Flex circuit manufacturer uses advanced microfiltration

A Duraflow case history

The Duraflow membrane-based water recycle system allows Company managers to sleep at night. They never worry about water discharge or compliance or whether there is enough high quality water to manufacture their products.

A billion dollar company in the electronics connector and printed circuit board industry has manufacturing plants all over the world. Duraflow Corporation located in Tewksbury, MA, has been providing wastewater engineering services for the flex circuits division in Nashua NH for ten years. Early in 2005 they contacted Duraflow regarding there business plans to purchase a Chinese company located in Guangzhou China. They asked Duraflow to help them design a wastewater treatment system for that factory.

This purchase would mean that the new entity would be relocating to a new factory located in a small village outside the Panyu district of Guangzhou. This relocation would mean that there would need to be a new wastewater discharge permit for the new facility. Unfortunately for them that winter there had been must unrest in the local community regarding pollution of the rivers and its effects on the local fishing industry. The local government was scrambling to develop new regulation for industry and they were asked to be on the leading edge of technological development for water recycling technology. Early negotiations proposed a 50% water recycle design.

They approached Duraflow with this design basis and a preliminary design was developed and reviewed with Chinese personnel. This design proposed the segregation of the waste into two different streams. The first stream would contain all of the heavy organic (COD limit of 120 mg/l) bearing wastes. These wastes are generated from the photo imaging processes of Developer and Stripper from the traditional DES line. These wastes would be treated and processed through a clarifier and discharged from the factory. This stream represented 25% of the wastewater flow at 40 l/min. The balance of the wastewater (120 l/min) containing all of the rinse water from the Plating process, the Cleaning process, the Etching process, the PTH (Plate Through Hole) or electroless copper process, and the Nickel/gold process would be Pre-treated with the Duraflow Microfiltration (DMF) membrane system and recycled using a Reverse Osmosis (RO)

system. The Duraflow membrane process would precipitate all of the toxic metals and filter all suspended solids from the wastewater and perfectly condition the water for subsequent dissolved salt removal with the RO membrane system. The RO system would have to operate at 66% recovery to result in 50% water recycle. Duraflow had previous experience with this process and was confident that this could be achieved.

As the project proceeded, the local government modified the recycle requirement and required 80% recycle. This required a design change. All of the rinse water including the organic rinse water would now have to be treated through the DMF and RO system.

And the RO would have to be operated at 80% recovery. Duraflow would have to modify the wastewater pretreatment chemistry to assure that all to the COD and metals were removed by the DMF and that these contaminants would not cause a reduction in the filtration rate in the DMF and RO systems.

Duraflow Microfiltration System

Duraflow microfiltration is designed around the Duraflow membrane. This membrane is constructed of chemically inert Polyvinyladiene fluoride, has a nominal porosity of 0.2 microns and is made as a 1-inch diameter tube six feet in length. The chemically resistant polyethylene porous tube that Duraflow uses is pressure rated at 150lbs. The Duraflow membrane is produced with 100% quality control testing. This level of testing assures that:

Advantages of the Duraflow Membrane System

- Removes metals, COD, TSS in one step and produces suspended solids free, crystal clear, clean filtrate perfectly condition for feed to reverse osmosis membranes
- Totally uniform pore distribution that never passes TSS
- Very high filtration rate allows for lower capital cost when compared to:
    - Conventional process of polymer enhanced gravity settling, followed by
    - Backwashing multimedia filtration, followed by
    - Backwashing activated carbon filtration, followed by
    - Backwashing disc microfiltration, followed by
    - Membrane ulrafiltration for precondition water prior to reverse osmosis
- Made from chemically inert plastics that allow for use of generic acids and oxiderzers (bleach) to membrane cleaning
- Very long membrane life (5-10 years). Membranes come with an extended membrane warranty.
- Duraflow Chemicals are specifically formulated to maximize the contaminant removal, filtration flow rate, and membrane life and minimize membrane cleaning.
- Duraflow local distribution provides rapid onsite service

- The membranes produce zero passage of suspended solids, and
- Have the specified porosity that allows for system design based on 500gfd (gallons of filtrate per foot squared of membrane surface area per day).

These two features make it the perfect product for economical pretreatment of industrial wastewater prior to salt removal by reverse osmosis membranes.

Duraflow membrane systems are built around the DF-415 membrane module. This module contains 10 membrane tubes (15ft^2 of surface area) and produces 20 to 40lpm of filtrate flow. The system in Panyu has a processing requirement of 15M^3 per hour (250 lpm or 7gpm). The Duraflow system is built on a 36-membrane frame. This system has one 30Hp process pump and an 8000L concentration tank (filter feed tank). The DF-415 membranes are plumbed into three parallel flow paths or trains. Each train contains a maximum of 12 membranes in series. Because of the flow processing requirement of only 250 lpm there are only nine DF-415 membranes installed in each train and there are three blank spaces available for future additional flow processing capacity.

