatomite) is the skeletal remains of tiny aquatic plants called diatoms. Over many years their skeletons formed deep deposits on the ocean floor which eventually rose to become part of the land mass. These microscopic plants have the unique capability of extracting silica from the water to produce their skeletal structure. The celite deposit is distinguished by high purity and an almost infinite variety of diatom shapes and sizes composed predominantly of pure silica. U.S. deposits in Lompoc, California are considered the largest and purest in the world. When deposited on a filter septum the diatomaceous earth forms a rigid but porous filter cake which sieves out particulate matter from liquids as they pass through the filter. Celite filter aid has virtually no effect on the odor and taste of liquids passing through the filter (Manville Bull., 1986).

Filtration using diatomaceous earth is a two-step operation. First, a thin protective layer of filter aid (diatomaceous earth), called the precoat, is built up on the filter septum by recirculating a filter aid slurry. After precoating, small amounts of filter aid (body feed) are continuously added to the liquid to be filtered. As filtering progresses, the filter aid mixes with suspended solids from the unfiltered liquid and is deposited on top of the precoat. Thus, a new filtering surface is continuously formed. The minute filter aid particles provide continuous microscopic channels which entrap suspended impurities but allow clear liquid to pass through without clogging.

The efficient, economical filter aid must: (1) have a rigid, intricately shaped, porous structure; (2) form a highly permeable, stable, incompressible filter cake; (3) remove fine solids at high flow rates; and (4) be chemically inert and essentially insoluble in the liquid being filtered. Diatomaceous earth meets these requirements due to the wide variety of intricately shaped particles and inert composition it possesses. It is practically insoluble in all but a few liquids.

For a given liquid, clarity of filtrate is governed principally by grade and amount of filter aid used in the body feed, grade and amount of filter aid used for precoat, and length of cycle and filtration rate which are governed by the degree of pressure increase in the filter cell. Variation in pressure, vibration and air bubbles may also affect the water clarity. The purpose of the precoat is to prevent the filter septum from becoming clogged by impurities which thus prolongs septum life, to give immediate water clarity and to facilitate cleaning of the septum at the end of the cycle. There are several DE filter types; plate and frame filter, tubular filter, vertical tank-vertical leaf filter, horizontal tank-vertical leaf filter, rotating leaf filter and horizontal leaf filter. The essential components of the DE filtration system consist of the filter, the filter feed pump, tanks containing filtered aid for precoating and body feed addition and the body feed pump for continuous addition of filter aid (Manville Bull., 1986).

Diatomite filters were initially used in the U.S. during World War II to supply drinking water to the combat forces engaged in world-wide military operations. Diatomite filter aids are now widely used in many industries and have become an integral part of many processes. Besides removing turbidity from process water, celite diatomite filter aids are used to remove catalysts, stabilization chemicals and adsorbents. Listed below are just a few of the products which are being filtered by celite diatomite filter aids: antibiotics, fruits and vegetable juices, alginates, oils, waxes, dairy products, gelatin, inorganic chemicals (brine, sodium hydroxide, magnesium salts), dry cleaning solvents, water (process, municipal, waste), cane sugar and beverages (beer, wine, soft drinks, fruit juices) (Manville Bull., 1986).

Diatomite filters have been used with success to remove iron and manganese from a number of ground waters. In each instance, preconditioning is necessary to change the dissolved iron or manganese compound into a chemical form that can be readily removed by filters. A diatomite filter can also effectively remove suspended substances from water and can produce water of equal or better clarity than conventional rapid sand filters (Bryant, 1977).

A comparative study of high-rate conventional treatments, direct filtration with granular media (lower filtration rates than conventional treatment) and ozone-diatomaceous earth filtration was conducted on an upland water supply. Water quality, efficiency of operation and maintenance and cost considerations were addressed. The effluent from the ozone-DE process had a 35% lower trihalomethane concentration than those achieved by conventional treatment (consisting of flocculation, sedimentation and high rate granular filtration) and a 43% lower concentration than those achieved by direct filtration (all tests were conducted using postchlorinated samples). For this particular application, the ozone-DE treatment proved to be the process of choice. The major reasons for selecting the ozone-DE process are that it is less costly to install and operate, it is more compatible with the neighborhood environment in appearance and operation and it is more adaptable to expansion and additions that may be needed in the future to meet more stringent organic residual regulations (Bryant et al., 1980). A second pilot plant study conducted by Bryant (1977) demonstrated that a process consisting of ozonation followed by diatomite filtration is a reliable and economical treatment for the effective removal of color, turbidity and iron and manganese for municipal water supplies. Futhermore, this newly developed process lends itself to fully automated operation both in the ozonation and in the diatomite filtration stages. Additional benefits include less material handling, effective diatomaceous earth recovery, and better manageability of the wastewater and sludge during processing. The major disadvantages of the ozone-DE filtration process is the lack of water treatment experience either in the operation of a large-capacity diatomaceous earth filter or in the recovery and recycling of diatomaceous earth and the high energy operating costs (Bryant, 1980).

When a filtration study is undertaken on a wastewater such as overflow chiller water, several filtration factors should first be established. The factors include: the amount of suspended solids (turbidity) that must be removed from the wastewater; the nature of the turbidity or suspended solids, i.e. compressible, gelatinous, crystalline, etc.; what is an acceptable clarity for the filtrate; and what is an acceptable filter cycle length or the length of time a filter must run between cleanings. When these criteria are established, testing should proceed in three series. The first series of tests should establish the correct type of celite to use for filtration. This is usually a grade that will maintain the fastest filtration flow rate without excessive pressure buildup, while providing an acceptable clarity. The second series of tests should determine the optimum body feed rate. Optimum may be defined as the amount of body feed which produces the maximum yield expressed in gallons of filtrate per pound of DE, as the amount of body feed which fills the filter cake space just as the practical limit of filter pressure is reached, or the amount of body feed which gives the longest possible cycle regardless of DE consumption. The final series of tests are run to determine a suitable filtration rate. Filtration rates are used to determine the size of the filter (and the capital costs) that will be necessary to treat a given volume of water in a specified period of time.

## OBJECTIVES

1. To identify and select a poultry processing plant(s) at which the on-site pilot-scale tests will be conducted.
2. To conduct a series of pilot-scale demonstration tests at the selected poultry processing plant(s) on the poultry chillers and final carcass rinse unit operations.
3. To sample and analyze the wastewater before and after treatment for COD, solids, FOG, and microbial loads.
4. To evaluate the technical and economic aspects of the water treatment system.
5. To develop a project report which details the system design and operation, the capital, operation and maintenance costs, and the payback.

## MATERIALS AND METHODS

### Processing Plant Site

A Golden Poultry Inc. broiler processing plant located in Durham, North Carolina was chosen to conduct the on-site pilot-scale demonstration tests for this project. The Durham plant processes an average of 115,000 broilers per day using two processing lines and can be classified as a medium-to-large size plant. All products are inspected by the United States Department of Agriculture with the direct supervision of veterinarians. Two sources of process water were treated in this study including the prechiller overflow water and final carcass rinse water. Water from these sources were either treated on-site or transported within 30 min of sampling to North Carolina State University to conduct preliminary trials for optimizing the DE filtration operating parameters.

## Water Sample Collection

For the preliminary filtration studies to optimize filtration parameters, 5 gallons of overflow prechiller water per trial were sampled two hours following plant startup and transported to NCSU. All sampled water was initially screened through a #20 mesh sieve (Fisher Scientific Co., Pittsburgh, PA) to remove large particulates. On-site filtration runs were conducted within two hours of plant startup at the site of each unit operation (prechiller and final carcass rinse station). Water samples, including non-treated and treated process water, used in determining the various water quality parameters were collected in sterile Whirl-Pak bags (Nasco Inc., Fort Atkinson, WI) and transported under ice to NCSU for analysis.

## Filtration Test Units

Process water was filtered through one of two DE pressure leaf filters. The first unit was a Walton constant rate pressure leaf filter having an active filter area of 20.4 $cm^2$ (Manville Products Corp., Denver CO). This filter was used to conduct the bench-top filtration optimization studies at NCSU. The stainless steel filter screen media was precoated with one of several different grades of Celite (DE) (Manville Products Corp., Denver, CO) to determine the optimum grade of DE to achieve the fastest flow rate while providing an acceptable water quality. The filter gap between the filter septum and pressure leaf walls was preset at 3.49 cm. DE precoat and body feed rates were determined by preliminary study and will be described in detail under Experimental Design. A homogeneous suspension of the chiller water and DE body feed was maintained by continuous stirring with a magnetic stirrer. The filtration unit was presanitized prior to each run by passing one liter of hypochlorite solution through the pump, lines, and filter followed by continuous rinsing with 5 liters of sterile distilled water.

The second filtration unit which was tested both at NCSU with smaller water volumes and during the on-site demonstration trials was a Manville one square foot (0.09 $m^2$) pressure leaf test filter. Data derived from using this filter may be directly used to size a production filter. The stainless steel filter screen was precoated with either 68 or 90 g of Celite (DE) (Manville Products Gorp.). The flow rate was maintained at either 0.75 or 1.0 gallon/min yielding a filtration rate of either 0.75 or 1.0 gallon/$ft^2$/min. The Celite body feed rate was adjusted to maintain a 5:l ratio of DE to suspended solids (wt/wt). Prior to each run the pumps, lines, and filtration unit were presanitized by circulating 18.9 liters of hypochlorite solution through the unit for 5 min and rinsed with tap water for 15 min at a flow rate of 18.9 liters per min. Filter head pressure readings were recorded at selected time intervals during the filtration cycle for the Walton and 1.0 square foot filters.

## Experimental Design

Experiment 1. The objective of this first series of experiments was to evaluate the effectiveness of the Walton DE pressure leaf filter by first determining the correct grade of Celite (DE) to use in filtering broiler prechiller overflow water. Several grades of DE (Manville Products Gorp.), precoat rates, body feed rates, and filtration flow rates were initially screened to optimize the filtration characteristics of the Walton filter. The ultimate goal was to select the correct DE and filter operating parameters to achieve the fastest flow rate, longest cycle time and best filtered water quality. Some of the physical and chemical characteristics of the different DE grades examined in these studies are summarized in Table 2.

Trial 1: In this first trial several grades of DE were screened for filtration characteristics including Filter Cel, Celite 577, Standard Super-Cel, Celite 512, Hyflo Super-Cel, Celite 501, Celite 503, and Celite 535. Based on preliminary findings the following filter operating parameters were used for each grade: pre-coat weight - 1.5 g, body feed rate - 1 g/liter of water, flow rate - 84 ml/min, filter gap - 1 3/8 inches, and volume of water filtered - 3 liters. Filtrates were sampled at approximately 5 min intervals, analyzed for light transmission (500 nm, %T), and compared to the nontreated water. Incremental filter leaf pressures and flow rates were monitored at approximately 1 min intervals.

Table 2. Physical and chemical characteristics of several grades of DE[1]

| Celite grade | median particle size (microns) | Median pore size (microns) | Density (dry) lbs./$ft^3$ | pH |
|---|---|---|---|---|
| Filter Cel | 14.0 | 2.5 | 7.5 | 8.0 |
| Celite 577 | 14.6 | 2.5 | 8.0 | 7.0 |
| Standard Super-Cel | 15.4 | 3.5 | 8.0 | 7.0 |
| Celite 512 | 16.4 | 5.0 | 8.0 | 7.0 |
| Hyflo Super-Cel | 22.3 | 7.0 | 9.0 | 10.0 |
| Celite 501 | 24.3 | 9.0 | 9.5 | 10.0 |
| Celite 503 | 28.6 | 10.0 | 9.5 | 10.0 |
| Celite 535 | 34.3 | 13.0 | 12.0 | 10.0 |

[1] Celite (DE) grades are the products of Manville Products Corp., Denver, CO

Trial 2: The objective of this second series of experiments was to examine the effects of one selected grade of DE using the Walton filter on reconditioning overflow prechiller water. The filter screen was precoated with 1.5 g (0.15% of the water volume) of Celite 512. The filtration rate was maintained at 84 ml/min (1 gal/ft$^2$/min). A body feed rate of 0.75 g/liter of water processed (0.075% by wt.) was chosen for these experiments. One liter of chiller water was filtered with filtrates collected over the following filtration time intervals: 1 to 2 min, 3 to 4 min, 5 to 6 min, 7 to 8 min, and 9 min to end. The filtrates were analyzed in duplicate for %T, chemical oxygen demand (COD), and aerobic plate counts (APC, 0, 1-2, 7-8 min samples only). Filter leaf pressure was monitored at 1 min intervals. The experiment was replicated three times using chiller overflow water collected on different days.

Experiment 2. The second phase of this project examined the effects of screening and DE pressure leaf filtration, using the 1.0 ft$^2$ filter, of overflow prechiller water on water quality which included at least %T, COD, APC, and in some trials coliforms and *E. coli*. These studies were conducted at NCSU using overflow prechiller water transported from Goldkist. The filter screen was precoated with 68 g of either Hyflo Super Cel or Celite 512. Flow rate was maintained at either 1.0 gal or 0.75 gal/min. The Celite body feed was adjusted to maintain a 5:l ratio of DE to suspended solids (SS) (wt/wt). A SS concentration of 500 mg/liter for prescreened overflow prechiller water was used in our calculations. Filtrate samples were collected at 0, 5, 15, and 25 min of filtration. Filter pressure readings were taken at approximately 30 second intervals.

