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Evaluation of Ultrafiltration for In-Process Recycling of Cleaning Solution at Ford's Chicago Stamping Plant

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ILLINOIS DEPARTMENT OF NATURAL RESOURCES

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EVALUATION OF ULTRAFILTRATION FOR IN-PROCESS RECYCLING OF CLEANING SOLUTION AT THE FORD STAMPING PLANT

EXECUTIVE SUMMARY

Solutions used to clean floors and dies at Ford's Chicago Heights, Illinois stamping plant contribute over 1.1 million gallons annually to the facility's wastewater treatment plant. The wasted cleaning solution tends to emulsify other oily wastes in the wastewater causing the current wastewater treatment system's inability to efficiently separate the water and oil under existing conditions. As a result of these factors, Ford has had a difficult time meeting the local sanitary district standards for fats, oils and grease (FOG) discharges and has paid $32,000 over the past 3 years as a result of exceeding FOG standards. Ford spends over $600,000 annually to operate their wastewater treatment operations but these costs account for only a portion of the total waste cost. This facility uses over 110,000 gallons per year of concentrated aqueous cleaning solution at an annual cost in excess of $200,000.

This project was conducted to evaluate the technical and economic potential for ultrafiltration to recycle aqueous cleaning solutions used at the Ford Stamping Plant. Membranes selected for this project were chosen for their ability to remove oil, grease, and particulate contaminants from aqueous cleaning solutions. An ultrafiltration system equipped with a series of 8 (10 foot long) Koch tubular membranes with a total membrane surface area of 17.6 square feet was retro-fitted to the existing Ford die washing system and evaluated for a period of 6 weeks. The system ran for approximately 575 operating hours and generated over 20,000 gallons of recycled "permeate" solution during the course of the project.

Ford employees who cleaned dies and floors using the recycled solution claimed that it cleaned as well or better than fresh, unrecycled cleaning solution. Analytical tests on the quality of the recycled cleaning solution indicate that it was essentially free of oil and grease and particulate contaminants. Cleaning chemical quality was also maintained at high levels with the exception of a nonionic surfactant removed by the ultrafiltration process. This surfactant comprises only 2.2% of the concentrated cleaner (.22% of the cleaning solution as it is actually used) and was easily metered back into the cleaning process during operation. It is estimated that total cleaning chemical consumption would be reduced by 80 to 85% through installation of a full-scale ultrafiltration system. Additionally, discharges of oily wastewater to the sewer would be reduced by over 1,000,000 gallons per year.

A capital investment of $52,500 would be required to install a permanent ultrafiltration system in this operation. Approximately $77,000 (1997 dollars) would be required annually to operate and maintain the system and purchase the small quantities of chemicals required to clean dies and floors. However, an estimated $237,000 in savings would be realized in reduced chemical consumption and reduced wastewater treatment and disposal costs. Investment in a permanent ultrafiltration system in this facility should pay back in less than 7 months.

BACKGROUND

The Ford Motor Company's Stamping plant located in Chicago Heights, Illinois uses approximately 4,500 gallons of concentrated aqueous cleaner solution on a bi-weekly basis. The solution is used primarily to clean stamping dies and floors. It contributes over 1.1 million gallons annually to the load on the facility's wastewater treatment plant. The cleaning solution in its raw form will produce elevated fats, oils and grease (FOG) readings based on the freon extraction laboratory procedure used by the local sanitary sewer district. In addition to this problem, the cleaning solution tends to emulsify oils that are introduced to the waste stream from various other operations in the plant. The existing oil/water separation equipment used in Ford's wastewater treatment system does not effectively break the emulsion or separate the soap and oil components from the wastewater stream. Consequently, Ford has had a difficult time meeting the local sanitary district's FOG discharge standards.

The existing methods for washing dies and floors at the Ford stamping plant are expensive. Ford spends in excess of $200,000 on cleaning chemicals annually and additional monetary resources are committed to treat these materials at the wastewater treatment plant when they become waste. The wastewater treatment plant at this facility costs Ford over $600,000 annually to operate. Further, Ford has paid approximately $32,000 over the past 3 years to the sanitary district as a result of exceeding FOG standards.

Ford may be able to substantially reduce their cleaning chemical usage, wastewater treatment, and subsequent discharge to the sanitary district by implementing closed-loop recycling of the cleaning solution. While the cleaning solution becomes contaminated with oil, grease, and dirt in the cleaning operations, many of the active ingredients in the chemicals are not depleted in the cleaning process. The active ingredients in the wasted cleaner have a tendency to combine with other oily waste streams that are sent to the wastewater treatment system and form a strong emulsion for the wastewater treatment plant operators to deal with. If Ford can effectively remove the contaminants from the used cleaning solution, the chemicals can be reformulated to replace lost components and reused to clean additional parts and floor areas.

ULTRAFILTRATION OF AQUEOUS CLEANING CHEMICALS

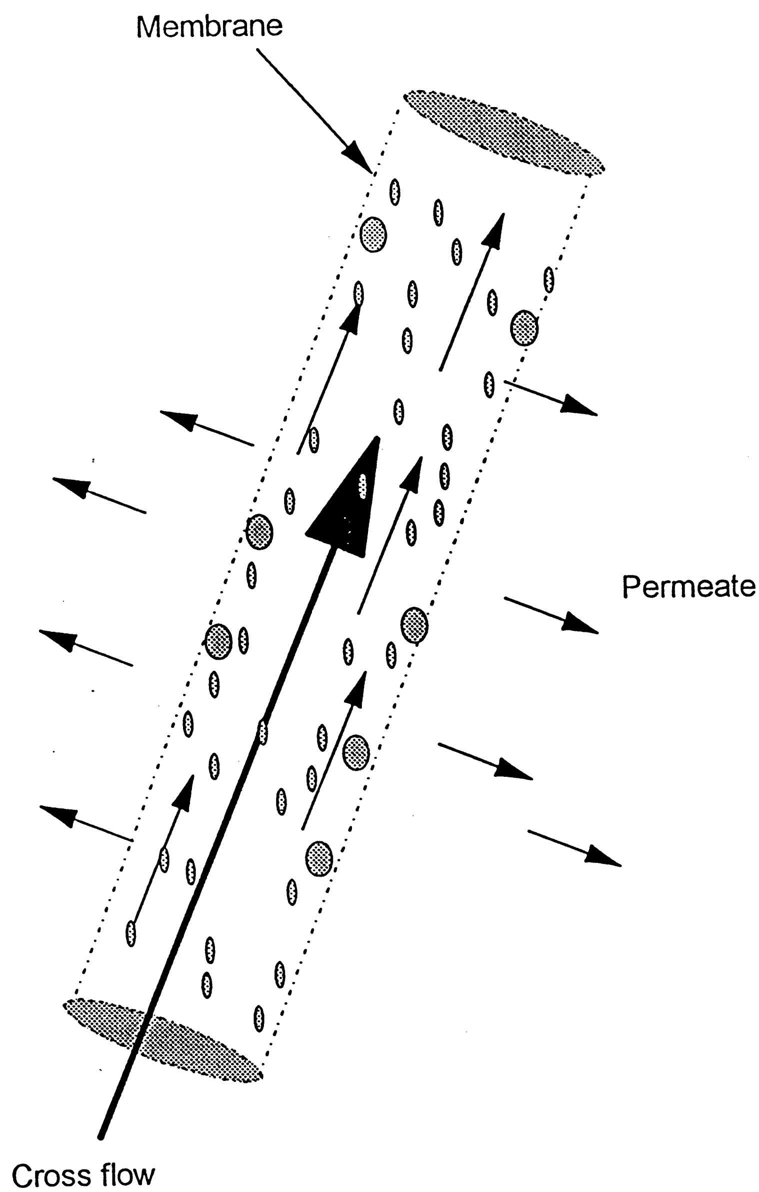
Conventional filtration techniques available for recycling aqueous cleaning solution rely on depth or screen filters to remove oil from a process solution. Using these filters, however, can be problematic for the filter media clog easily, requiring frequent backflushing or disposal, which results in additional wastes. Membrane filtration techniques, such as ultrafiltration, are a more advanced technique that takes advantage of thin-film membranes and turbulent flow patterns to deliver a more consistent flow rate and a higher quality filtrate (commonly referred to as permeate) than conventional filtration.