> ***"The Duraflow Microfiltration System is truly the state of the art for recycling industrial waste water"***
>
> — Research Manager

Duraflow DF 415

Membrane module

The three membrane flow paths are plumbed and valved so that they may be isolated individually for cleaning with the clean-in-place system. This allows them to operate one train of membranes to process all of the waste produced by the plant and be cleaning the other banks of membranes at the same time. Since the Duraflow membrane is a critical component of the 80% water recycle system it is imperative that it operate to produce sufficient water to feed to the RO system and ensure the supply of high quality water back to the factory.

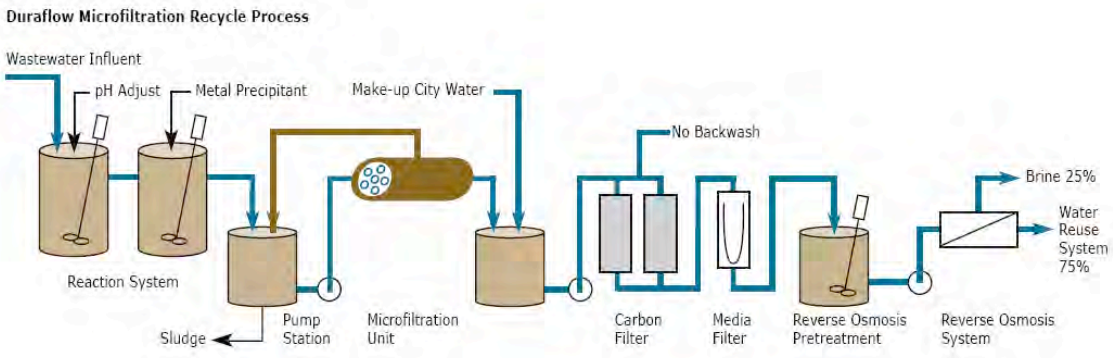
Duraflow Treatment Process

Since the Duraflow membrane filter has nominal porosity of 0.2 microns, it is designed to filter out all particles greater than 0.2 microns. When trying to apply this filter for pretreatment to spiral wound reverse osmosis membranes it requires a working knowledge of the requirements for the quality of feed water needed to keep the RO running well. Since historically this knowledge has all been developed based on the use of RO membranes for processing city water, brackish water, or seawater, not much operating data has been developed for the use in recycling of industrial wastewater. Duraflow has had experience successfully developing this application in the US.

Based on that experience, Duraflow realized the key to success would be:

- Proper segregation of the waste streams
- Batch treatment or offsite disposal of all concentrated wastes
- Disciplined waste management controls in production, and
- Effective chemical pretreatment

Effective pretreatment would ensure that any and all compounds that could foul the DMF or RO membranes were either eliminated from the feed or properly pretreated for removal by the DFM system. If Duraflow could execute this design the water recycle system would operate reliably producing high quality water and maximize the life of the RO membrane. The process that was chosen is as follows:



Duraflow System Engineering

When considering the pretreatment process Duraflow needed to conduct a complete process review of every chemical step and analyze the containment levels of all rinse water. These analyses included: pH, ORP, TDS, TSS, COD, Cu, Sn, Pb, Ni, and Cyanide. This analysis included the quantification and bench testing of all concentrated wastes to determine if onsite batch treatment or offsite disposal was the most economical option for treatment.

This analysis reflected Duraflow's in-depth working knowledge of the chemical manufacturing process for making FPC. For example, it is well known that photo resist developer and stripper chemistries contain dissolved photo polymer that have a high MW and charge. If they remain dissolved in the wastewater or if incorrectly precipitated at very low pH, photo resist particles will stick and foul the Duraflow microfiltration membrane. To prevent this from happening in Panyu, Duraflow used a specially formulated chemical treatment product, DF-781.

After completing the water analysis, Duraflow met with company engineers and proposed the following process for segregation and pretreatment of all of the process chemistries from the site. All rinse water would be co-mingled in one 20,000 L equalization tank. The concentration of the contaminated water varied greatly in the incoming rinse water as the process baths get more and more contaminated. Table 1 is a chart of the variation of the various contaminates in the wastewater feed. The EQ tank is designed to dampen out or equalize the fluctuations in the incoming concentrations.

