TECHNOLOGY DIGEST

Timely Technology Transfer

EXTENDING THE LIFE OF RAILROAD SHOP CLEANERS WITH ULTRAFILTRATION

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Summary

Ultrafiltration technology can be used to substantially reduce the costs of parts cleaning and waste water treatment at railroad shops. Waste water treatment is the second largest environmental cost for North American railroads, and discharges from large parts washing machines are the primary contributor to treatment costs at major shops. An AAR study has determined that ultrafiltration technology can be a practical way to reduce the volume of this discharge and the costs of parts cleaning. AAR test results indicate a potential payback period of between one and two years for investment in an ultrafiltration system, depending on the cost of cleaning chemicals and the volume of parts washed. This payback period is based on savings in parts cleaning chemicals alone, and will be even shorter if the reduced costs of waste water treatment are included.

This filtration process uses a membrane filter to separate dirt and oil from the cleaning solution, thereby substantially extending its life. The productivity of the parts washer is also increased because of the reduced time required for general maintenance and replenishing the cleaning solution. In addition to these benefits, the burden on the waste water treatment plant is reduced because the volume of waste water and mass of cleaners and oils reaching the plant are diminished. Taken together, the savings from these factors will justify investment in ultrafiltration equipment at many railroad facilities.

Results of this study will help railroads evaluate potential applications of ultrafiltration with specific parts cleaners, and provide information to help evaluate manufacturers' performance claims for filters and filtration units.

Suggested Distribution:

- ☐ Environmental
- ☐ Mechanical
- ☐ Purchasing

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INTRODUCTION AND CONCLUSIONS

Waste water treatment is a major environmental expense for North American railroads costing the industry over $40 million annually. Most of the treatment is to separate oil and grease from the water. This treatment is more difficult and costly when waste water containing dirty cleaning solutions is discharged to the treatment plant. The dirty cleaning solutions contain a high concentration of oil and dirt. They also contain large amounts of cleaning chemicals that are still useful, but they inhibit the separation of oil and water. If these useful chemicals could be separated from the oil and dirt and returned to the parts cleaning machine, the cost of replenishing these chemicals and the cost of waste treatment would both be reduced.

Preliminary testing by the Burlington Northern and Santa Fe Railway (BNSF) in conjunction with the Illinois Waste Management Research Center (WMRC) indicated that ultrafiltration might be successfully employed for recycling the cleaning solutions used in railroads' large parts washers. Based on these findings, AAR constructed and operated a prototype ultrafiltration unit to test the performance and compatibility of ultrafiltration membranes with the cleaners commonly used by North American railroads. The goal was to determine the general design features necessary for broad application of ultrafiltration technology in North American railroad shops and to evaluate the economics of this application. Preliminary test results indicate that application of the technology is feasible, and that there is a large potential for cost savings from ultrafiltration. The anticipated savings are the result of:

- Reduced consumption of cleaner solutions.
- Increased productivity of the parts washing machine by decreasing the time for cleaning and refilling the parts washer.
- Reducing the load on the shop waste water treatment plant.

For the high-usage parts washers typically found in many large shops, the estimated return on investment for an ultrafiltration unit is between one and two years. This will vary depending on the cost of the cleaner and the production load on the parts washer.

LOCOMOTIVE PARTS WASHING

Most large North American railroads operate one or more major shops in which they overhaul and rebuild locomotives. Locomotives are taken apart and components are removed, disassembled, repaired and reassembled. Large washing machines that rely on high temperature and water pressure, along with chemical cleaning solutions, clean these parts prior to repair and rebuilding. These cleaning solutions are reused until they become sufficiently fouled with oil and dirt that they no longer satisfactorily clean the parts. At this stage the dirty solution is discharged to the railroad's waste water handling and treatment system, and a fresh solution of water and cleaning compound is prepared. The operation of these parts washers is a major activity in locomotive rebuilding facilities, and railroads expend a large amount of money operating them. A substantial contributor to this cost is the cleaning compounds used in these washers.

ULTRAFILTRATION

With ultrafiltration, instead of discharging the dirty parts cleaning solution to the waste water system, the chemical compounds and water in the cleaning solution pass through a filter and are recycled back to the parts washer (Figure 1). Oil and dirt particles too large to pass through the filter accumulate in a concentrated solution called the retentate.