Trial 1: In this trial either Celite 512 or Hyflo Super Cel DE were used for the precoat and body feed. Flow rate was adjusted to 1.0 gal/min. Analyses included %T, COD, APC, and monitoring filter leaf pressure.

Trial 2: Trial 2 was a repeat of Trial 1 with the following exceptions: analyses included %T, COD, APC, coliforms, E. coli, Salmonellae, and monitoring leaf pressure.

Trial 3: In this trial Celite 512 was used as the precoat and body feed at the same rates described above. Flow rate was maintained at 0.75 gal/min. Analyses included %T, COD, APC, and monitoring leaf pressure.

Experiment 3. Using the optimized filtration parameters identified in the previous studies, the final phase of this project was conducted on-site at the Golden Poultry Inc. processing plant to demonstrate the feasibility of the water treatment on reconditioning both overflow prechiller water and final carcass rinse water and to establish the approximate filter run cycle times before flushing and recharging of the filter would be necessary. This information would also be needed in calculating equipment requirements and costs for scaling-up for commercial operations. Sufficient prechiller or final carcass rinse waters necessary to establish filter run times were screened and filtered (1.0 $ft^2$ filter). Water quality (%T, COD, APC) and filter leaf pressure were monitored at selected time intervals as outlined below.

Trial 1: The following filtration operating parameters were used in this trial: overflow prechiller water; Celite 512 precoat (68 g) and body feed (5:1, DE:SS by wt.); flow rate (1.0 gal/min); filtration time (160 min); pressure readings (ca 2 min intervals); water sampled at (0, 8, 20, 35, 50, 65, 120, 160 min).

Trial 2: Overflow prechiller water; Celite 512 precoat (90 g) and body feed (5:1, DE:SS by wt.); flow rate (0.75 gal/min); filtration time (210 min); pressure readings (5 min intervals); water sampled at (0, 5, 30, 60, 90, 120, 150, 180, 210 min).

Trial 3: Same as trial 2 with the following exceptions: filtration time (130 min); water sampled at (0, 30, 60, 90, 120 min).

Trial 4: Same as trial 2 with the following exceptions: filtration time (155 min); water sampled at (0, 30, 60, 90, 120, 150 min).

Trial 5: Same as trial 2 with the following exceptions: final carcass rinse water; average SS load of 162 mg/liter; filtration time (120 min); water sampled at (0, 15, 30, 60, 90, 120 min).

Trial 6: Same as trial 5 with the following exceptions: filtration time (120 min); water sampled at (0, 15, 30, 60, 90, 120 min).

Experiment 4. The final experiment evaluated the biocidal efficacy of combining either UV disinfection or hydrogen peroxide with screening and DE pressure leaf filtration. Forty gallons of broiler overflow chiller water were screened through the # 20 sieve, filtered through the 1.0 $ft^2$ pressure leaf filter at 1.0 gal/min (Celite 512, 68 g precoat, 5:1/DE:SS by wt.) and either pumped at a rate of 1 gal/min through a UV sterilizer or sufficient hydrogen peroxide (50%) added to a portion of the treated water to obtain concentrations of 0, 1, 3, or 5% by wt. hydrogen peroxide.

Trial 1: In this trial the screened and filtered water was passed through a preactivated Tami 5 UV sterilizer (Selectro Inc., Marietta, GA). The sterilizer employs a 0.64 cm exposure gap between the quartz and 304 stainless steel sleeves and has a UV lamp emitting 85% of its radiation at a wavelength of 253.7 nm. The lamp has a radiation dose rating of 32,000 microwatt second per sq. cm at 253.7 nm. Water samples were taken at 0, 3, 8, 15, and 32 min and analyzed in duplicate for %T, COD, and APC. This experiment was replicated only once.

Trial 2: In this trial the screened and filtered prechiller water was treated with 50% by wt. hydrogen peroxide to achieve final concentrations of 0, 1, 3, and 5% by wt hydrogen peroxide. Water samples (8 ml) were removed at 30 seconds, and at 1, 5, and 10 min of exposure, neutralized with catalase (56 ul of a 700 u1/100 ml stock solution), and the APC determined in duplicate.

### Water Quality Analyses

COD, %T at 500 nm, and SS were determined on sampled waters according to the Standard Methods for the Examination of Water and Wastewater (American Public Health Association et al., 1980). Optical densities were determined at 500 nm using a Gilford Model 2600 spectrophotometer. Tap water from the processing plant served as the blank. Optical densities were converted to % light transmission.

### Bacteriological Methods

Process water samples were serially diluted in 0.1% peptone water. Total aerobes (37°C, 48 h) were enumerated using plate count agar (PCA, Difco). Total coliforms and E. coli were enumerated by a 5 tube most probable number (MPN) technique (1 ml sample size) using lauryl sulfate tryptose, brilliant green bile lactose and EC broths (BBL). Gas positive EC tubes were streaked on Levine's eosin methylene blue agar (BBL). Typical dark colonies with or without a metallic sheen were streaked on PCA slants before confirming using the IMViC classification (American Public Health Association, 1976).

Isolation and enumeration of Salmonellae were based on a 3 tube MPN technique as described by Sheldon and Brown (1986) using a 100, 10, 1, and 0.1 ml water sample size. Positive cultures were identified using Roche Enterotube II test kits. Counts for water samples were reported on a per ml basis.

### Statistical Analyses

Where applicable the data were analyzed by analysis of variance and the mean differences separated by the Waller Duncan t test (SAS, 1982).

## RESULTS & DISCUSSION

In the initial stages of this project various grades of Celite (DE) were screened for their ability to remove particulate matter (suspended solids) from overflow prechiller water. See Appendix A for a description of the relationship between experiments, trials, tables, and figures. In conducting this screening, DE precoat rates, DE body feed rates and filtration flow rates were held constant. The goal was to identify a DE grade that allowed for the fastest filtration rate, longest filter run cycle (slowest pressure increase), and highest quality water. Water quality was monitored by measuring percent light transmission at 500 nm. Incremental filter leaf pressure and flow sates were also monitored throughout the filter run. Obviously, there are tradeoffs in trying to optimize these three parameters, ie., DE grades having smaller median pore sizes in general yield the highest quality water yet have slower filtration rates due to faster filter plugging and shorter filtration cycle times. The best filter aid is that grade which provides the fastest flow rate (or greater throughput per dollar's worth of filter aid) while maintaining an acceptable water clarity and microbial load.

In Trial 1 of experiment 1, seven grades of DE having a range in median pore sizes from 2.5 to 13.0 microns (Table 2 ) were evaluated. Filter-Cel had the smallest median particle and pore size (14.0 and 2.5 microns, respectively) examined in this study and thus would be expected to yield the highest quality water. As illustrated in Figure 1, flow rate dropped off significantly as leaf pressure increased indicating plugging of the filter cake. After 60 min of filtration the flow was only 21 ml/min whereas pressure had reached a maximum of 12.4 psi. Water clarity (Table 3) as measured by light transmission improved from 25.8% in screened water to an average of 96.0% (95.4-97.7%) after filtration. The water would easily meet the USDA water clarity criteria for recycling (60-80%). In general, a curvlinear increase in leaf pressure caused by filter cake plugging is indicative of a decrease in flow rate during filtration.

Celite 577 had similar physical characteristics to Filter-Cel and thus would be expected to act similarly to Filter-Cel during filtration. The pressure and flow profiles of the Celite 577 run (Fig. 2, Table 4) were similar to the Filter-Cel run. The two grades can be compared by examining the time required to reach 10 psi and the corresponding flow rates at this time. For Filter-Cel, it took 18 min compared to 32 min for Celite 577 to reach 10 psi. Furthermore, their corresponding flowrates at 10 psi were approximately (ca) 37 and 44 ml/min, respectively. Thus, Filter-Cel's pressure rise was almost twice that of Celite 577. Light transmission averaged 95.4% (90.3-97.7%) compared to 25.8% for the screened control.

The third DE grade evaluated (Standard Super Cel, SSC) had a median pore size of 3.5 microns and yielded a more linear (r= 0.97) pressure rise indicating a more gradual decrease in flow rate during filtration (Fig. 3, Table 5). The maximum pressure reached was 8.0 psi after 45 min of filtration. As expected, the average light transmission value dropped to 84.5% compared to the first two grades tested (95.4-96%). This water still exceeds the most stringent water recycling light transmission requirement of 80%.

Celite 512 which has a median pore size of 5.0 microns was screened next. The time/pressure data followed a linear trend (r= 1.0) indicating a stable flow rate throughout the filter run (Fig. 4, Table 6). A pressure of 10 psi was reached after 34 min of filtration. Light transmission averaged 95.3% (85.9-97.5%) which was higher than predicted based on pore and particle size characteristics. This improvement in water clarity may be partially attributed to the more constant flow rate achieved with this DE and therefore more constant filtration characteristics.

Hyflo Super-Cel (HSC, Fig. 5, Table 7) also yielded a linear increase in leaf pressure during filtering (r= 0.99). The median particle and pore size of this DE (22.3 and 7.0 microns, respectively) resulted in only a 2.14 psi rise in pressure over 40 min of filtration. The average flow rate was 75 ml/min. Water clarity averaged 90.9% (87.3-94.2%) compared to 22.4% for the screened control.

The leaf pressure of the Celite 501 run increased in a similar linear slope as the HSC run (Fig, 6, Table 8). Light transmission of the filtrate averaged 91.2% compared to 9.9% for the unfiltered water. This DE grade had a median particle and pore size of 24.3 and 9.0 microns respectively.

Celite 503 was screened next and showed a linear rise in leaf pressure (r= 0.99, Fig. 7, Table 9). Flowrate remained stable at 84 ml/min. The relatively large median particle and pore size of 28.6 and 10 microns respectively, allowed more SS through the filter cake which resulted in a lower %T. The average %T was 78.8% (74.6-83.4%).

The final DE grade to be tested was Celite 535 (Fig. 8, Table 10) which has the largest median particle and pore size of 34.3 and 13 microns respectively. Consequently, the linear pressure rise was slowest of all DE grades. The pressure reached a high of 2 psi after 42 min of filtration. The chiller water and Celite 535 did not mix well during stirring. Large globules formed which rose to the surface of the feed tank. The globules also partially clogged the tubing which restricted water flow and disrupted the filter cake. This problem was most evident at 15 min when the %T dropped to 48.5% compared to an average figure of 76.0% (48.5-88.6%).

The results of this screening showed that as median particle and pore size increased, percent light transmission decreased in the filtrate. Furthermore, the rate of pressure increase in the filter leaf was slower as median particle and pore size increased. Finally, the filtration time versus pressure relationship was linear if flowrate remained constant. This finding indicated that the filter cake was not plugging while a curvlinear rise in pressure was indicative of filter cake plugging and a reduction in flow rate.

Trial 2: The objective of this trial was to examine the water quality of overflow chiller water following a short filtration run through the Walton filter. Based on the results of the preliminary screening studies, the filter screen was precoated with Celite 512. Water quality was determined by measuring %T, COD, and APC. Filter leaf pressure increased gradually from 0.75 to 3.6 psi after 9 min of filtration. A projected filter run time of 95 min to reach the 30 psi maximum filter pressure is estimated under these conditions (Table 11). Filtration rate is a function of SS present in the water, the type of filter aid and filter back pressure (Manville Bull., 1986). The solids content of prechiller water can vary from hour to hour, from day to day, and from plant to plant but averaged over 8 h ca 571 mg/L (+/- 150 mg/L) from the Golden Poultry Inc. plant following prescreening (#20 sieve). The ratio of filter aid precoat and body feed to total solids used in this study was 2.6:l and 1.3:l (wt:wt), respectively. Since the amount of body feed used is a direct function of the solids to be removed, it will be necessary to adjust the DE body feed periodically as solids fluctuate to maintain an optimum ratio. It is generally suggested for commercial filters that the ratio of body feed to SS be 1:l for noncompressible solids.

Significant reductions in COD and APC were achieved with the Walton filter. The average %T was 97.9% which easily surpassed the minimum USDA chiller water recycling requirement of 60%. No significant differences in water clarity over time were detected between the filtered water samples. DE filtration also resulted in significant reductions in the APC. Log,, reductions of 1.02-1.4 (90-96%) were found following filtration which would qualify this treated water for recycling at a rate of 1.25 gallons of reconditioned water to replace each gallon of fresh water. Lillard (1978a) reported similar results of 1.4 log reduction in APC, a 2.0 log reduction in fecal coliforms and a 68-76% reduction in COD following filtration of broiler chiller water through a vertical tank pressure leaf DE filter. COD was significantly reduced in the present study by an average of 71%. This type of filter proved to be effective during short filter runs in reconditioning chiller overflow water.