Contaminate	Inflow Variation	Duraflow Discharge	RO Brine
pH	-2.0 - 10.0 SU	9.0 - 10.0 SU	6.0 - 7.0
TDS	300 -1200 mg/l	400 -1500 mg/l	1600 - 6000 mg/l
TSS	20 -100 mg/l	< 1 mg/l	< 4 mg/l
COD	200 - 400 mg/l	50-75 mg/l	< 100 mg/l
Cu	5-50 mg/l	< 0.1 mg/l	< 0.5 mg/l
Ni	0.5-1 mg/l	< 0.1 mg/l	< 0.5 mg/l
ORP (measures oxidizer levels)	+100 to + 400 mv	+75 to +125 mv	NA

Table 1: Duraflow System Performance

Because one train of membranes on the microfilter system can process all the waste water — while cleaning of the spare membranes takes place at the same time — there is no risk of failing to keep up with production. Consequently, Duraflow has advised the company to keep the EQ tank full at all times to maximize the equalization volume. As a result, they have reduced their chemical usage by 30% since the initial startup.

Duraflow Chemical Treatment Process

After equalization, the water flows to the first reaction tank. This tank is 4000 L and is equipped with a mixer, pH and ORP controls. Caustic and acid are added to keep the pH between 8.0-9.0 s.u. The ORP is monitored. Treatment chemical, DF-781 is added with a volumetric dosage of 25ml/min. Based on a feed rate of 15m3/hr, this calculates to a dosage rate of 10mg/l (10 ppm). In addition, powdered activated carbon is also added at a rate of 1.5 kg/hr or 100mg/l. These two treatment chemicals are added to stabilize and maintain high filtration rates and assure good removal of metals, TSS. COD, and destruction of most oxidizers. The selection and usage of these products is required because of the need for 80 percent recycle. If lower percentages of recycle were required the chemical usage and operating cost would be much less.

After precipitation of all of the non-chelated metals via hydroxide precipitation, the waste flows to a second reaction tank, also equipped with a mixer, pH and ORP controls. The pH is adjusted between 9.0 to 9.5 s.u. and the ORP is maintained between +75 mv and +150 mv, using a Duraflow metal precipitant DF-610. This product has a negative ORP, which make the dosage controllable with an ORP controller. DF 610 chemically binds with any and all complex or chelated metals virtually assuring no passage of metals to the RO system. The operators do a manual check of the ORP set point every hour to assure complete metal removal and to minimize the over dosing of treatment chemical.

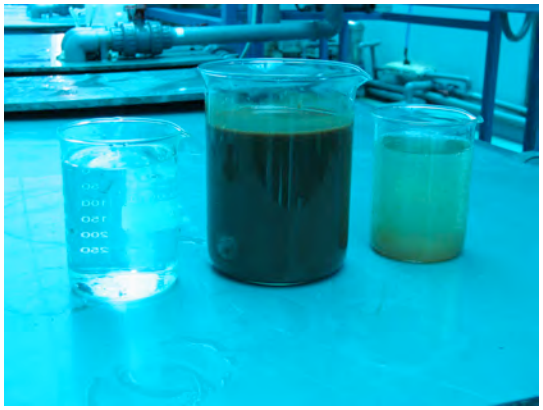
Duraflow Membrane Treatment Process

After the contaminants (metals, TSS, COD, dissolved photo polymer) are properly precipitated, coagulated or absorbed. The wastewater flows to the concentration tank at between 100 to 300mg/l of TSS.

This tank is equipped with level controls and pump suction to the membrane feed pump. This feed pump, pumps 1325 L/Min (350 gpm) of treated wastewater to each train of membranes at 50 psi. The pressure squeezes the clean water through the pores of the membrane. The membrane rejects all of the suspended solids. So anything that needs to be filtered must be a particle. All dissolved salts pass through the Duraflow

membrane and flow on to the RO system for removal by the RO membranes. Only a small percentage (17%) of the inlet feed water is filtered on a single pass through the membrane train, (1325 Lpm in and 230 Lpm filtered water). The remaining 1095 Lpm of water not filtered provides for a turbulent scrubbing action of the inside of each membrane tube. This pumping energy creates the fluid dynamics, which prevents the formation of a filter cake on the surface of the membrane. As a result the solids remain suspended as a slurry and are carried back to the concentration tank.

The concentration tank is the collection place for all of the solids. This is why it is called the concentration tank. The solids will concentrate here from 150 mg/l to 15,000 mg/l or higher, yielding a 100 X concentration factor or in other words a 99% recovery of filtered water. For every 100 liters of feed at 150 mg/l TSS the Duraflow system produces 99 liters of filtrate (zero TSS) and 1 liter of 15,000 mg/l of TSS.



DURAFLOW DF1036 SYSTEM filtrate concentrate feed

Table 1 gives the discharge quality for the Duraflow membrane system. This water is of perfect quality to be fed to a reverse osmosis system. But that does not mean that the reverse osmosis system is easy to design because this is recycled wastewater not city water. Waste water has hundreds of added chemical species resulting from the proprietary plating baths used in complex FPC manufacturing process.