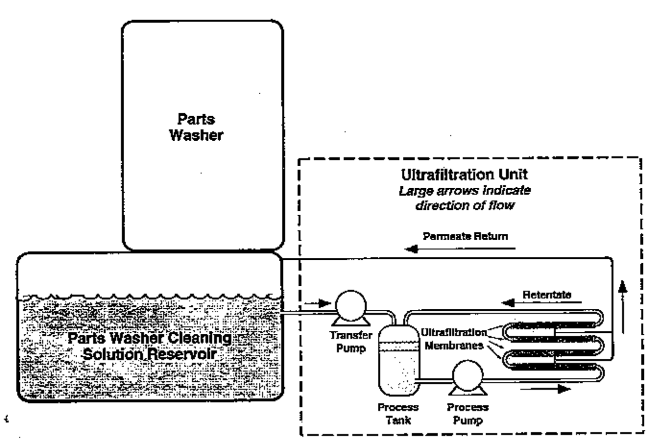

Figure 1. Schematic diagram of an ultrafiltration unit connected to a parts washer.

The transfer pump periodically pumps dirty cleaning solution from the parts washer reservoir into the process tank. A process pump continuously circulates the mixture through the membrane tubes and back to the process tank. The permeate, containing the filtered water and cleaning chemicals, is returned to the parts washer, while the oil and dirt are concentrated in the process tank. Eventually, the increasing concentration of dirt and oil in the retentate will coat the membranes and reduce the permeate flow through them. The membranes are then cleaned by circulating a special solution through the system to remove the built up deposits. The concentrated sludge in the process tank is transferred into a drum for separate disposal. This cycle of filtration - membrane cleaning - filtration continues until the cleaning solution is no longer capable of satisfactorily cleaning the parts. The cleaning solution may then be replaced. Sometimes the useful life of the cleaning solution can be further extended by replenishing it with appropriate chemicals.

TEST RESULTS

The AAR constructed a prototype ultrafiltration unit and conducted tests with a parts washer that cleaned traction motor parts at the BNSF locomotive shop in West Burlington, Iowa. The test of the AAR unit showed that it was highly effective at keeping the concentration of oil, grease, and suspended solids in the parts washer reservoirs at acceptably low levels over an extended period of operation. Figure 2 compares these levels with and without ultrafiltration. The levels of both contaminants rapidly rise when ultrafiltration is not used, whereas they decline or remain stable at low levels when ultrafiltration is used. After about 16 days of operation without ultrafiltration, the high concentration of dirt and oil required that the cleaning solution be discharged. By contrast, during the 50-day period when the test ultrafiltration unit was in operation, discharge of the cleaning solution was never required. The economic feasibility of membrane filtration will be determined by the volume of parts washed, the cost and concentration of the cleaner, the volume of the cleaning solution, and the frequency of its replacement if ultrafiltration is not used.

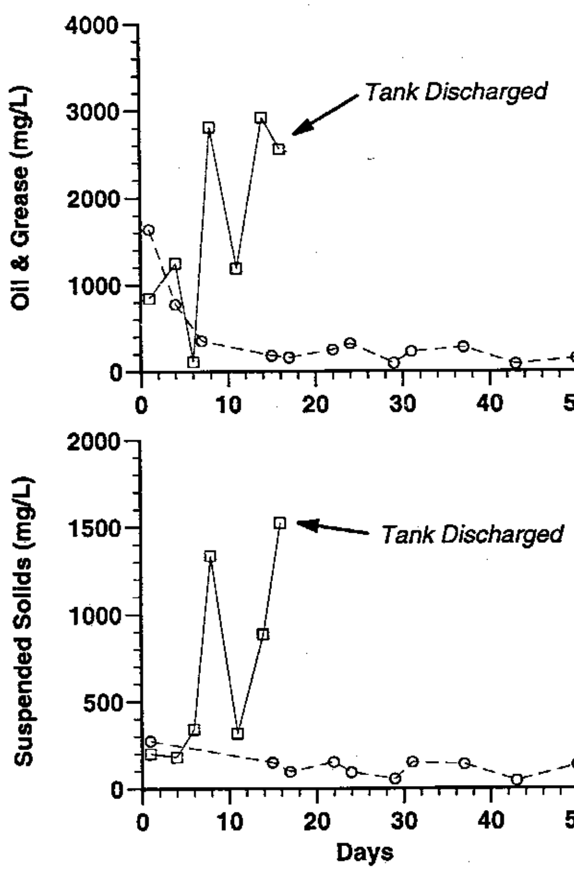

Figure 2. Levels of Oil & Grease and Suspended Solids in a parts cleaning machine when ultrafiltration was not used (squares and solid lines) compared to when ultrafiltration was used (circles and dashed lines).