Experiment 2. The objective of this next phase of the research was to test the effects of the 1.0 $ft^2$ DE pressure leaf filter on reconditioning overflow prechiller water. This experiment consisted of three trials of relatively short filter runs of 25 min.

Trial 1: Both Celite 512 and Hyflo Super Cel (HSC) DE grades were tested in this experiment at a precoat and body feed rate of 68 g and 5:l (DE:SS, wt/wt) respectively. Flow rate was maintained at 1.0 gal/min. A linear increase in leaf pressure was obtained using both Celite 512 (r= 0.99) and HSC DE (r= 0.97) (Fig. 9). The pressure increase rate for 512 was approximately 2.5 times faster than HSC. As expected, 512 removed about 5% more bacteria from the water than HSC (Table 12). The average reduction in APC was 97.8% for 512 and 92.1% for HSC. Both grades easily surpassed the USDA minimum microbial reduction (60%) requirements for recycling chiller water. The water clarity of Celite 512 filtered water averaged 98.3% T whereas HSC yielded an average %T of 94.7%. Both treatments surpassed the 80% maximum water clarity requirement for recycling chiller water. Reconditioned water from both treatments would qualify for recycling at the 1.25 gal1ons:l gallon fresh water recycle rate. COD was significantly reduced by an average of 67.7% and 72.7% for 512 and HSC respectively. This finding was somewhat surprising since HSC has a larger median pore size than 512 and thus would allow more SS to pass through. One explanation might be that the larger particle size of

HSC may physically entrap more solids than 512.

Trial 2: Trial 2 was a repeat of trial 1 except the analyses included enumerating coliforms, E. coli, and Salmonellae in addition to %T, APC, and COD. Both Celite 512 (r= 1.0) and HSC (r= 0.97) demonstrated similar time/pressure slopes as seen in trial 1 (Fig. 10). Similar reductions in APC and COD and increases in %T were detected in this trial compared to trial 1 (Table 13). Significant reductions were detected in COD, APC, coliforms, and E. coli of 60.5%, 95.8%, 98.4%, and 90.7% respectively for the Celite 512 trial and 62.0%, 88.5%, 77.1%, and 86.8% respectively for the HSC trial. Celite 512 was more effective than HSC in removing contaminating microorganisms while HSC removed about 1.5% more COD than 512. The %T of filtered water averaged 95.6% in the 512 run and 94.9% in the HSC filtered water. Salmonellae populations were reduced by approximately 57% following HSC filtration.

Trial 3: The final trial of experiment 2 examined the effects of filtering overflow prechiller water through Celite 512. Flow rate was reduced from 1.0 gal/min to 0.75 gal/min. Analyses included %T, APC, COD, and filter pressure. Figure 11 illustrates the effect of lowering flow rate on the time/pressure curve. In general, a reduction in flow rate increases the cycle length by reducing the rate of pressure increase. The APC and COD concentrations were significantly reduced by 98.0% and 67.4% respectively following filtration (Table 14). Light transmission increased from 18.7% for the screened control to an average of 99.4% after filtration.

The findings of this second group of experiments indicated that DE filtration of prechiller water with either Celite 512 or HSC diatomaceous earth at 1.0 or 0.75 gal/min significantly improved water quality. Although both grades of DE and flow rates were effective, Celite 512 was chosen over HSC to conduct the on-site demonstration studies. Celite 512 was more effective than HSC in removing contaminating bacteria yet is projected to have a shorter cycle length. To offset this factor, a flow rate of 0.75 gal/min was chosen over 1.0 gal/min to extend the 512 filter cycle length in the on-site demonstration trials.

Experiment 3. The objective of the final phase of this project was to conduct on-site filtration trials (1.0 $ft^2$ DE pressure leaf filter) on overflow prechiller and final carcass rinse waters using the optimized filtration parameters identified in the previous experiments. Secondly, filtration cycle lengths were estimated from these trials.

Trial 1: This first trial tested Celite 512 at a precoat weight of 68 g and flow rate of 1.0 gal/min. The time/pressure curve followed a linear increase (r= 0.99, Fig. 12). Similar improvements in water quality were obtained in this trial as summarized in the previous trials. Water clarity improved from 21% to an average of 96.1% T over the 160 min filter run (Table 15). Other than a slight pink color attributed to the soluble blood proteins, the water had very few particulates and resembled potable water. Significant reductions in COD and APC averaging 44% and 89.1% respectively, were achieved throughout the filter cycle. The efficiency of the pressure leaf filter improved during the run as indicated by further microbial reductions over the 160 min. Under the conditions of this study, a projected filter run cycle of 3.1 h to reach the 60 psi pressure leaf maximum is predicted ($y = 2.244 + 0.309x$).

Trials 2,3,4: The next three trials were similar to trial 1 except the precoat weight was increased to 90 g and the flow rate was decreased to 0.75 gal/min to extend the filter cycle. These runs were carried out for different lengths of time depending on the incoming water quality. The time/pressure curves for the three trials are pictured in Figure 13. All three trials followed a similar linear increase in pressure (r= 0.998). A projected average filter run time of 5.16 hours to reach the 60 psi pressure leaf filter maximum was calculated from these trials. The projected filtration cycles ranged from 4.2 h to 5.7 h for the three trials. Thus, the pressure leaf filter would require cleaning, sanitizing and the reapplication of the DE precoat every 5.2 hours. Thus, most commercial users of DE pressure leaf filters would have two pressure leafs, one in use while the other is reconditioned and precoated.

Water quality was significantly improved in each trial (Table 16). Water clarity averaged 93.4% across the three replicates and ranged from 87.6% to 96.8% T. These light transmissions easily surpass the USDA chiller water recycling requirements (60-80%). As illustrated in Table 16, water turbidity increased at the 30 min sampling yet still met the 60% minimum recycling requirement. Lack of clarity of the filtrate could be caused by any of several factors including a partially blinded septa, air in the feed liquid, and loss of flow during switch-over from precoating to filtering, resulting in disruption of the precoat or improper formation of the precoat.

The total microbial load in the chiller water was reduced an average of 94.2% across the three trials and ranged from 89.3% to 97.5%. Taking the %T and microbial reduction data into account, these trials demonstrated that the water would qualify for recycling back to the chiller at a rate of 1.25 gallons of reconditioned chiller water to replace every gallon of fresh water. This data does not take into account that %T increases and microbial reductions were calculated by comparing the water quality of the screened and filtered chiller water to the screened chiller water. In actuality the comparisons should be made between the water filtrate and the nontreated overflow prechiller water prior to screening. Screening alone was shown to remove 22% or more of the nontreated COD prior to filtration (Sheldon and Carawan, 1988). COD reductions in turn increased the light clarity or transmission by an average of 6.3 percentage points and may help to reduce the overall microbial loads. Thus, our calculations reflect a conservative approach in determining the recycle rate of reconditioned chiller water. In reality, the water would most likely qualify at the ratio of 1.1 gallon reconditioned water:l.O gallon fresh water.

COD loads were reduced an average of 61.8% across the three trials when calculated against the screened water samples. If calculated against nonscreened chiller water, an additional 22% of the COD would be removed giving a total reduction in COD of ca 84%. The results of these three trials will be used in calculating the size of the filter required at a broiler processing plant with a processing capacity of 200,000 broilers per day and the savings in water and sewer use costs, excess effluent load surcharges, energy, and recovered biomass.

Trials 5,6: Final carcass rinse water was screened and filtered in these two trials to estimate the filter cycle times and water quality. The water quality of final carcass rinse water was significantly better than prechiller water. The filter pressure followed a linear rise with time (Fig. 14, r= 0.998). An average filter cycle time of 12.8 hours (9.58-16.05 h) to reach 60 psi was calculated from the regression equations describing each time/pressure plot. The filter leaf would thus not require reconditioning during a processing shift.

Water quality parameters significantly improved following treatment (Table 17). Percent light transmission averaged 99.8% following filtration and resembled fresh tap water. Significant reductions in COD and APC averaging 91.6% and 95.8% respectively, were achieved following treatment. Although the USDA does not currently permit final carcass rinse water to be recycled for further product contact, these results clearly indicate that the quality of final carcass rinse water can be significantly improved by screening and filtration through DE. In fact, the quality of reconditioned final carcass rinse water surpasses the quality of chiller water.

<u>Experiment 4.</u> The objective of the final experiment was to evaluate two disinfectants, UV irradiation and hydrogen peroxide, for treating screened and DE filtered overflow chiller water. The final disinfectant step was added to provide a safety factor to ensure adequate microbial reductions following filtration.

Trial 1: Similar improvements in COD and light transmission as reported in previous experiments were found in this trial (Table 18). Water clarity improved from 30.7% (post screening) to an average of 95.9% T after filtration and UV irradiation. Furthermore, COD values decreased from 900 mg/L to an average of 294 mg/L or 67.3% reduction. No culturable microorganisms were recovered from the filtered and UV irradiated water which amounts to over a

3.9 log reduction. These findings indicate that UV disinfection of DE filtered process water would provide a significantly greater assurance of obtaining a microbiologically clean reconditioned process water that would qualify for recycling at a rate of 1.1 gallons of reconditioned water:l.O gallon of fresh water. Furthermore, this study demonstrates that the water quality of screened and filtered chiller water has sufficient water clarity permitting W radiant energy to transmit across the water stream and thus effectively kill all contaminating microorganisms.

Trial 2: The final experiment demonstrated that hydrogen peroxide at 1%, 3%, or 5% (by vol.) was sufficient to destroy any remaining microorganisms in screened and DE filtered chiller water (Table 19). No culturable microorganisms were detected in the treated water after 30 seconds of contact with hydrogen peroxide (1, 3, or 5%).

The findings of this project demonstrated that both overflow prechiller water and final carcass rinse water can be successfully reconditioned by screening and DE pressure leaf filtration. Furthermore, microbial reductions in the screened and filtered process water could be improved significantly by adding a final disinfection step. Chiller water undergoing such a treatment would qualify for recycling back to the chiller at a rate of either 1.25 or 1.1 gallons of reconditioned chiller water for each gallon of fresh tap water. The frequency of cleaning and precoating of the pressure leaf filter was projected to be 5.2 h for treating chiller water and 12.8 h for treating final carcass rinse water depending on the quality of the effluent process water and the operating parameters of the filter (precoat rate, body feed to SS ratio, flow rate, DE type and mesh size, type of organic matter in the process water, etc.) In addition to qualifying for recycling, significant reductions in the concentration of organic matter of over 60% was obtained with the tested water treatments.

## POTENTIAL ECONOMIC IMPACT AND WATER TREATMENT COSTS

The potential impact of introducing this water reconditioning treatment into a broiler processing plant will be discussed in the remaining portion of this final report. A broiler processing plant with a capacity of 200,000 broilers per day would consume at least 100,000 gallons of chiller water daily or 25,000,000 gallons annually. At a cost of $1.90 per 1000 gallons which includes a water cost of $.90/1000 and a sewer use cost of $1.00/1000 gallons, the annual cost of chiller water is $47,500. Assuming the reconditioned prechiller water does qualify for recycling, an estimated 85% of this water could be recycled or 21.2 million gallons annually valued at approximately $41,000 (250 days). Approximately fifteen percent of the chiller water is needed for the initial chiller fill and lost by spillage and absorption by the carcasses. In addition to the water savings, the plant’s effluent discharge load could be reduced by approximately 186,000 pounds of COD (61.8% reduction) and 145,000 pounds of total solids (65% reduction) per year. These amounts are approximately equivalent to 119,000 pounds of BOD and 47,000 pounds of SS per year (Carawan et al., 1974). Thus, annual savings in BOD surcharges of nearly $24,000 and SS surcharges of $9,500 are predicted (BOD and SS surcharge rate of $0.20/lb). Furthermore, the recovered solids could be sold to renderers for an annual savings of $1300 ($0.009/lb). Finally, significant energy savings in refrigeration costs of nearly $15,500 per year ($O.O6/kwh) is possible if these recycling practices are followed. The water temperature of the prechiller overflow water is ca 54.5°F versus 55.2°F after reconditioning. The incoming potable water temperature is ca 59.4°F (April, 1988) which must be chilled to ca 35.1°F. Thus, there is ca a 4.2°F differential in temperatures between untreated and reconditioned waters. A total annual savings of approximately $91,300, less operating costs and capital investments, are projected with the reconditioning of chiller water.

If we again assume that we have a broiler processing plant with a capacity of 200,000 broilers per day, the plant would use at least 116,000 gallons of final carcass rinse water daily or 29,000,000 gallons annually. At a cost of $1.90 per 1000 gallons, the annual cost of final carcass rinse water is $55,100. Assuming the reconditioned rinse water does qualify for recycling back to either the carcass rinse station or poultry chillers, an estimated 85% of this water could be recycled or 24.6 million gallons annually valued at approximately $46,835 (250 days). In addition to the water savings, the plant's effluent discharge load could be reduced by approximately 149,000 pounds of COD (91.2% reduction) and 78,500 pounds of total solids (estimated 65% reduction) per year. These amounts are approximately equivalent to 95,200 pounds of BOD and 25,600 pounds of SS per year (Carawan et al., 1974). Thus, annual savings in BOD surcharges of nearly $19,000 and SS surcharges of $5100 are predicted (BOD and SS surcharge rate of $0.20/lb). Furthermore, the recovered solids could be sold to renderers for an annual savings of $700 ($0.009/lb). A total annual savings of approximately $71,635, less operating costs and capital investments, are projected with the recycling of reconditioned final carcass rinse water.