The membranes are semi-permeable barriers capable of separating feed stream components according to particle size relative to the pore sizes of the membrane. Feed stream components that have a particle size larger than the pore sizes of the membrane are retained while components that are smaller than the pore sizes of the membrane are allowed to pass through. A major difference between conventional filtration practice and "membrane" filtration is with respect to the mechanism of contaminant capture. Conventional filters operate by capturing particles within the filter matrix, a process termed depth filtration. The filters cannot be regenerated after use, as the particles accumulate within the filter matrix. Membrane filters are usually sized to have pores that are too small for particles to enter. Therefore, the bulk of the filtration occurs at the surface of the filter. Membrane filters can, therefore, be reused by removing the particulate matter from the surface by flushing or cleaning. Figure 1 illustrates the common mode of operation employed in ultrafiltration. This mode, termed "cross-flow" filtration, describes the flow of feed solution in a direction parallel to the membrane surface or filter. This facilitates the "sweeping" of the membrane surface and limits filter cake buildup and allows for longer periods of operation without having to clean the membrane. A small portion of the solution is forced through the membrane by the applied pressure and recovered as "permeate".

The development of more durable membranes, such as polyvinylidene difluoride (PVDF), has expanded the application of membrane filtration beyond its origins in the food industry to successfully handle industrial process solutions with extreme pH's, high temperatures, and high oil concentrations. Because of its unique capabilities to concentrate oily wastewater and produce a clean permeate, ultrafiltration has emerged as a promising technology for extending the life of aqueous cleaners. Most of the valuable cleaning chemicals present in these cleaning solutions pass through the membrane with the permeate and are returned to the cleaning operation. The concentrated oily phase typically comprises a small fraction of the original wastewater volume, so the volume of waste disposed is reduced as are disposal costs.

Some automotive manufacturing facilities have used ultrafiltration technology to treat oily wastewaters as a component of their wastewater treatment process. However, utilization of the technology further upstream in the production process to recycle process solutions such as aqueous cleaners and metal working fluids has proven to be a far more efficient application of the technology. Ultrafiltration of process solutions such as aqueous cleaners enables reuse of the chemicals as opposed to simply reducing a waste volume. Additionally, when ultrafiltration is performed on a single process solution instead of a mix of multiple streams, optimization of the ultrafiltration process is simpler with respect to membrane selection, system size, membrane cleaning methods, etc.

Figure 1. Cross Flow Filtration



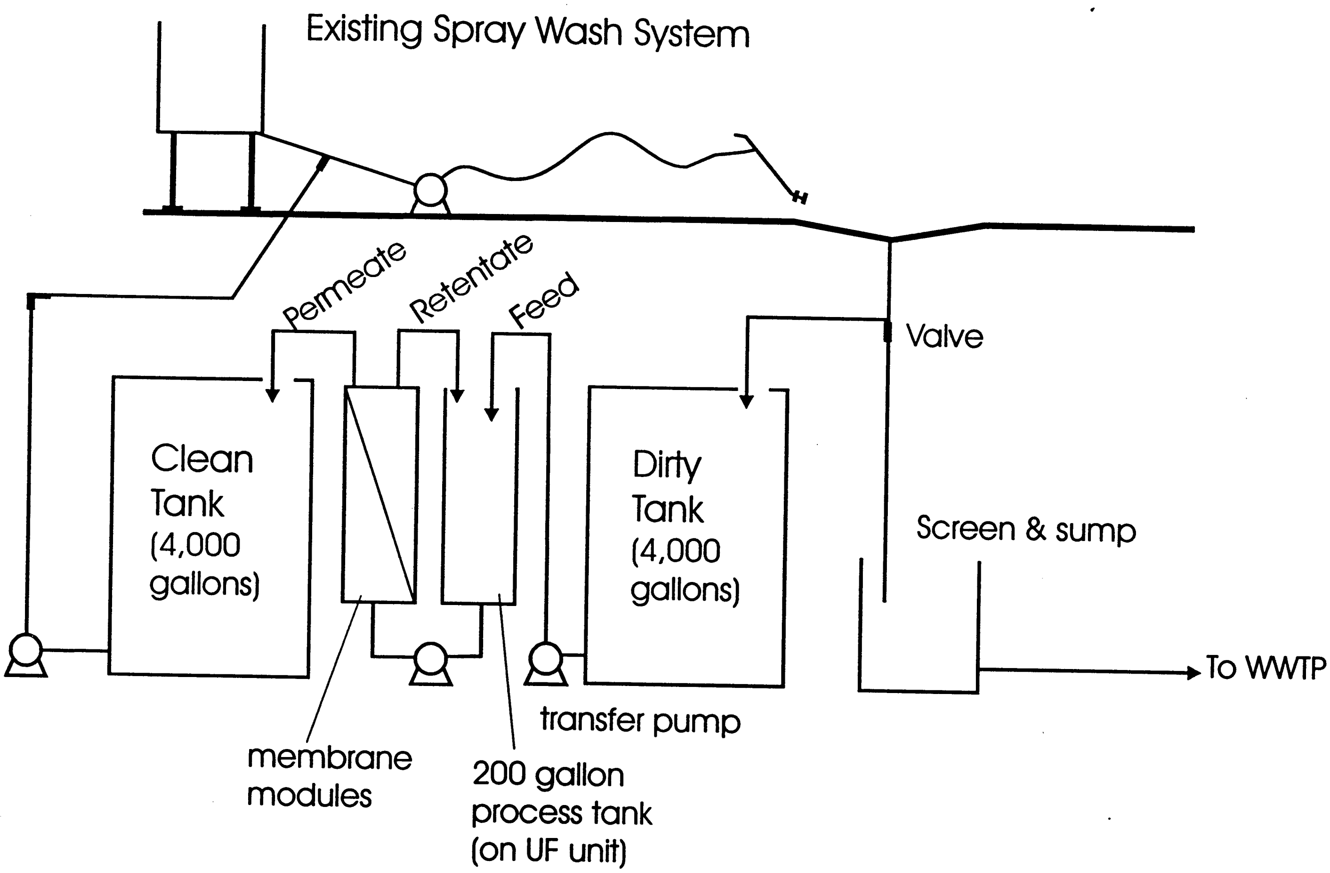
Previous research performed by Lindsey et. al. (1994) and Karrs and McMonagle (1993) on similar types of aqueous cleaning chemicals suggests that the majority of chemical components will permeate the membrane such that the chemicals can be recycled. The chemical formulation utilized at the Ford stamping plant is a metasilicate-based alkaline cleaner with a mixture of anionic and nonionic surfactants, glycol solvent, and phosphates. The only components in question with respect to recyclability are the surfactants. Surfactants are an important component to these types of cleaning solutions, but typically comprise less than 10% of the total raw chemical formulation. Membrane filtration systems commonly remove some surfactants from cleaning chemicals and can significantly reduce the efficacy of the cleaning solution unless an appropriate additive is formulated and added to the cleaning solution at appropriate rates.