Table 1 summarizes the cost and savings from the initial AAR test at the BNSF locomotive shop. These calculations do not include the estimated reduction in waste water treatment plant operation that would accrue. The variation in estimated monthly savings and payback period is due to the price differences among the commonly used parts cleaning chemicals.

Table 1: Pay Back Calculations

Capital Invested:	$25,762
Monthly Savings:	$1,557 - $2,701
Monthly Costs:	$560
Net Savings per Month:	$997 - $2,141
Payback Period:	12 - 26 months

TECHNICAL ISSUES

Railroad parts washers typically operate with cleaning solutions at temperatures of 180 degrees Fahrenheit, or higher, and at a pH between 10 and 12. The currently available ultrafiltration membranes can withstand either these high temperatures or the high pH of the solutions, but not both at the same time. To protect the membranes, we reduced the temperature of the cleaning solution to approximately 125 degrees Fahrenheit. We accomplished this by equipping the test unit with a cooling radiator in the processing tank.

All membrane filters will eventually foul and require cleaning. However, the degree of fouling and the ease of cleaning a membrane can vary significantly due to interactions between the compounds in the dirty solution and the membrane material. Each potential application of membrane filtration should be tested for chemical compatibility among the cleaner, the facility's water, the dirt and oil in the cleaning solution, and the membrane material.

Chemical interactions affecting filter performance can occur for a variety of reasons. For example, during the testing a white precipitate formed on the inside of the membranes, cutting off the permeate flow. This was due to the hardness of the water at the shop. Calcium salts were becoming concentrated in the wash solution due to water evaporation. A small water softener unit was added to treat only the makeup water, and this successfully prevented the buildup of salts in the cleaner.

In some applications, fine, hard particles in the dirty cleaning solution may cause excessive wear on pump seals. To circumvent this problem, installation of a small flushing line to the seal housing may be necessary.

MEMBRANE AND CLEANER COMPATIBILITY TESTING

AAR also conducted laboratory testing to evaluate the compatibility of the major cleaners used by railroads with some common ultrafiltration membrane materials. Four polymer membranes and one ceramic membrane, selected for their resistance to high pH and temperature conditions, were tested for compatibility with four alkaline cleaners. These four cleaners were representative of those used by major North American railroads. All the combinations of cleaners and membranes showed some interaction, resulting in a reduction in the rate of permeate passage, or flux rate. This is attributed to the physical process of the cleaner molecules occupying passageways in the membrane.

The membranes were also tested against three samples of used cleaner solutions obtained from railroad shops. These dirty solutions produced a larger decrease in the flux rate of all the membranes. Membrane surfaces can get fouled by particulate matter and by coating the interior passageways with other chemicals. Particles in the solution can also form a layer on the inside of the membrane filter surface. As the layer builds, the flux rate decreases and some cleaner compounds can be stripped from the permeate. At this point in an actual application, the concentrated retentate in the filtration unit would be removed, and the filters would be cleaned.

The membrane and cleaner compatibility testing showed that a filter pore size of 0.1 µm was appropriate for most railroad cleaner applications. The results also indicated that the flux range for each filtration membrane was affected by the particular cleaner but that a flux rate of 15 - 30 liters/m^2/hour was typical. We also investigated the effect on flux rate of pressures ranging from 20 psi to 60 psi. Flux rate was generally independent of pressure; however, at pressures below about 30 psi there was less buildup of particulate matter on the inside of the membranes.

Note: Contact Roger Andes at (202) 639-2210 if you would like a copy of the AAR technical report on ultrafiltration, or with any questions or comments about this document.

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A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, WILL BE AVAILABLE AT A LATER DATE THROUGH THE AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, WASHINGTON, DC 20001