## ESTIMATED CAPITAL AND OPERATING COSTS FOR RECYCLING CHILLER WATER

The following table (20) presents an approximation of what the estimated capital and operating costs would be for reconditioning chiller water using a water treatment system which includes screening and diatomaceous earth filtration using a pressure leaf filter. These figures are calculated for a processing plant with a capacity of 200,000 birds per day.

## TABLE 20. SUMMARY OF INITIAL AND ANNUAL COSTS AND INCOME FOR PROCESS AND EQUIPMENT CHANGES AND WATER AND WASTE MANAGEMENT, 1989

### Initial Costs

| ITEM | |
|---|---|
| Material costs (2-145 $ft^2$ DE filters, screens, pumps, lines, etc.) | $65,000 |
| Tax (5%) | 3,250 |
| Installation | 10,000 |
| Shipping | 2,000 |
| Total Initial Costs | $80,250 |

### Annual Budget (Increased Costs)

| | |
|---|---|
| Interest (loan)<br>(5% of initial costs; assumes 10% interest rate) | $4,012 |
| Maintenance (10% of material costs) | 6,500 |
| Depreciation (6.67% of material costs) | 4,336 |
| Labor per year (4 h/day @ $8.00/h:$5.00 + fringes) | 8,000 |
| Diatomaceous earth (3:l ratio DE:ss, 341,055 lb/year, @ $0.15/lb)[1] | 51,265 |
| Electricity (5hp pump, $0.35/h, 16 h/day) | 1,400 |
| Total Increased Costs | $75,513 |

### Annual Savings

| | |
|---|---|
| Total Savings: | $91,300 |
| Increased Costs: | - $75,513 |
| Annual Savings: | $15,787 (projected payback period: 5 years) |

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[1] Diatomaceous earth costs will vary depending on the ratio of DE:SS used. At a ratio of 5:l the cost would be $85,264/year; 4:l - $68,21l/year; 2:l - $34,106/year; 1:l - $17,053/year. The annual savings can vary significantly depending on the ratio of DE:SS used.

# CONCLUSIONS AND RECOMMENDATIONS

Poultry processors are one of the largest water consumers of all food processing industries, consuming in the range of 6-9 gallons of water per broiler processed. The average cost of water and sewer use service has been steadily increasing over the last several decades and will probably continue this upward trend. Broiler price increases will parallel the rise in water and sewer use costs. The objectives of this project were to identify and test an effective and economical water treatment to recondition and subsequently recycle poultry process water. The impact of these investigations would be a reduction in the water demand by processors, a reduction in sewer use charges and surcharges, and ultimately a reduction in the pollutant loads discharged to Publically Owned Treatment Works and the environment.

Passage of poultry chiller water through a screen and DE pressure leaf filter significantly improved the quality of the water and satisfied the USDA microbiological and water clarity standards for recycling chiller water. The discharge waste loads from the chillers were reduced more than 60% which would reduce the plant's total waste load discharge to municipal treatment works.

A projected annual savings of $91,300 is estimated for a 200,000 broiler per day processing plant if such a system were implemented. The projected initial costs for implementation of this system is estimated to be $80,250. The annual operating costs are estimated to be $75,513. Thus, the annual savings are estimated to be ca $15,787. We feel these savings can be significantly increased by optimizing the DE filtration system which would reduce the amount of DE needed. Furthermore, this study also provided evidence that other broiler process waters such as the final carcass rinse water can be reconditioned to a quality level that satisfies the USDA chiller water recycling regulations. This data would thus be useful for supporting a petition to the USDA for allowing other broiler process waters to be recycled, further reducing the poultry industries wastewater burden.

We would recommend that a full size filter be installed in a poultry plant to secure the necessary information to support such a petition. The successful completion of this additional study would confirm a savings by broiler processors of greater than 150,000,000 gallons of water yearly.

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The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service, nor criticism of similar ones not mentioned.

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Table 3. Effect of Filter-Cel diatomaceous earth filtration of chiller water on filter pressure, flowrate, and water clarity

| Filtration Time (min) | Pressure (psig) | Flowrate (gal/min) | % light Transmission (500 nm) |
|---|---|---|---|
| 2 | 3.81 | 74 | 97.2 |
| 3 | 4.75 | | |
| 4 | 5.75 | | |
| 6 | 7.15 | | |
| 7 | 7.62 | | |
| 10 | 8.50 | | 96.9 |
| 12 | 8.80 | | 97.7 |
| 14 | 9.20 | 39 | |
| 15 | 9.5 | | 96.1 |
| 16 | 9.6 | | |
| 18 | 10.0 | | |
| 20 | 10.2 | | 97.2 |
| 22 | 10.4 | | |
| 24 | 10.6 | | |
| 25 | 10.8 | 32 | 95.4 |
| 26 | 10.9 | | |
| 28 | 11.0 | | |
| 30 | 11.2 | | 96.8 |
| 32 | 11.4 | | |
| 34 | 11.5 | | |
| 35 | 11.6 | | 96.4 |
| 36 | 11.6 | 26 | |
| 38 | 11.8 | | |
| 40 | 11.9 | | 96.4 |
| 42 | 11.9 | | |
| 44 | 12.0 | 24 | |
| 45 | 12.1 | | 97.4 |
| 46 | 12.1 | | |
| 48 | 12.0 | | |
| 50 | 12.1 | | 95.8 |
| 52 | 12.2 | 22 | |
| 54 | 12.2 | | |
| 55 | 12.3 | | 92.9 |
| 56 | 12.3 | 21 | |
| 58 | 12.3 | | |
| 60 | 12.4 | | 91.9 |
| Control | | | 25.8 |

Table 4, Effect of Celite 577 diatomaceous earth filtration of chiller water

| Filtration Time (min) | Pressure (psig) | Flowrate (gal/min) | % light Transmission (500 nm) |
|---|---|---|---|
| 2 | 2 | 84 | 90.3 |
| 4 | 3.4 | | |
| 5 | 4 | | 94.1 |
| 6 | 4.4 | | |
| 7 | 4.8 | | |
| 8 | 5.2 | | |
| 9 | 5.6 | | |
| 10 | 6 | | 94.0 |
| 11 | 6.2 | | |
| 12 | 6.5 | | |
| 13 | 6.8 | | |
| 14 | 7 | | |
| 15 | 7.1 | | 93.8 |
| 16 | 7.4 | | |
| 17 | 7.6 | | |
| 18 | 7.9 | | |
| 19 | 8.2 | | |
| 20 | 8.5 | | 96.1 |
| 22 | 9 | 50 | |
| 23 | 9 | | |
| 24 | 9 | | |
| 25 | 9.1 | | 96.3 |
| 26 | 9.2 | | |
| 28 | 9.4 | | |
| 30 | 9.8 | | 95.4 |
| 32 | 10 | 44 | |
| 34 | 10 | | |
| 35 | 10 | | |
| 36 | 10.2 | | 96.9 |
| 38 | 10.5 | | |
| 40 | 10.6 | 42 | 97.8 |
| 42 | 11 | | |
| 44 | 11 | | |
| 45 | 11.1 | | 96.1 |
| 46 | 11.1 | 40 | |
| 48 | 11.3 | | |
| 50 | 11.4 | 38 | 96.6 |
| 52 | 11.5 | | |
| 54 | 11.6 | | |
| 55 | 11.7 | | |
| 56 | 11.8 | 36 | 96.3 |
| 58 | 11.8 | | 96.8 |
| Control | | | 25.8 |

Table 5. Effect of Standard Super Cel diatomaceous earth filtration of chiller water on filter pressure, flowrate, and water clarity

| Filtration Time (min) | Pressure (psig) | Flowrate (gal/min) | % light Transmission (500 nm) |
|---|---|---|---|
| 2 | 1 | 79 | 84.7 |
| 3 | 1.3 | | |
| 4 | 1.6 | | |
| 5 | 1.8 | | |
| 6 | 2 | | |
| 7 | 2.3 | 65 | |
| 8 | 2.5 | | |
| 9 | 2.6 | | |
| 10 | 2.8 | | 85.1 |
| 11 | 3.1 | 61 | |
| 12 | 3.2 | | |
| 13 | 3.4 | | |
| 14 | 3.5 | | |
| 15 | 3.8 | | 84.4 |
| 16 | 3.9 | | |
| 17 | 4.1 | 58 | |
| 18 | 4.3 | | |
| 19 | 4.5 | | |
| 20 | 4.6 | | 84.5 |
| 21 | 4.8 | 55 | |
| 22 | 5 | | |
| 24 | 5.2 | | |
| 25 | 5.4 | | 85.3 |
| 26 | 5.5 | | |
| 27 | 5.6 | | |
| 28 | 5.8 | | |
| 29 | 5.9 | 50 | |
| 30 | 5.9 | | 84.4 |
| 31 | 6 | | |
| 35 | 6.3 | | |
| 36 | 6.5 | 46 | |
| 38 | 6.5 | | |
| 40 | 6.6 | | 83.6 |
| 42 | 7.1 | | |
| 44 | 7.1 | 43 | |
| 45 | 7.2 | | 84.8 |
| 46 | 7.2 | | |
| 48 | 7.4 | | |
| 50 | 7.5 | 40 | 84.8 |
| 52 | 7.6 | | |
| 54 | 7.8 | 39 | |
| 55 | 7.8 | | |
| 56 | 7.8 | | |
| 58 | 8 | 38 | 83.7 |
| Control | | | 25.2 |

Table 6. Effect of Celite 512 diatomaceous earth filtration of chiller water on filter pressure and water clarity

| Filtration Time (min) | Pressure (psig) | % light Transmission (500 nm) |
|---|---|---|
| 2 | 0.9 | 85.9 |
| 5 | 1.8 | 95.9 |
| 6 | 1.9 | |
| 8 | 2.4 | |
| 10 | 3. | 97.3 |
| 12 | 3.4 | |
| 14 | 4 | |
| 15 | 4.2 | 96.8 |
| 16 | 4.6 | |
| 18 | 5.2 | |
| 20 | 5.9 | 94.6 |
| 22 | 6.4 | |
| 24 | 7 | |
| 25 | 7.5 | 96.6 |
| 26 | 7.8 | |
| 28 | 8.5 | |
| 30 | 9 | 97.5 |
| 32 | 9.4 | |
| 34 | 10 | |
| 35 | 10.6 | 97.5 |
| Control | | 23.7 |

Table 7. Effect of Hyflo Super Cel diatomaceous earth filtration of chiller water on filter pressure and water clarity

| Filtration Time (min) | Pressure (psig) | % light Transmission (500 nm) |
|---|---|---|
| 2 | 0.2 | 94.2 |
| 4 | 0.2 | |
| 5 | 0.2 | 87.3 |
| 6 | 0.3 | |
| 8 | 0.5 | |
| 10 | 0.8 | 90.2 |
| 12 | 1 | |
| 15 | 1.1 | 90.7 |
| 16 | 1.1 | |
| 18 | 1.2 | |
| 20 | 1.5 | 89.9 |
| 22 | 1.6 | |
| 24 | 1.6 | |
| 25 | 1.6 | 91.2 |
| 28 | 1.8 | |
| 30 | 1.8 | 92.8 |
| 32 | 1.9 | |
| 34 | 2.1 | |
| 35 | 2.2 | 91.4 |
| 36 | 2.2 | |
| 38 | 2.3 | |
| 40 | 2.4 | 90.8 |
| Control | | 22.4 |

Table 8. Effect of Celite 501 diatomaceous earth filtration of chiller water on filter pressure and water clarity

| Filtration Time (min) | Pressure (psig) | % light Transmission (500 nm) |
|---|---|---|
| 2 | 0.2 | 98.4 |
| 4 | 0.3 | |
| 5 | 0.4 | 92.1 |
| 6 | 0.4 | |
| 8 | 0.6 | |
| 10 | 1.0 | 90.6 |
| 12 | 1.2 | |
| 14 | 1.4 | |
| 15 | 1.6 | 88.8 |
| 16 | 1.6 | |
| 18 | 1.6 | |
| 20 | 1.9 | 90.6 |
| 22 | 2.0 | |
| 24 | 2.0 | |
| 25 | 2.3 | 84.7 |
| 26 | 2.3 | |
| 28 | 2.6 | |
| 30 | 2.8 | 94.2 |
| 32 | 2.9 | |
| 34 | 3.0 | |
| 35 | 3.0 | 90.8 |
| 36 | 3.0 | |
| 38 | 3.2 | 90.9 |
| Control | | 9.9 |