PROJECT DESCRIPTION

Ultrafiltration System Set-up

A pilot-scale ultrafiltration system manufactured by Arbortech corporation was installed in the basement of the Ford facility, immediately below the die washing station. The system was operated by Chemical Management Services, LLC and was equipped with a series of 8 (10 foot long) Koch PVDF membrane tubes with a total membrane surface area of 17.6 square feet. Figure 2 shows how the pilot-scale ultrafiltration system was set up at the facility. As shown, the system was set up in a closed-loop fashion where dirty "feed" solution was collected in a 4,000 gallon "dirty" tank, pumped into a 200 gallon process tank on the ultrafiltration unit then the solution moves through the ultrafiltration membrane modules. The clean "permeate" solution that passed through the membrane was placed in a 4,000 gallon "clean" tank where it was re-introduced into the die washing process. Contaminants removed from the cleaning solution by the ultrafiltration system, a "retentate" stream, were pumped into the same 200 gallon process tank as the feed solution from the dirty tank where the contaminants become progressively concentrated over time. When the contaminants became concentrated to a level such that system performance was severely impaired, the concentrated retentate solution was removed as waste and the ultrafiltration system was cleaned.

Figure 2. Pilot Scale Ultrafiltration Test System at the Ford Stamping Plant



Although the ultrafiltration system used for this project was the largest pilot unit available for the test, due to the relatively high utilization rate of cleaning chemicals at the plant, the pilot unit would only process approximately one half of the total volume of die cleaning solution required by Ford. Therefore, while the ultrafiltration system ran almost continuously throughout the duration of this test, recycled solution was used for die washing only about half of the time the ultrafiltration system was running. Ford employees monitored the ultrafiltration system regularly and switched the die wash operation on and off of the recycled solution depending on the availability of sufficient recycled solution.

At the beginning of this project, a fresh (4,000 gallon) batch of cleaning solution comprised of "Blue Giant" cleaner, manufactured by Chempace corporation, was mixed with softened water at a 10% concentration and placed in the "clean" tank. The soft water was used to improve both membrane performance and cleaning efficiency. The solution was used to clean dies and collected in the "dirty" tank where it was transferred to the ultrafiltration system for processing. This same 4,000 gallon batch of cleaning solution was used throughout the duration of this project, although small (200 gallon) quantities of concentrated contaminants were purged from the system at regular intervals when the ultrafiltration system was cleaned.

Previous experience using ultrafiltration to recycle the "Blue Giant" cleaner indicated that the nonionic surfactant in this formulation, which comprises 2.2% of the raw concentrated chemical (.22% of the chemical when it is mixed to its usable concentration) is removed during the ultrafiltration recycling process. Therefore, a separate container of nonionic surfactant was supplied by Chempace, and a metering pump was set up to continuously dose appropriate quantities of the nonionic surfactant into the "clean" tank to replace losses of the nonionic surfactant brought on by the ultrafiltration system.

Laboratory Testing

Samples of feed, permeate, and retentate were collected at regular intervals throughout the duration of the study. Additionally, several grab samples were collected at the floor drain to the die washing station and from the spray gun for comparison purposes. All samples were analyzed for the various parameters described below. Oil and grease, and total suspended solids analysis were performed because these parameters represent the primary sources of contamination in the cleaning solution. Analysis of pH, free and total alkalinity, and anionic and nonionic surfactants were performed because they provide indicators of the primary raw material components of the cleaning solution. A brief description of each parameter's performance and the methods of analysis are provided below for each of the parameters analyzed.

- Oil and Grease - Buildup of this contaminant is one of the primary factors that can deteriorate performance of the cleaner. Draw lubricants that are washed from the dies and oily floor residues removed by the floor scrubbers are the principle sources of this contaminant in the cleaning solution. Analysis of oil and grease was performed by introducing the sample onto a non-polar solid phase oil and grease disk. The disk allows isolation of the oil and grease fraction of the sample, followed by gravimetric analysis. The primary quality assurance procedures include analysis of blanks, duplicates and spike recoveries.

- Total Suspended Solids - Dirt buildup on dies and floors, and metal fines from stamping operations are the principle sources of this contaminant. Analysis of total suspended solids was performed by filtering a known volume of sample through a pre-weighed filter and drying at 105 degrees (C). TSS is calculated from the increase in weight per unit sample (American Public Health

Association, 1995 - Method 2540D).

- pH - This parameter provides an indicator of the solution's aggressiveness against soils or contaminants. It was measured using a pH meter calibrated with standards.

- Free and Total Alkalinity - These parameters are strongly related to pH and provide a measure of the ability of the solution to vigorously attack soils present on the surfaces to be cleaned. It was measured by titrating a 10 ml sample with a standardized acid to indicator endpoints. The first endpoint was established with phenolphthalein indicator and provides the free alkalinity measurement while the second endpoint was established with methyl orange and provides total alkalinity (American Public Health Association, 1995 - Method 2320B).

- Anionic and Nonionic Surfactants - Surfactants are some of the chemical components of a cleaning solution. Anionic surfactants serve primarily to remove soils from surfaces to be cleaned. Nonionic surfactants act to keep soils in an emulsified state and to prevent the solution from foaming. Analysis of these parameters was performed by reversed-phase high-performance liquid chromatography with fluorescence detection after the sample was diluted appropriately and filtered through a nylon syringe filter to remove oil and particulates. Blank, check standards, duplicates and spikes were run to ensure data quality.

Permeate production, commonly referred to as the "flux" rate, was monitored throughout the project using a flow meter connected directly to a datalogger located on the ultrafiltration system. Total gallons of permeate produced were also tabulated by the datalogger.

RESULTS AND DISCUSSION

Ultrafiltration System Performance

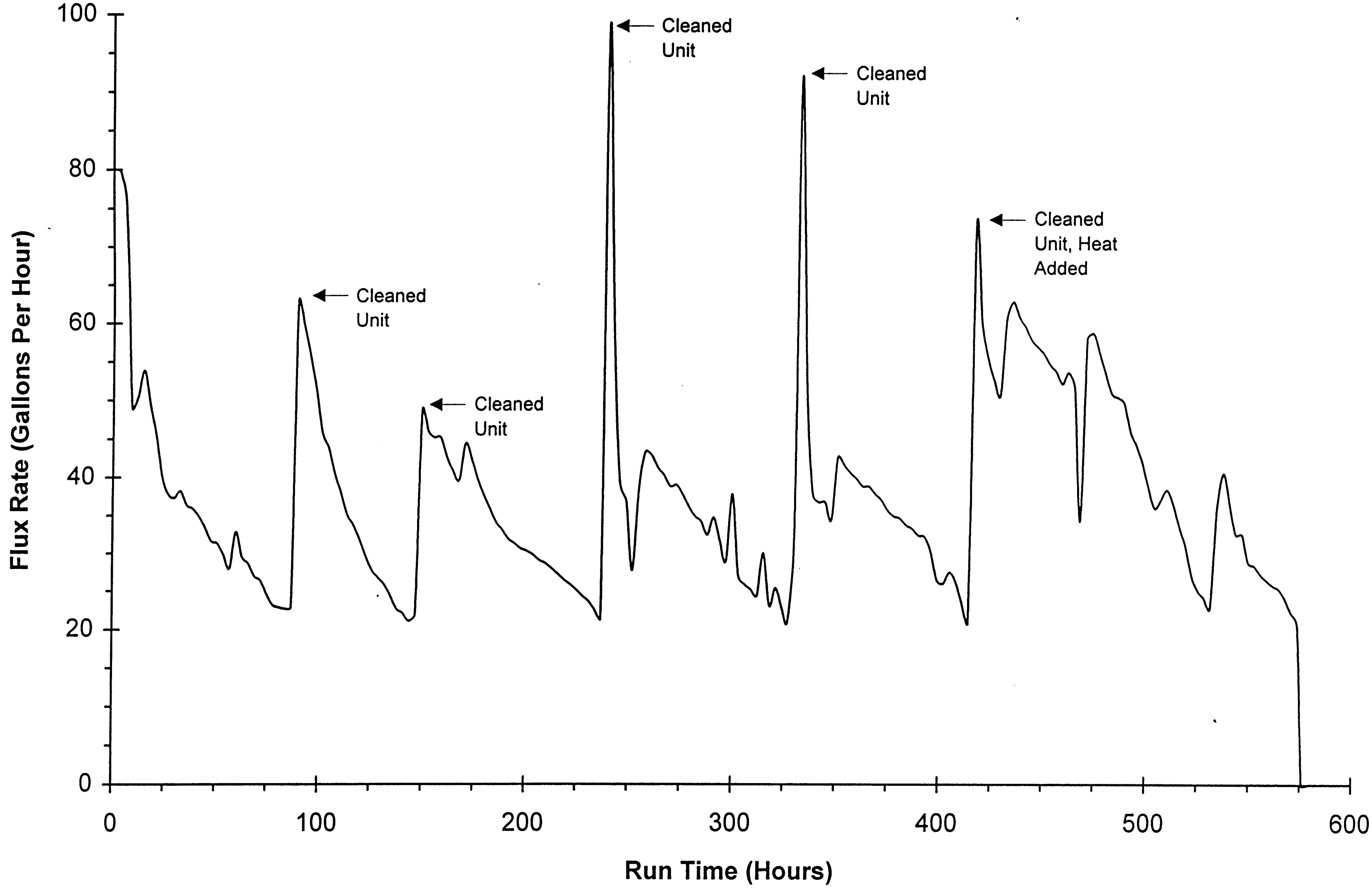
The ultrafiltration system ran for approximately 575 operating hours over a six week period during the duration of this test and generated over 20,000 gallons of permeate that was reused in the die washing process. Additionally, at the conclusion of the project, several hundred gallons of permeate were used in Ford's floor scrubber to wash floors. On the 19th day of the project, Ford employees inadvertently dumped several hundred gallons of waste oil from an oil pumper into the system. Although this event caused some spikes in the analytical data, it had little effect on the performance of the ultrafiltration system.