Table 9. Effect of Celite 503 diatomaceous earth filtration of chiller water on filter pressure and water clarity

| Filtration Time (min) | Pressure (psig) | Flowrate (gal/min) | % light Transmission (500 nm) |
|---|---|---|---|
| 2 | 0.2 | 84 | 83.4 |
| 4 | 0.4 | | |
| 5 | 0.6 | | 74.6 |
| 6 | 0.6 | | |
| 8 | 0.7 | | |
| 10 | 0.8 | | 76.7 |
| 12 | 1.0 | 84 | |
| 14 | 1.1 | | |
| 15 | 1.1 | | 78.5 |
| 18 | 1.5 | | |
| 20 | 1.6 | | 79.4 |
| 22 | 1.8 | | |
| 24 | 1.8 | 84 | |
| 25 | 2.1 | | 79.4 |
| 26 | 2.1 | | |
| 28 | 2.2 | | |
| 31 | 2.8 | | 79.8 |
| 32 | 2.8 | | |
| 34 | 2.9 | | |
| 35 | 3.1 | | 78.5 |
| Control | | | 37.6 |

Table 10. Effect of Celite 535 diatomaceous earth filtration of chiller water on filter pressure and water clarity

| Filtration Time (min) | Pressure (psig) | % light Transmission (500 nm) |
|---|---|---|
| 2 | 0.2 | 88.6 |
| 5 | 0.3 | 71.8 |
| 6 | 0.2 | 80.3 |
| 10 | 0.5 | 74.1 |
| 12 | 0.5 | |
| 14 | 0.8 | |
| 15 | 0.8 | 48.5 |
| 18 | 0.8 | |
| 20 | 1.0 | 79.8 |
| 22 | 1.1 | |
| 24 | 1.2 | |
| 25 | 1.2 | 80.8 |
| 26 | 1.3 | |
| 28 | 1.2 | |
| 30 | 1.5 | 82.6 |
| 32 | 1.6 | |
| 34 | 1.6 | |
| 35 | 1.8 | 76.3 |
| 36 | 1.8 | |
| 38 | 1.8 | |
| 40 | 2.0 | 79.7 |
| 42 | 2.0 | 78.4 |
| Control | | 22.5 |

Table 11. Effect of DE filtration on improving the quality of overflow prechiller water (3 replicates)

| Time of Filtration (min) | pressure psi | Water Quality[1] %T 500 nm | COD mg/L | APC cfu/ml |
|---|---|---|---|---|
| $0^2$ | $0.75^e$ | $20.6^b$ | $1171^a$ | $3.95^a$ |
| 1-2 | $1.55^d$ | $99.1^a$ | $279^c$ | $2.55^b$ |
| 3-4 | $2.10^c$ | $97.8^a$ | $348^b$ | $----^3$ |
| 5-6 | $2.70^b$ | $98.4^a$ | $363^b$ | ----- |
| 7-8 | $3.33^a$ | $97.1^a$ | $373^b$ | $2.93^b$ |
| 9 | $3.60^a$ | $97.0^a$ | ----- | ----- |

$^{a-e}$ Means within the same column with different superscripts are significantly different ($P<0.01$), n= 6 values per mean.

[1] %T: percent light transmission at 500 nm; COD: chemical oxygen demand; APC: aerobic plate count ($\log_{10}$).

[2] Chiller water after screening.

[3] Filtrates not analyzed.

Table 12. Effect of Celite 512 and Hyflo Super Cel DE filtration on improving the quality of overflow prechiller water

| Time of Filtration (min) | pressure psi | Water Quality[1] | | |
|---|---|---|---|---|
| | | %T 500 nm | COD mg/L | APC cfu/ml |
| Celite 512 Diatomaceous Earth | | | | |
| 0 | 2.0 | 14.7 | 1165 | 3.98 |
| 5 | 3.0 | 98.9 | 357 | 2.26 |
| 15 | 4.2 | 97.7 | 393 | 2.32 |
| 25 | 8.0 | 98.4 | 379 | 2.34 |
| Mean[2] | | 98.3 | 376 | 2.31 |
| % Reduction[3] | | | 67.7 | 97.8 |
| Hyflo Super Cel Diatomaceous Earth | | | | |
| 0 | 2.5 | 16.9 | 1736 | 3.89 |
| 5 | 2.5 | 94.1 | 446 | 2.69 |
| 15 | 3.2 | 94.8 | 491 | 2.81 |
| 25 | 4.5 | 95.2 | 484 | 2.85 |
| Mean[2] | | 94.7 | 474 | 2.78 |
| % Reduction[3] | | | 72.7 | 92.1 |

[1] %T: percent light transmission at 500 nm; COD: chemical oxygen demand; APC: aerobic plate count ($\log_{10}$).

[2] Average of 5, 15, and 25 min samples.

[3] % reduction relative to the 0 time (control) samples.

Table 13. Effect of Celite 512 and Hyflo Super Cel DE filtration on improving the quality of overflow prechiller water

| Time of Filtration (min) | pressure psi | Water Quality[1] | | | | | |
|---|---|---|---|---|---|---|---|
| | | %T 500 nm | COD mg/L | APC cfu/ml | Coliforms MPN/ml | *E. coli* MPN/ml | Salmonellae MPN/100ml |
| Celite 512 Diatomaceous Earth | | | | | | | |
| 0 | 2.0 | 22.0 | 925 | 4.24 | 3.11 | 2.35 | no confirmed Salmonellae |
| 5 | 3.5 | 97.0 | 335 | 2.81 | 1.23 | 1.23 | |
| 15 | 6.5 | 97.5 | 384 | 2.85 | 1.36 | 1.36 | |
| 25 | 8.8 | 92.3 | 375 | 2.91 | 1.36 | 1.36 | |
| Mean[2] | | 95.6 | 365 | 2.86 | 1.32 | 1.32 | |
| % Reduction[3] | | | 60.5 | 95.8 | 98.4 | 90.7 | |
| Hyflo Super Cel Diatomaceous Earth | | | | | | | |
| 0 | 2.5 | 19.0 | 1307 | 4.23 | 3.24 | 3.04 | 2.84 |
| 5 | 2.5 | 92.5 | 463 | 3.30 | 2.73 | 2.34 | 2.48 |
| 15 | 4.0 | 95.7 | 494 | 3.29 | 2.54 | 2.54 | 2.48 |
| 25 | 4.8 | 96.6 | 533 | 3.28 | 2.54 | 1.60 | 2.48 |
| Mean[2] | | 94.9 | 497 | 3.29 | 2.60 | 2.16 | 2.48 |
| % Reduction[3] | | | 62.0 | 88.5 | 77.1 | 86.8 | 57.1 |

[1] %T: percent light transmission at 500 nm; COD: chemical oxygen demand; APC: aerobic plate count ($\log_{10}$).

[2] Average of 5, 15, and 25 min samples.

[3] % reduction relative to the 0 time (control) samples.

Table 14. Effect of Celite 512 DE filtration (0.75 gal/min) on improving the quality of overflow prechiller water

| Time of Filtration (min) | Water Quality[1] | | |
|---|---|---|---|
| | %T 500 nm | COD mg/L | APC cfu/ml |
| 0 | 18.7 | 1088 | 3.80 |
| 5 | 98.9 | 306 | 1.70 |
| 15 | 99.3 | 375 | 2.36 |
| 25 | 100.0 | 384 | 2.26 |
| Mean[2] | 99.4 | 355 | 2.11 |
| % Reduction[3] | | 67.4 | 98.0 |

[1] %T: percent light transmission at 500 nm; COD: chemical oxygen demand; APC: aerobic plate count ($\log_{10}$).

[2] Average of 5, 15, and 25 min samples.

[3] % reduction relative to the 0 time (control) samples.

Table 15. Reconditioning of broiler overflow prechiller water using a one $ft^2$ DE pressure leaf filter (Celite 512)

| Time of Filtration (min) | Water Quality[1] | | |
|---|---|---|---|
| | %T 500 nm | COD mg/L | APC cfu/ml |
| 0 | 21.0 | 912 | 3.73 |
| 8 | 94.0 | 550 | 2.94 |
| 20 | 95.0 | 488 | 2.99 |
| 35 | 96.0 | 520 | 2.90 |
| 50 | 97.0 | 488 | 2.77 |
| 65 | 97.0 | 505 | 2.74 |
| 120 | 97.0 | 475 | 2.36 |
| 160 | 97.0 | 555 | 2.08 |
| Mean[2] | 96.1 | 511 | 2.68 |
| % Reduction[3] | | 44.0 | 89.1 |

[1] %T: percent light transmission at 500 nm; COD: chemical oxygen demand; APC: aerobic plate count ($\log_{10}$).

[2] Average of all samples except 0 time.

[3] % reduction relative to the 0 time (control) samples.

Table 16. Reconditioning of broiler overflow prechiller water using a one ft$^2$ DE pressure leaf filter (Celite 512), 3 trials

| Time of Filtration (min) | Water Quality[1] | | |
|---|---|---|---|
| | %T 500 nm | COD mg/L | APC cfu/ml |
| Trial 1 | | | |
| 0 | 26.4 | 1090 | 3.57 |
| 5 | 99.6 | 283 | 1.36 |
| 30 | 96.3 | 450 | 2.18 |
| 60 | 96.0 | 470 | 2.17 |
| 90 | 96.7 | 495 | 2.00 |
| 120 | 94.7 | 455 | 1.85 |
| 150 | 97.4 | 588 | 1.90 |
| 180 | 97.4 | 495 | 1.84 |
| 210 | 96.2 | 520 | 1.90 |
| Mean[2] | 96.8 | 470 | 1.90 |
| % Reduction[3] | | 56.9 | 97.9 |
| Trial 2 | | | |
| 0 | 19.1 | 1592 | 3.64 |
| 30 | 73.8 | 551 | 2.36 |
| 60 | 89.0 | 594 | 2.30 |
| 90 | 93.1 | 616 | 2.07 |
| 120 | 94.5 | 644 | 2.27 |
| Mean[2] | 87.6 | 601 | 2.25 |
| % Reduction[3] | | 62.2 | 95.9 |
| Trial 3 | | | |
| 0 | 23.8 | 1651 | 3.95 |
| 30 | 96.5 | 522 | 3.36 |
| 60 | 95.3 | 549 | 2.92 |
| 90 | 97.1 | 593 | 3.03 |
| 120 | 96.7 | 586 | 2.47 |
| 150 | 93.8 | 530 | 2.41 |
| Mean[2] | 95.9 | 556 | 2.84 |
| % Reduction[3] | | 66.3 | 92.2 |

[1] %T: percent light transmission at 500 nm; COD: chemical oxygen demand; APC: aerobic plate count ($\log_{10}$).

[2] Average of all samples except 0 time.

[3] % reduction relative to the 0 time (control) samples.

Table 17. Reconditioning of broiler final carcass rinse water using a one ft$^2$ DE pressure leaf filter (Celite 512), 2 trials

| Time of Filtration (min) | Water Quality[1] | | |
|---|---|---|---|
| | %T 500 nm | COD mg/L | APC cfu/ml |
| Trial 1 | | | |
| 0 | 68.9 | 698 | 4.69 |
| 30 | 100.0 | 52 | 2.11 |
| 60 | 100.0 | 61 | 2.35 |
| 90 | 100.0 | 58 | 2.53 |
| 120 | 100.0 | 61 | 2.72 |
| Mean[2] | 100.0 | 53 | 2.43 |
| % Reduction[3] | | 92.4 | 99.4 |
| Trial 2 | | | |
| 0 | 56.8 | 892 | 4.08 |
| 15 | 98.8 | 70 | 2.97 |
| 30 | 100.0 | 94 | 3.19 |
| 60 | 100.0 | 81 | 3.08 |
| 90 | 99.1 | 80 | 2.88 |
| 120 | 100.0 | 83 | 2.62 |
| Mean[2] | 99.6 | 82 | 2.95 |
| % Reduction[3] | | 90.9 | 92.6 |

[1] %T: percent light transmission at 500 nm; COD: chemical oxygen demand; APC: aerobic plate count ($\log_{10}$).

[2] Average of all samples except 0 time.

[3] % reduction relative to the 0 time (control) samples.

Table 18. Effect of screening, diatomaceous earth filtration (1.0 $ft^2$ filter) and UV irradiation of overflow prechiller water on water quality

| Filtration Time (min)[2] | Water Quality[1] | | |
|---|---|---|---|
| | %T 500 nm | COD mg/L | APC cfu/ml |
| 0 | 30.7 | 900 | 3.94 |
| 3 (no UV) | 96.0 | 200 | 2.35 |
| 8 (UV) | 95.1 | 340 | 0 |
| 15 (UV) | 97.3 | 317 | 0 |
| 32 (UV) | 95.1 | 320 | 0 |

[1] %T: percent light transmission at 500 nm; COD: chemical oxygen demand; APC: aerobic plate count ($\log_{10}$).

[2] UV irradiation was initiated following 3 min of filtration.

Table 19. Effect of screening, diatomaceous earth filtration (1.0 $ft^2$ filter) and hydrogen peroxide treatment of overflow prechiller water on aerobic plate count ($\log_{10}$ cfu/ml)

| Hydrogen Peroxide Concentration (by wt.) | Time of Exposure to $H_2O_2$ following filtration (min) | | | |
|---|---|---|---|---|
| | 0.5 | 1.0 | 5.0 | 10.0 |
| 0% | 3.29 | 3.34 | 3.32 | 3.32 |
| 1% | 0 | 0 | 0 | 0 |
| 3% | 0 | 0 | 0 | 0 |
| 5% | 0 | 0 | 0 | 0 |

Figure. 1. Effect of Filter-Cel diatomaceous earth filtration of chiller water on filter pressure and flowrate.

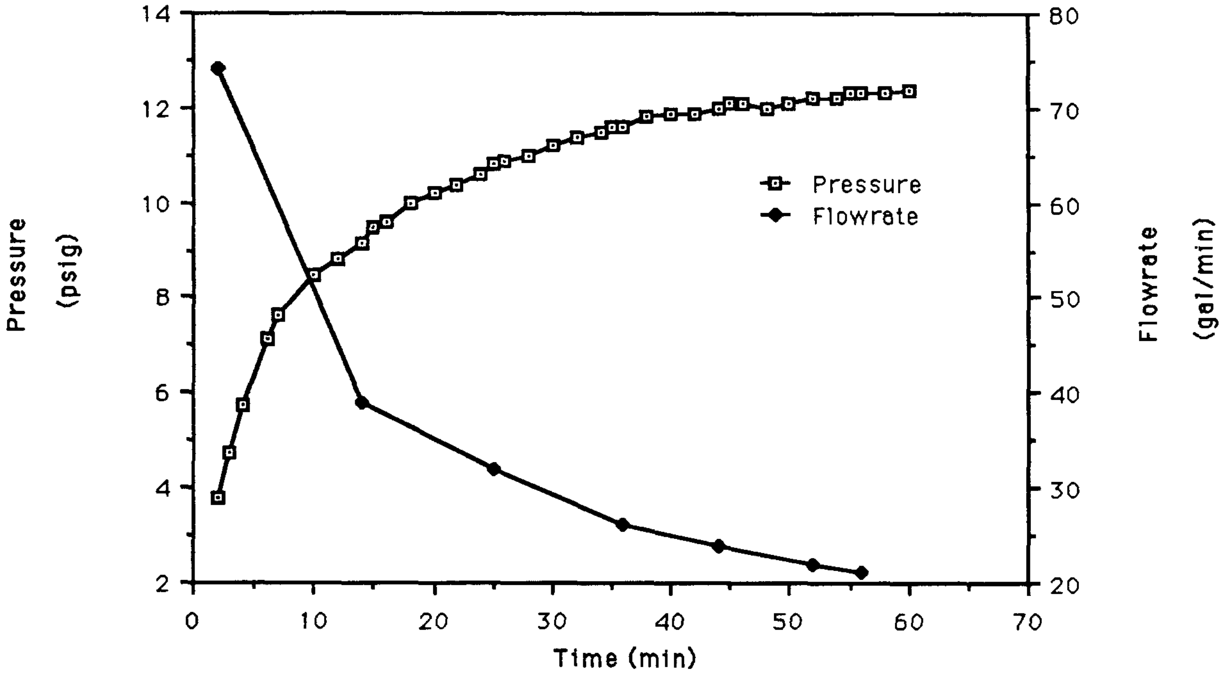


Figure. 2. Effect of Celite 577 diatomaceous earth filtration of chiller water on filter pressure and flowrate.

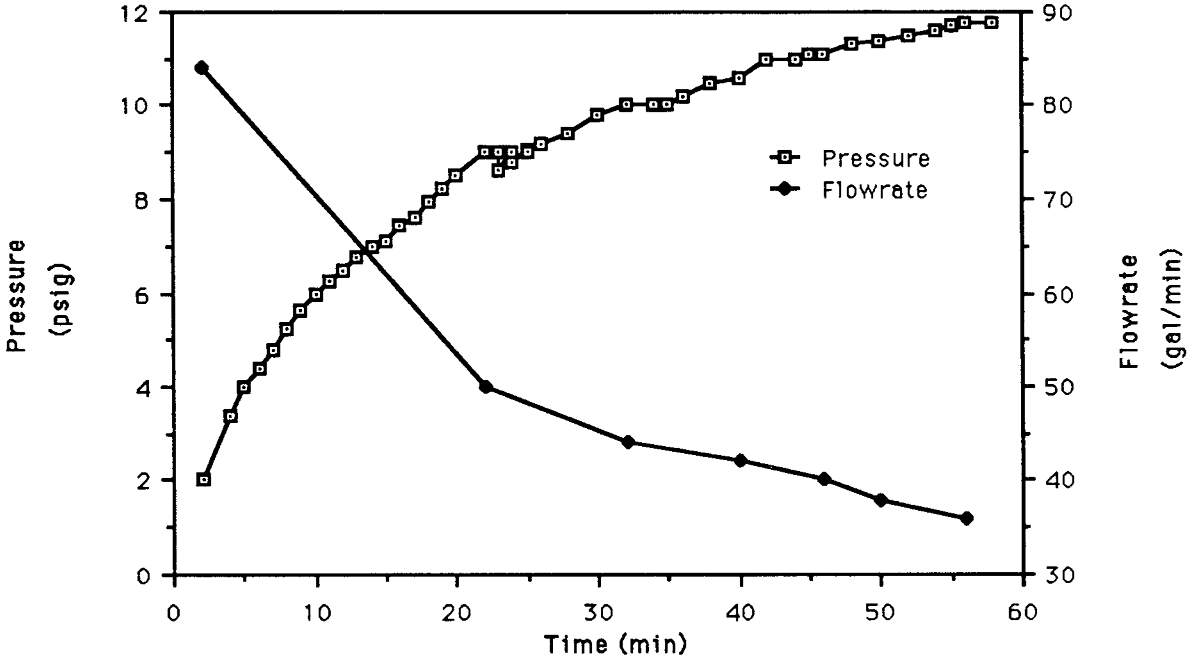


Figure. 3. Effect of Standard Super Cel diatomaceous earth filtration of chiller water on filter pressure and flowrate.

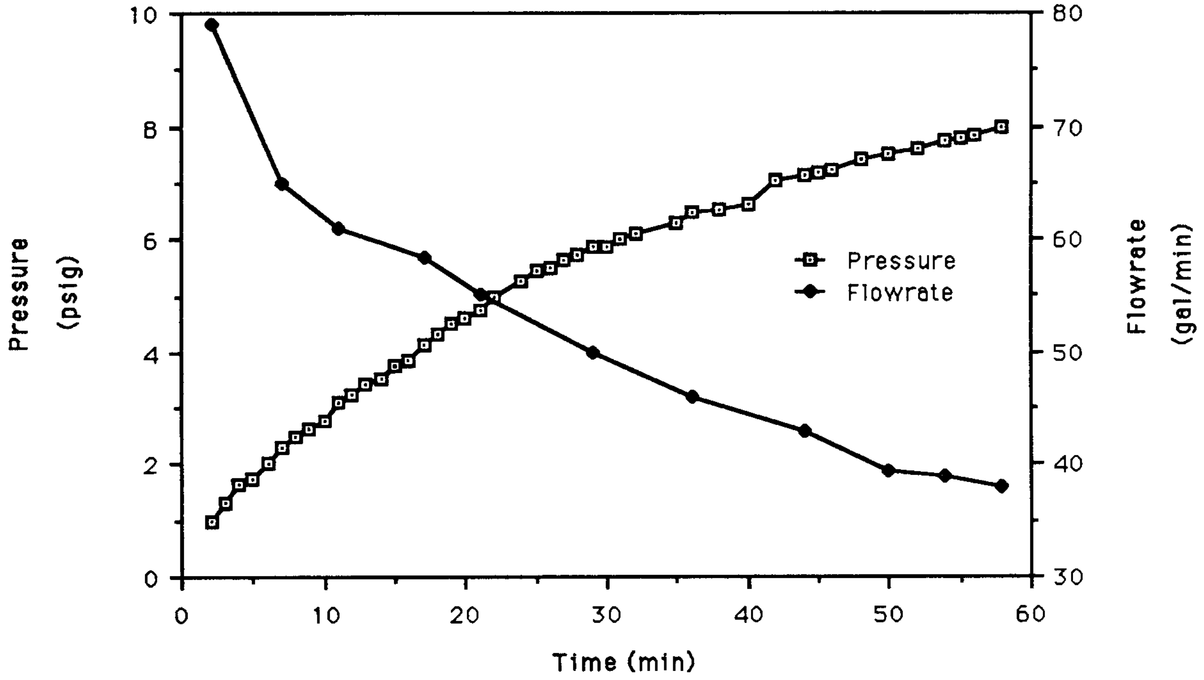


Figure. 4. Effect of Celite 512 diatomaceous earth filtration of chiller water on filter pressure.

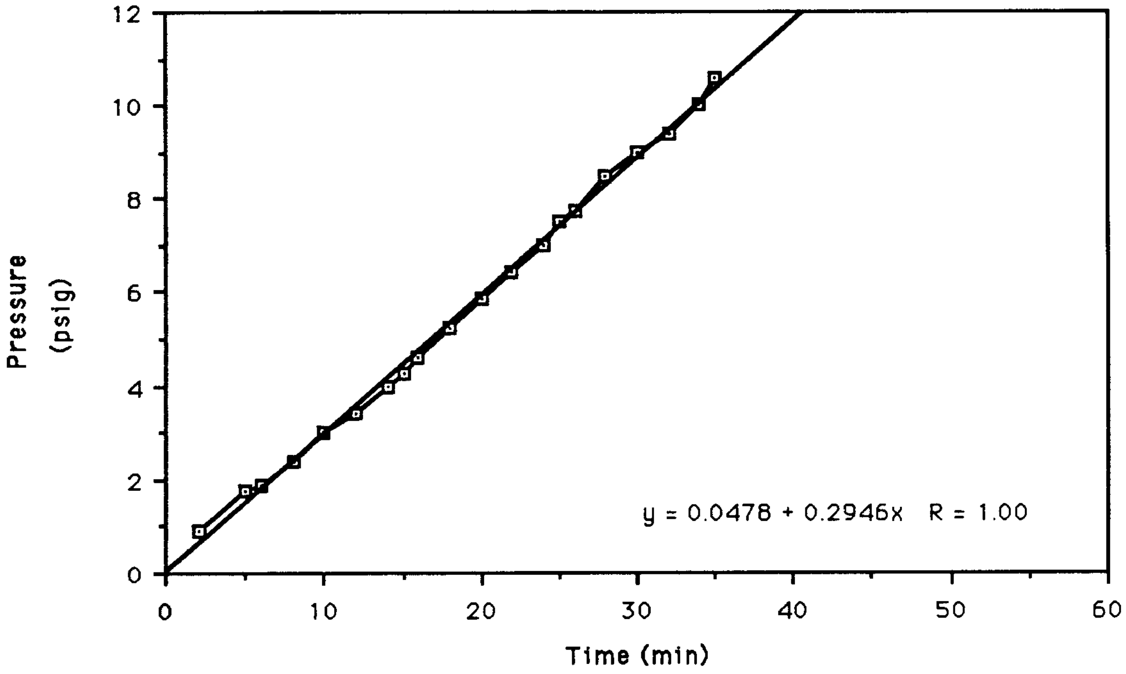


Figure 5. Effect of Hyflo Super Cel diatomaceous earth filtration of chiller water on filter pressure.

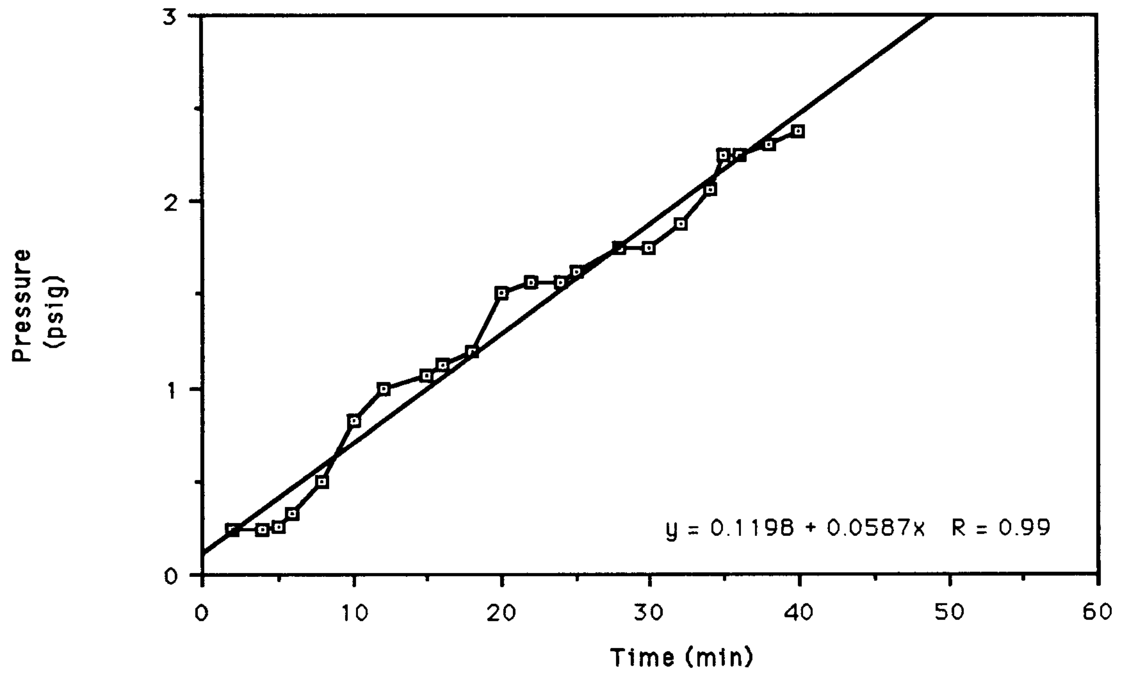


Figure. 6. Effect of Celite 501 diatomaceous earth filtration of chiller water on filter pressure.