Ford employees who cleaned dies and floors using the recycled cleaning solution were questioned at various times during the project to solicit their input regarding system performance. In each case, they claimed that the recycled solution cleaned as well or better than the raw cleaning solution. Improvements in cleaning efficiency were probably due to the use of soft water in the initial make-up of the recycled solution, as well as elevated temperatures that were achieved with the recycled die washing solution. The recycled solution started at higher temperatures (the basement temperature stayed between 76 and 78 degrees [F] for the duration of the project) than fresh cleaning solution which was mixed with much cooler tap water.

During the first several weeks of operation, the ultrafiltration system maintained average flux rates of only 30 to 35 gallons per hour. Additionally, the membranes required cleaning approximately every 3 to 4 days. The flux rates and cleaning frequency were unsatisfactory compared to similar applications of ultrafiltration technology on aqueous cleaning solutions. Therefore, a decision was made to elevate the temperature of the ultrafiltration process tank from about 94 degrees (F) to about 120 degrees (F) through addition of a steam-supplied heat exchanger. Addition of the heat exchanger increased the flux rate to an average of about 35 to 45 gallons per hour and increased the time between membrane cleanings to about 1 week. The improved flux rates and reduced cleaning frequency achieved through the addition of heat are considered acceptable compared to similar applications of this technology. Figure 3 shows the flux rate over time during the course of the project. No extra "Blue Giant" chemical was added to the system during the course of this project.

Addition of replacement anionic surfactant with the metering pump to compensate for losses caused by ultrafiltration represented the only cleaning chemicals added to the system. It is estimated that total cleaning chemical consumption would be reduced by 80 to 85% through installation of a full-scale ultrafiltration system. Additionally, the volume of oily wastewater generated from the cleaning processes would be reduced by over 90%, which would equate to over 1 million gallons per year.

Figure 3. Flux Rates Over Time



Chemical Analysis

Figure 4 shows oil and grease levels in the feed and permeate streams over the duration of the project. As shown, the oil and grease levels in the permeate were maintained at very low concentrations (56 - 96.5 mg/L) that were similar to the initial concentrations in the feed solution (73.7 mg/L) suggesting that the ultrafiltration membranes were effective at removing oil and grease from the cleaning solution (note: the laboratory procedure used for oil and grease analysis reads some of the cleaner components as oil and grease, consequently, the initial feed and permeate samples were essentially free of true oil and grease). It is noteworthy that the ultrafiltration system was able to remove the oil and grease from the solution even though an oil pumper was inadvertently dumped into the system on day 19 of the project. Table 1. provides a description of the composition of the final concentrated waste compared to the feed solution processed by the equipment. As shown, the system was able to concentrate the oil and grease levels in the retentate to concentrations as high as 10% Therefore, the ultimate waste generated from this process would be comprised of about 10% oil and grease. It is probable that the oil and grease could be further separated from this waste through use of chemical additives or centrifugal separation. If this additional step is implemented, the recovered would probably have monetary value and could be sold to an oil recycler.