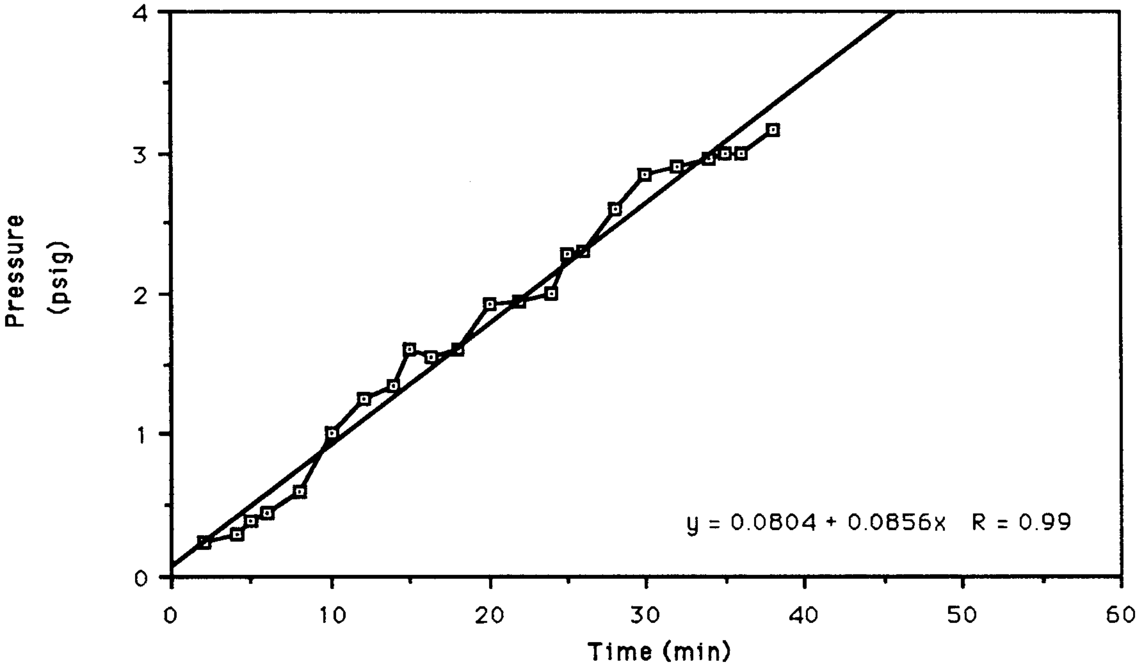


**Figure 7. Effect of Celite 503 diatomaceous earth filtration of chiller water on filter pressure.**

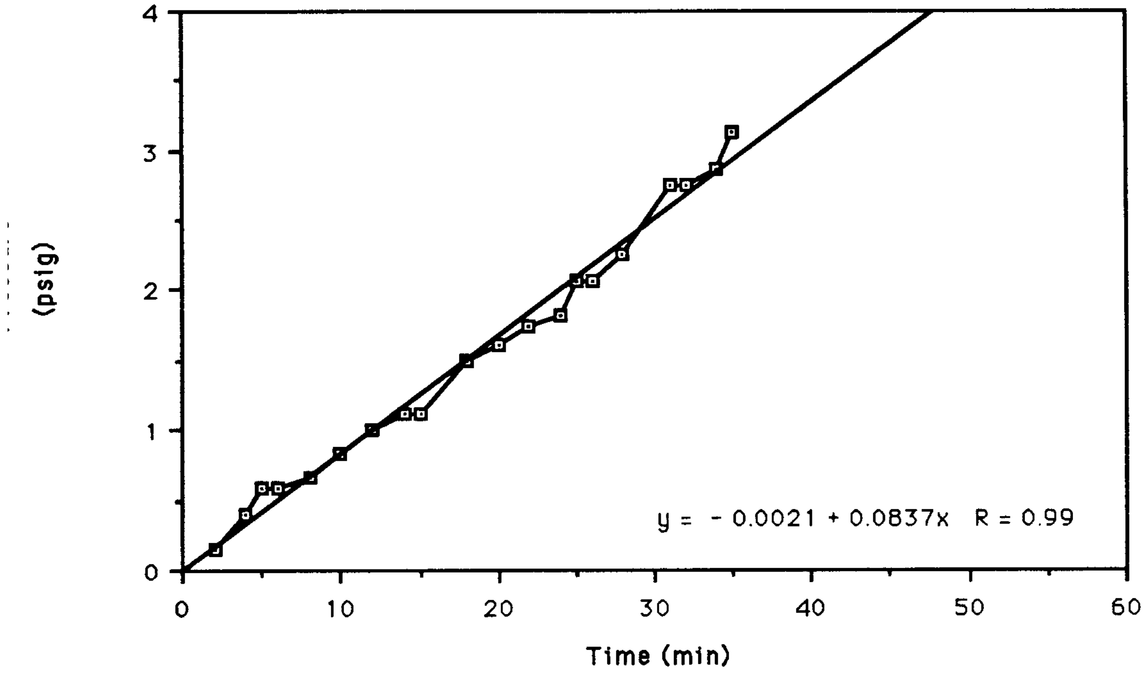


Figure. 8. Effect of Celite 535 diatomaceous earth filtration of chiller water on filter pressure.

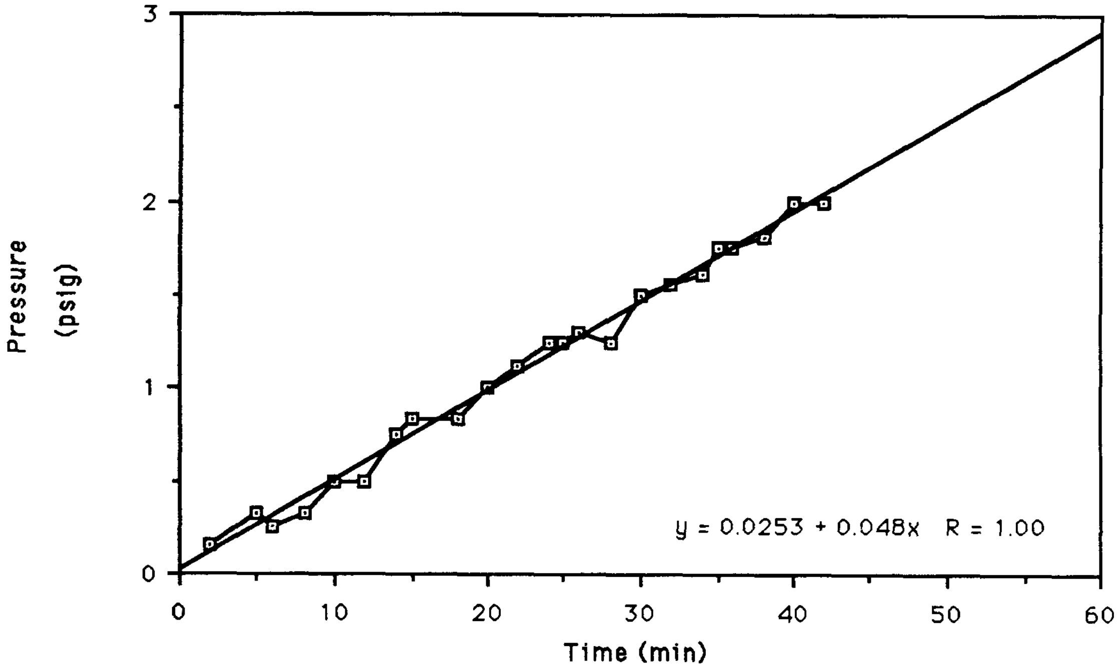


Figure 9. Effect of Celite 512 and Hyflo Super Cel diatomaceous earth filtration of overflow prechiller water on filter pressure.

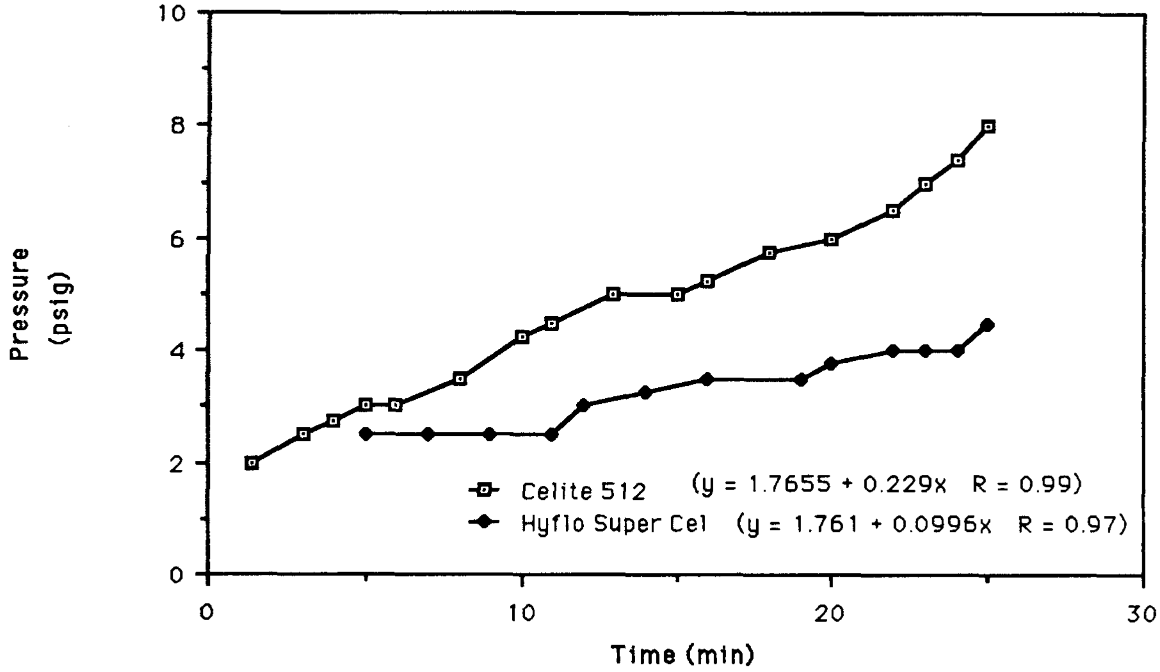


Figure 10. Effect of Celite 512 and Hyflo Super Cel diatomaceous earth filtration of overflow prechiller water on filter pressure.

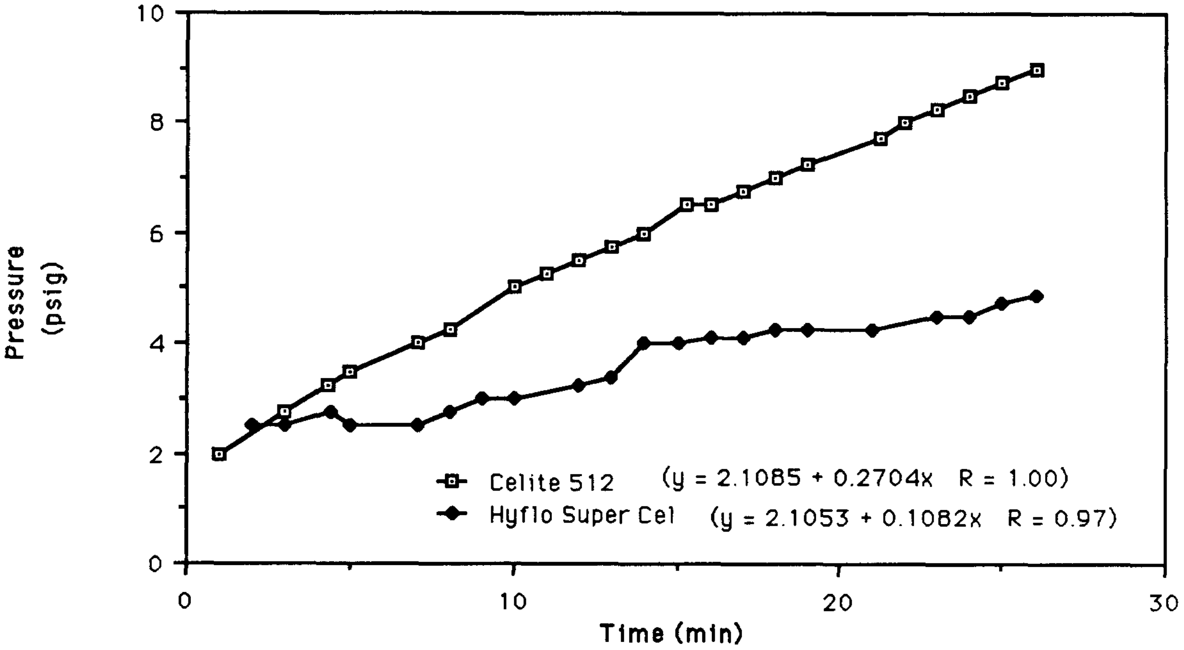


Figure 11. Effect of Celite 512 diatomaceous earth filtration of chiller water on filter pressure and flowrate.