Figure 4. Oil and Grease Levels of Various Process Streams

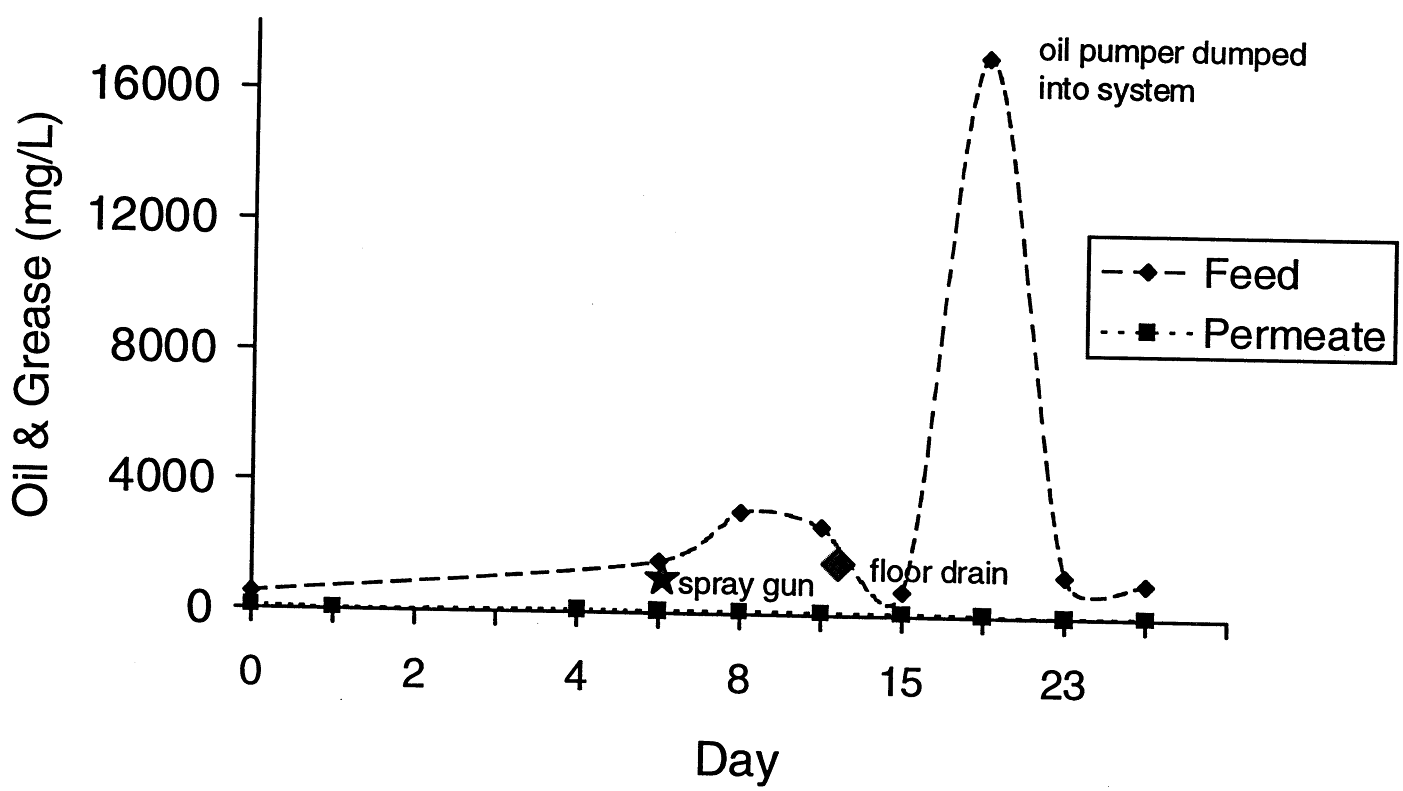


Table 1. Concentration of Various Parameters Before and After Ultrafiltration

Parameter Measured	Initial Concentration (Dirty Feed Solution)			Waste Concentration (Concentrated Retentate)
	Low	High	Mean	
Oil and Grease (mg/L)	520	17,200[1]	3,536	97,300
Total Suspended Solids (mg/L)	271	22,000[1]	3,354	>40,000
pH	10.4	12.4	11.66	9.7
Free Alkalinity (eq/L)	16	93	48	N/A[2]
Total Alkalinity (eq/L)	42	160	90.39	N/A[2]
Anionic Surfactants (% of target concentration)	48.3%	234%	120.6	197%
Nonionic Surfactants (% of target concentration)	67.7%	147%	104.2	1,010%

[1]High levels occurred due to dumping of oil pumper waste into system.

[2]Free and total alkalinity could not be determined on the retentate waste due to the extremely dark color of the samples.

The ultrafiltration system affected total suspended solids (TSS) levels in the feed and permeate streams in much the same way it affected oil and grease. Figure 5 shows TSS levels of both the feed and permeate streams. As shown, TSS levels in the permeate remained virtually non detectable for the duration of the project. TSS levels of the feed ranged from a low of 277 mg/L at project startup to a high level of 22,000 mg/L when the oil pumper was accidentally dumped into the system. Due to limitations associated with the analytical method used for TSS analysis, it was impossible to determine precisely the TSS levels in the final retentate waste, however, the level was estimated to be in excess of 40,000 mg/L (Table 1).

Figure 5. TSS Levels of Various Process Streams

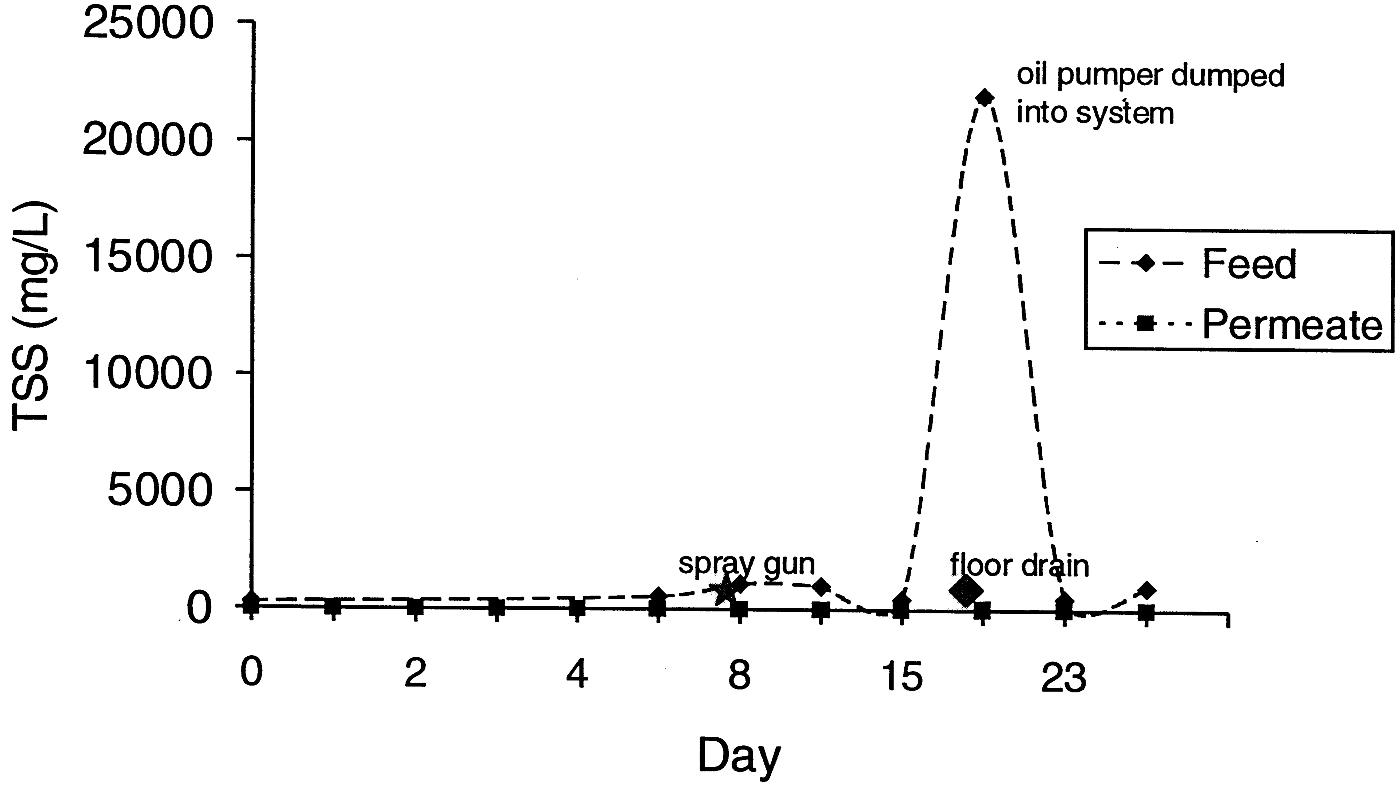
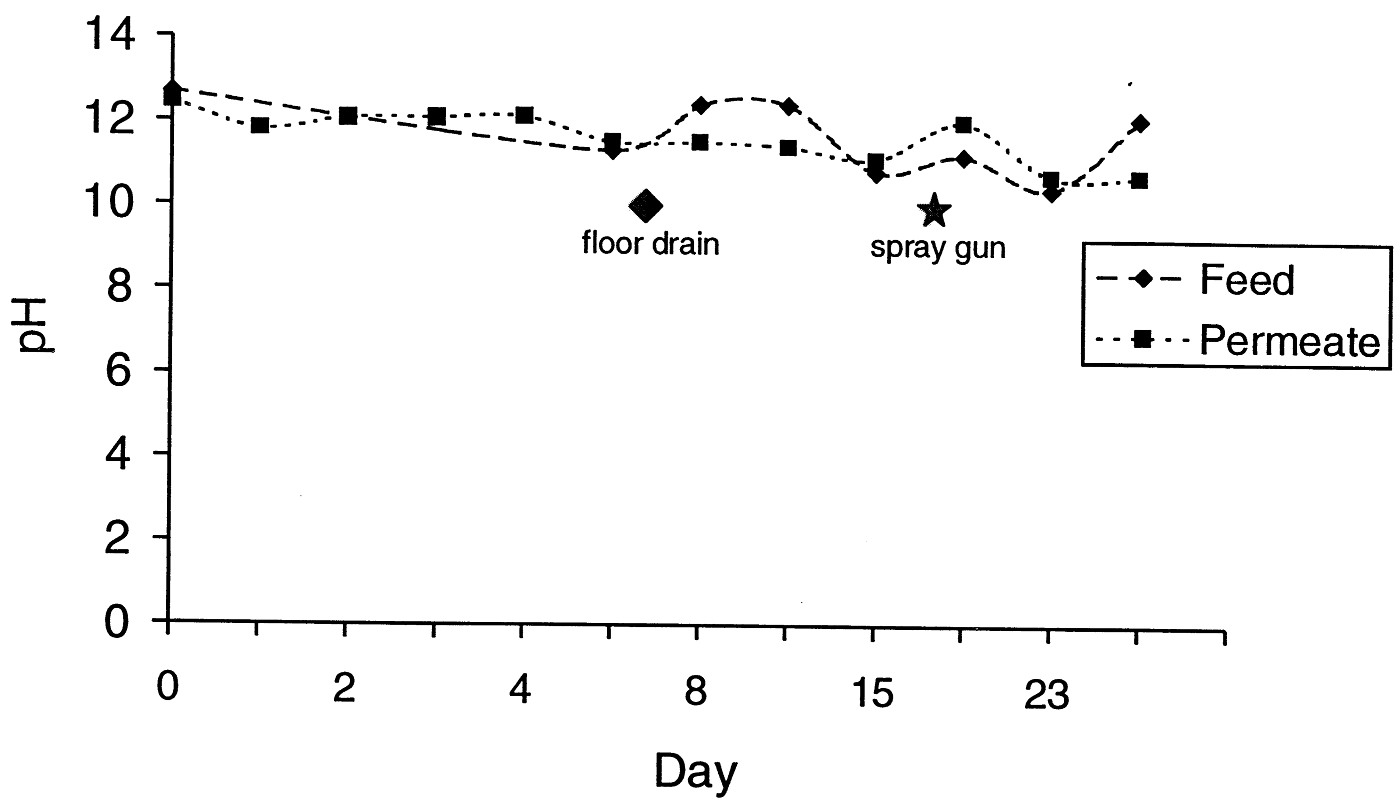