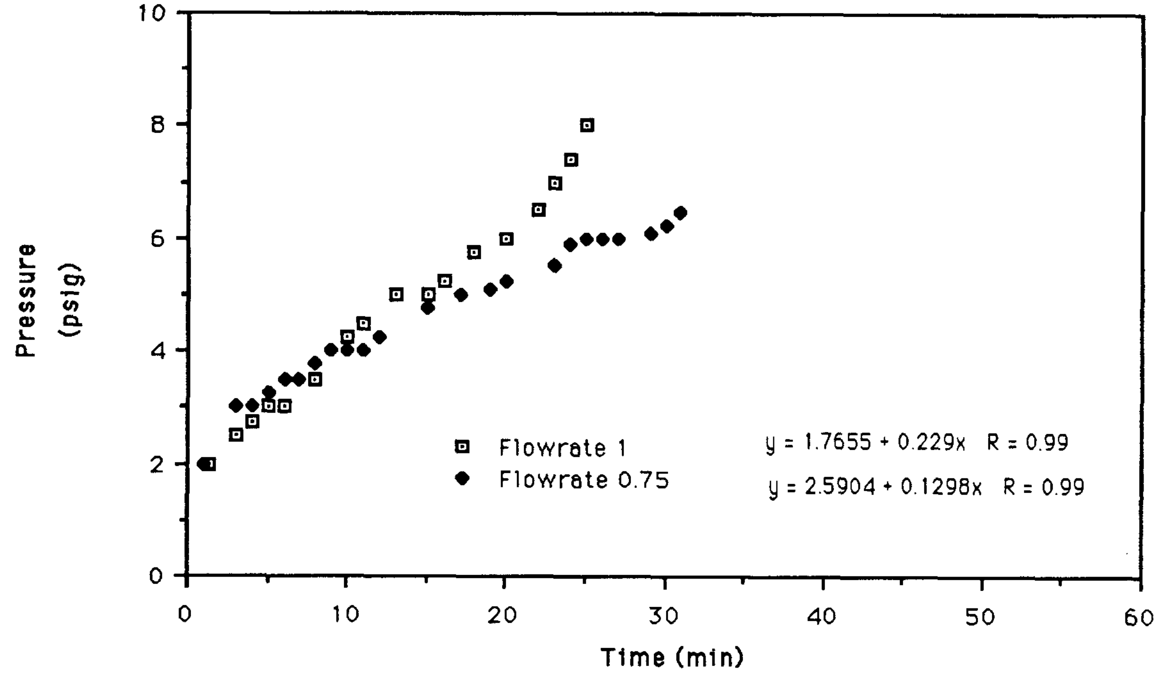


**Figure 12. Effect of Celite 512 diatomaceous earth filtration of chiller water on filter pressure.**

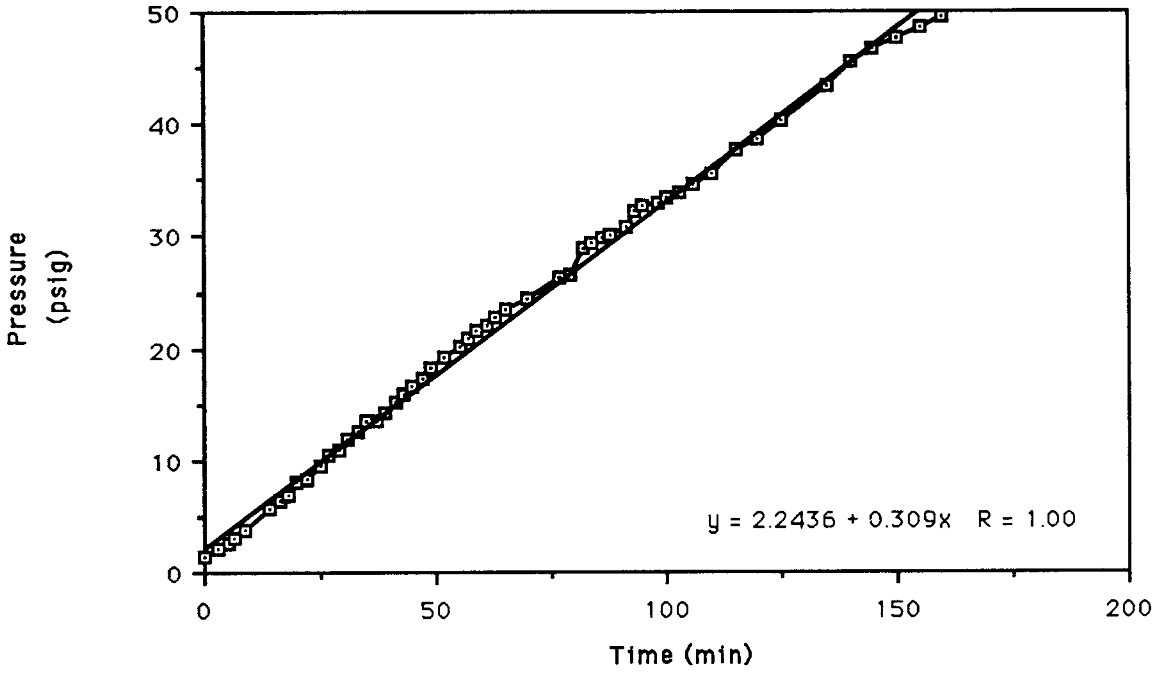


Figure 13. Effect of Celite 512 diatomaceous earth filtration of overflow prechiller water on filter pressure.

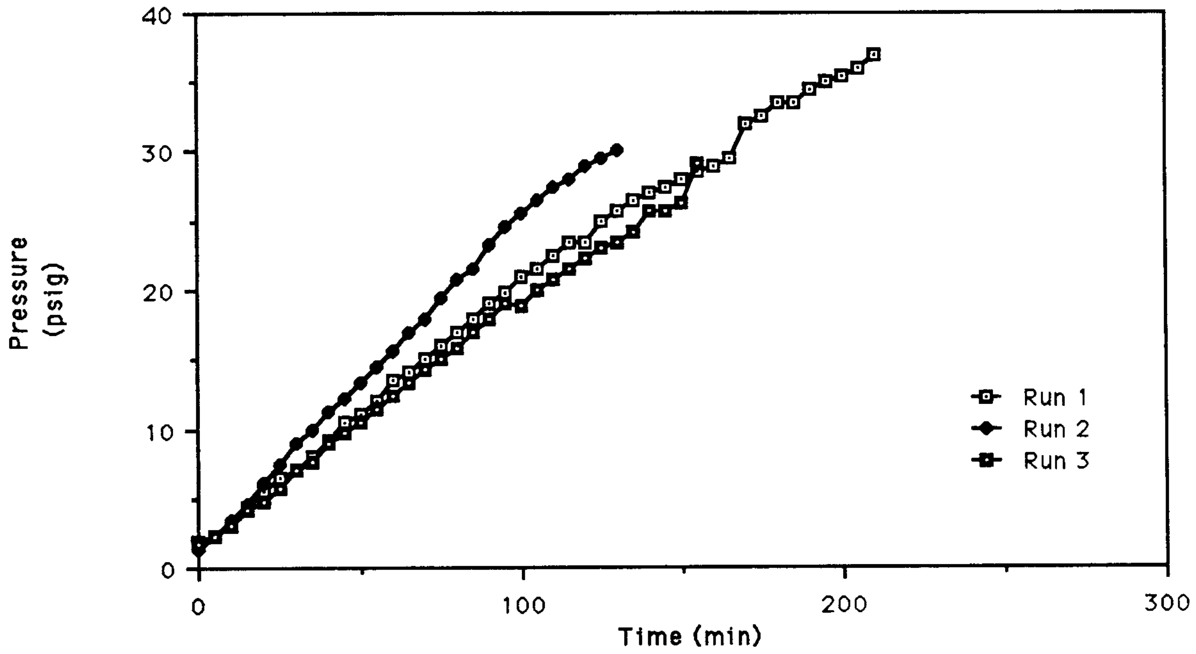
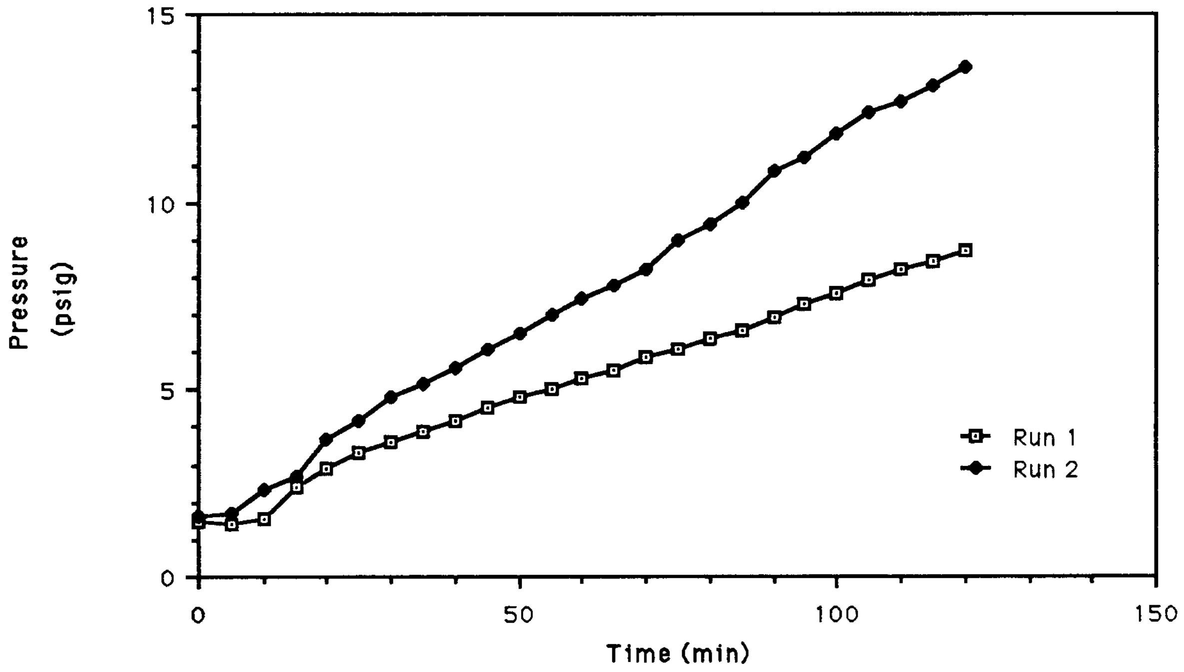


Figure 14. Effect of Celite 512 diatomaceous earth filtration of final carcass rinse water on filter pressure.



## APPENDIX A. Relationship Between Experiments. Trials. Tables. and Figures

| | | |
|---|---|---|
| Experiment 1. | Trial 1 | Table 3. Figure 1 |
| | | Table 4. Figure 2 |
| | | Table 5. Figure 3 |
| | | Table 6. Figure 4 |
| | | Table 7. Figure 5 |
| | | Table 8. Figure 6 |
| | | Table 9. Figure 7 |
| | | Table 10. Figure 8 |
| | Trial 2 | Table 11 |
| Experiment 2. | Trial 1 | Table 12. Figure 9 |
| | Trial 2 | Table 13. Figure 10 |
| | Trial 3 | Table 14. Figure 11 |
| Experiment 3. | Trial 1 | Table 15. Figure 12 |
| | Trial 2 | Table 16, Figure 13 |
| | Trial 3 | Table 16, Figure 13 |
| | Trial 4 | Table 16, Figure 13 |
| | Trial 5 | Table 17, Figure 14 |
| | Trial 6 | Table 17, Figure 14 |
| Experiment 4. | Trial 1 | Table 18 |
| | Trial 2 | Table 19 |

# APPENDIX B. Publications, Presentations, Thesis, and Reports Generated From This Research Project

Sheldon, B. W. and Chang, Y. 1987. The application of ozone and other physical processes for treating spent poultry chiller water. In: G. E. Valentine, Jr., 1987 Food Processing Waste Conference Proc., Georgia Institute of Technology, Atlanta, GA. Sect. 9, p. 1-16.

Chang, Y. and Sheldon, B. W. 1987. Effect of chilling broiler carcasses with recycled prechiller water. Poultry Sci. 66(Supplement 1):79.

Chang, Y. H. and Sheldon, B. W. 1988. Effect of chilling broiler carcasses with reconditioned poultry prechiller water. Poultry Sci. (In Press).

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