Figure 6 shows how pH levels varied in feed and permeate streams during the course of the project. As shown, there was little difference between the pH levels in pH of the feed versus the pH of the permeate. These data suggest that the ultrafiltration process had little effect on pH levels. However, there is a slight downward trend in the pH levels for both solutions over time. This trend suggests that, if ultrafiltration is to be implemented in this plant on a permanent basis, some small quantities of caustic chemicals will need to be added to the cleaning solution occasionally to maintain pH at original levels. The pH level of the concentrated waste stream was 9.7 (see Table 1) which was substantially lower than the feed or permeate streams.

Figure 6. pH Levels of Various Process Streams



Based on the results shown in Figures 7 and 8, little difference in either free alkalinity (Figure 7) or total alkalinity (Figure 8) is apparent when comparing the levels of these parameters in the feed stream versus the permeate. A spike in the data associated with both parameters was noted on the 8th day of operation. The cause of these elevated levels is unknown, however, the volume of the system's storage tanks also increased at this time and it is suspected that some chemical wastes (possibly from a floor scrubber) may have inadvertently been dumped into one of the tanks. Aside from the one data spike, a slight downward trend is apparent for both parameters, again suggesting that small quantities of caustic chemical will need to be added from time to time to the cleaning solution if a permanent ultrafiltration system is installed in the cleaning process.

Figure 7. Free Alkalinity Levels of Various Process Streams

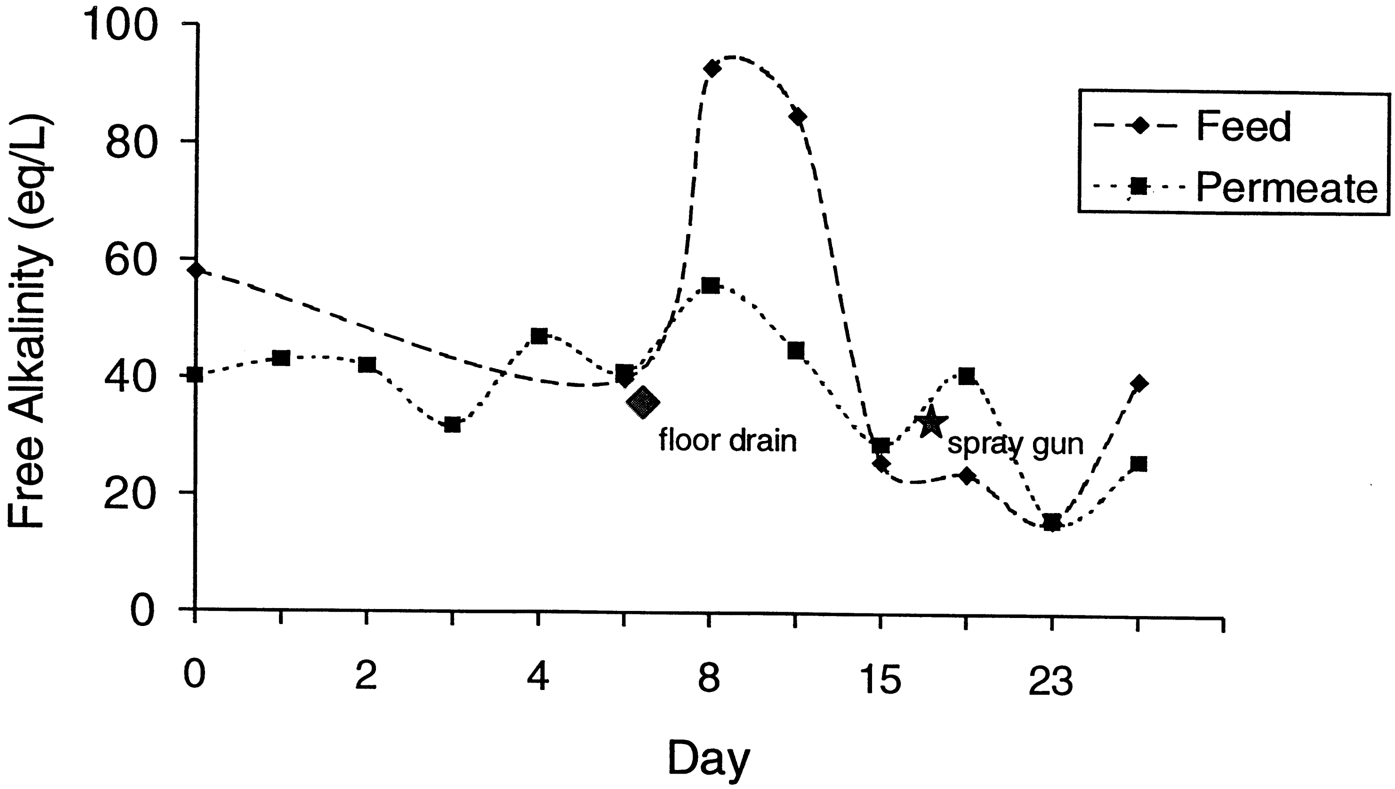
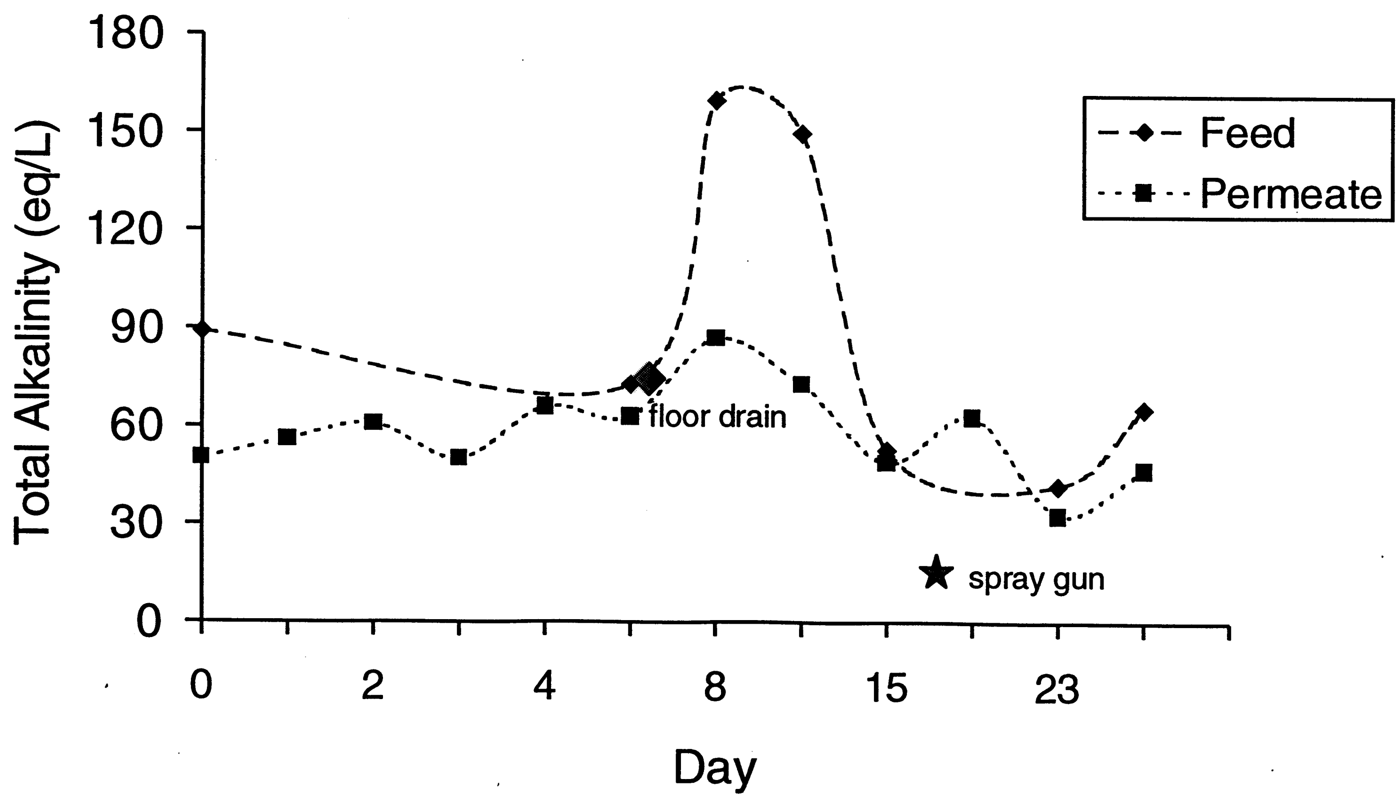


Figure 8. Total Alkalinity Levels of Various Process Streams



According to Figure 9, anionic surfactant levels in the permeate stream were slightly lower than the feed levels for most of the project. However, anionic surfactant levels in the recycled permeate remained over 50% of the target concentration for the entire duration of the project. These data suggest that a permanent ultrafiltration system at the stamping plant will require some slight additions of anionic surfactants on a periodic basis. As was the case with the free and total alkalinity data, a spike in the anionic surfactant data was noted on the 8th day of operation.

Figure 9. Anionic Surfactant Levels of Various Process Streams

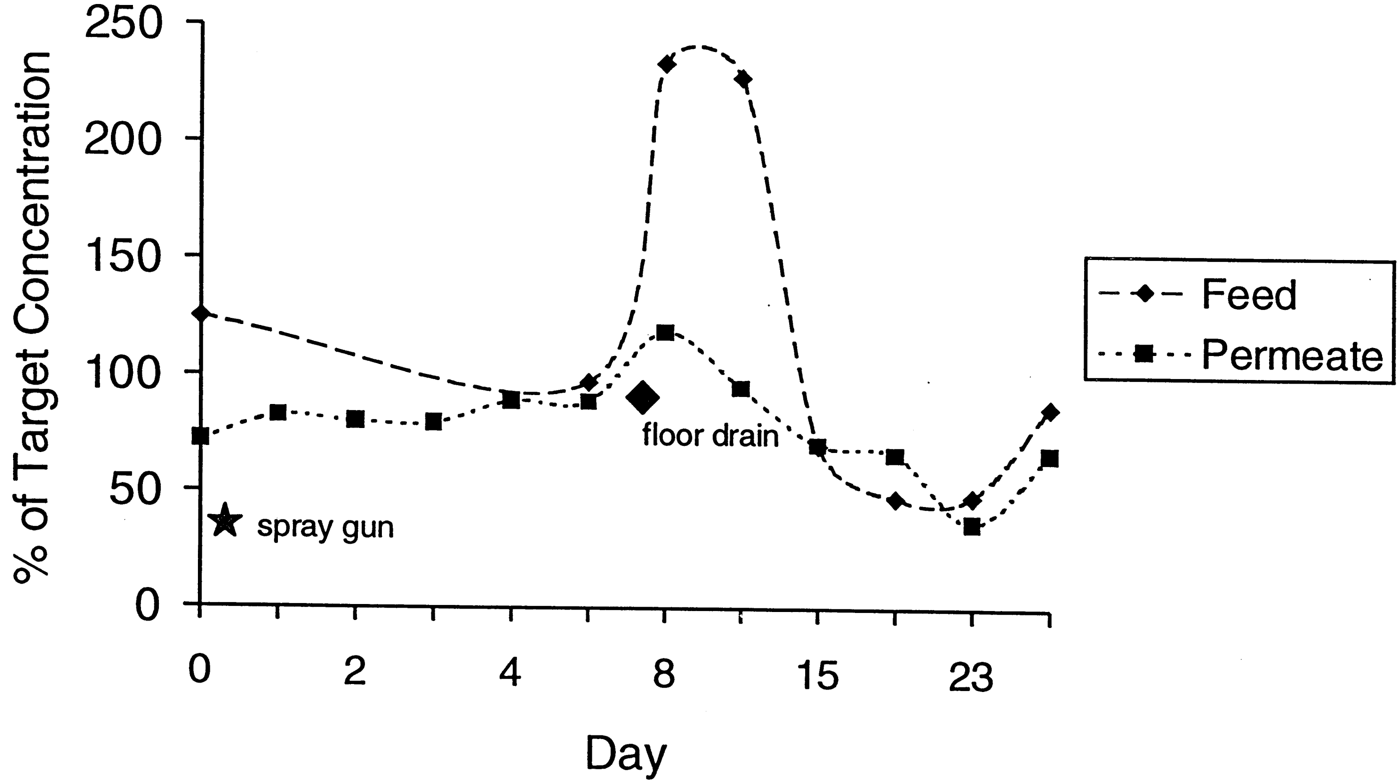
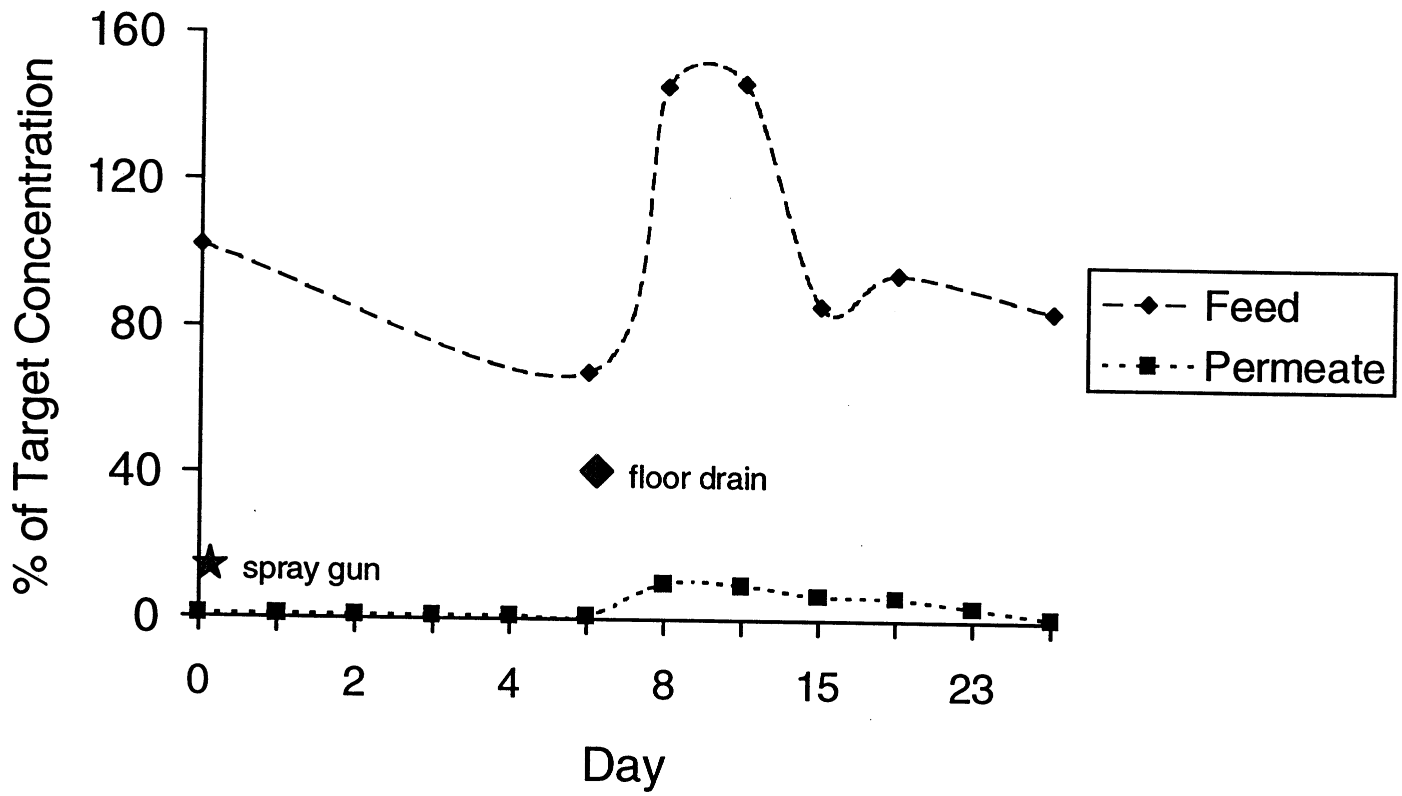


Figure 10 shows that, as expected, very little of the nonionic surfactants remained in the permeate following the ultrafiltration process. These data suggest that the membrane did, in fact, remove the nonionic surfactants from the cleaning solution. However, it is noteworthy, that the nonionic surfactant levels in the feed stream remained near the target concentration throughout the project. Based on these results, it appears that the metering system that was set up to replace the nonionic surfactants removed by the ultrafiltration membrane performed well. Table 1 shows that nonionic surfactants accumulated to levels in the waste tank that were more than

10 times higher than the initial concentration in the feed solution. These data confirm further that the nonionic surfactants were rejected by the membrane in much the same way the oil and grease and TSS were rejected. Ford should consider implementing a metering system, similar to the one used in this project, to continuously replace lost nonionic surfactants if a permanent system is installed at this facility.

Figure10. Nonionic Surfactant Levels of Various Process Streams



ECONOMIC ANALYSIS

The economic summary provided below is a summary of projected costs and benefits associated with implementing and operating a full-scale ultrafiltration system and the Ford stamping plant. The system could be installed and operated under a variety of scenarios which include ownership and operation by Ford personnel to ownership and operation by a vendor and a variety of options between these extremes. The estimates provided in Table 2 do not take into account variations in costs that could occur based on whatever purchase/operation scenario Ford implements. The payback calculation does not take into account the time value of money because the compelling nature of the savings associated with this investment did not appear to warrant a more thorough return on investment analysis.

As indicated in Table 2, an estimated $52,500 capital investment would be required to purchase and install an ultrafiltration system of adequate size to process all of the aqueous cleaning solution used at this facility. Approximately $85,594 (1997 dollars) would be required annually to operate and maintain the system and purchase the chemicals that would still be required for washing operations. The total first year investment of $129,166 would be paid back in less than 7 months with savings from a combination of reduced chemical cost, wastewater treatment cost and sanitary district expenses.

Table 2. Economic Summary of Full-Scale Ultrafiltration System

CAPITAL COSTS		
• Ultrafiltration system with 24, 10′ membranes and 7.5 hp pump		$41,500
• Utility Hookups		5,000
• Heat exchanger		6,000
Total Capital		**52,500**
EXPENSE COSTS		
• Membrane Replacement (assume 1 year life)		12,000/yr.
• System Labor (16 hrs/wk @ $20/hr.)		16,640/yr.
• Maintenance (parts - 10% of capital)		5,250/yr.
• Soft Water		1,200/yr.
• Electricity (108 kwh/day @ $.05)		1,971/yr.
• Steam (252 million BTUs/yr x $8/1million BTU)		2,016/yr.
• Chemicals		
- Maintenance		
Blue Giant (4,100 ga./yr. @ $1.86/ga.)	7,626/yr.	
Surfactant (1,596 ga./yr. @ $13.18/ga.)	21,035/yr.	
- Makeup (assumes dirty tank is dumped every month)		
Blue Giant (4,800 ga./yr. @ $1.86/ga.)	8,928/yr.	

Table 2. Continued

Total Chemicals	$37,589 /yr.
Total Annual Expenses	**$76,666/yr.**
TOTAL FIRST YEAR INVESTMENT (Total Capital & 1 yr. Annual Expenses)	**$129,166**

SAVINGS SUMMARY

- Chemicals

  Previous Costs = 2,250 ga./wk @ $1.86/ga x 50 wks. = $209,250

  Costs with UF = $37,589 (from above expenses)

  Chemical savings = $209,250 (previous cost) - 37,589 (cost with UF) $171,661

- Wastewater Treatment

  - Sanitary District
    Estimate reduction of fats, oils and grease charges by 50% — 5,333

  - Wastewater treatment operations
    Assume 10% reduction in wastewater treatment costs — 60,000

TOTAL FIRST YEAR SAVINGS $236,994

SIMPLE PAYBACK CALCULATION

$129,166 (1st year investment)----> $236,994 (Savings) = 7 month payback period

CONCLUSIONS

Pilot-scale ultrafiltration was successfully demonstrated on Ford's aqueous cleaning solutions for a 6 week period. The system effectively removed oil, grease and particulate contaminants and facilitated recycling of the majority of cleaning chemical components. One of the nonionic surfactants in the cleaning chemical mixture that comprises 2.2% of the concentrated chemical could not be recycled by the ultrafiltration process and had to be replaced through use of a metering pump system. Total cleaning chemical consumption would be reduced by 80 to 85% per year if a full-scale system is installed at this facility while oily wastewater generation would be reduced by over 90% (1 million gallons).

The economics associated with installing a permanent full-scale system at the Ford Stamping Plant are quite compelling. A capital investment of $52,500 and annual operating expenses of $76,666 (1997 dollars) would pay back in less than 7 months through cost reductions associated with chemical consumption, waste treatment and disposal.

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