Duraflow Reverse Osmosis Desalting System

Duraflow experience has recommended that the discharge water from the DMF be collected in a tank and pH adjusted to pH 6.0 before introduction into the RO membrane. This minimizes the solubility of most soluble salts remaining in the feed to RO system reducing fouling and cleaning requirements. The water then passes through

an activated carbon column. This activated carbon treatment is provided so that any city water make up feed (40,000 L/day) can be introduced and de-chlorinated prior to the RO. It will also absorb any excess treatment reagents.

The system was supplied by a local Chinese company. It is equipped with a feed of anti scalent, which is added at a dosage of 5-10 mg/l. The RO system is designed using a 2-1 configuration with Dow Film Tech membranes. The first pass has two membrane shells each containing (5) 40" X 8" spiral membranes. The feed flow to each pass is 82L/min and the filtrate is 41L/min. The balance of the flow, 82/min., is fed to the second stage where 41L/min. filtrate is produced for a total of 123L/min. of filtrate or 80% recovery. 41L/min of brine is discharged from the plant.

The system operates at a feed pressure of 170 psi (kg/m2). The normal operating process recycles 200,000 L/day back to the manufacturing plant. The TDS of the feed ranges between 500 micro Seimens and 2,000 micro Seimens and the permeate averages 25 to 75 ms. The concentrated brine (40,000L/day) is discharged to the sewer system. The quality of the brine is compliant with the discharge requirements of 0.5mg/L Cu, 120mg/L COD. The reverse osmosis system is pictured as follows:

Reverse Osmosis System 55 gpm

System Maintenance

The treatment system requires daily monitoring of the chemical feeds and pH and ORP probe cleaning.

The operator must monitor the level of concentration of the suspended solids in the concentration tank and periodically transfer the solids to a sludge storage tank. From the sludge storage tank the solid are further dewatered in a plate and frame filter press.

The DFM only requires daily water flush with city water to keep the flow high. Once every month the membranes are cleaned with a 0.5% acid solution. This process is done on line while the other bank of membranes is processing waste water. The cleaning solutions are batch treated.

The RO system requires cleaning periodically. When the pressure needed to deliver 120L/min of recycled water gradually increases over 2-4 weeks to 200 psi, then the RO membranes are cleaned with citric acid. This citric acid is also batch treated prior to disposal.

Batch treatment and Concentrate management are the most important parts of the maintenance procedures. Most of the concentrated wastes contain contaminants such as, COD or metals at relatively low levels compared to the salt concentration of the baths. Even though these contaminants could be easily removed by the DFM system, doing so would result in the build up of excessive salts concentrations in the water feeding to the RO system. This would increase the salt concentration in the discharge from the RO system. If a certain quality of RO permeate is needed then the salt concentration of the feed must be controlled. Metering in concentrated wastes could also either reduce the flow or increase the operating pressure needed. It would also increase the amount of RO membrane cleaning required and shorten RO membrane life.

Operating Costs

The operating cost for chemicals, electricity, waste hauling and membrane replacement are outlined in Table 2. Keep in mind that these are for 80% water recycle, low percentages would be less.

Chemicals	Usage	Price	$/M^3
DF 781	10g/M^3	$ 2.40 / KG	$ 0.25
DF 610	10g/M^3	$ 2.50 / KG	$ 0.25
Electricity			
DFM	30hp 1 kw/M^3		$ 0.15
RO	20hp 0.67 kw/M^3		$ 0.10
Labor			$ 0.12
Sludge	25 kg/day		No charge
Replace Membrane DFM	5 – 10 years	$2200 X 27	$ 0.07 to 0.03
Replace Membrane RO	2 – 3 years	$1000 x 15	$ 0.07 to 0.05

Table 2: Operating Costs 300 M^3/ day

Summary

The Duraflow membrane base water recycle system has allowed company management to sleep at night. According to the Business Development Manager, since this system has been installed he has never had to worry about water discharge or compliance or having enough high quality water for use in the manufacturing of his product. He can devote 100% of his time to meeting the needs of his customers. When they were in the old plant, they never really wanted to show the customers the waster water treatment system. Now the Duraflow water recycle system has become part of the companies facilities marketing plan. All customers are given a tour of this area and they sell its capabilities for assuring production of high quality products.

The Research Manager, was very worried at startup. He had never seen any thing like this technology. All of the other contractors on site thought, 'This will never work!'

"When we started the microfilter system and I saw how dirty the feed water was and it was flowing into the membranes that we just installed, I was worried. Then the water came out crystal clean. I was amazed, but I thought we will see how long this lasts. When it was still running with out a chemical cleaning one month later, I became a believer.

"As long as we follow Duraflow instructions and prevent the introduction of concentrated waste to the system it performs with out problems. The only problems we have encountered have been with the control of the chemical addition, which are mechanical and electrical in nature. Duraflow's advise and guidance has solved these problems as well.

"We tried a local source of treatment chemicals in order to compare to Duraflow's chemical products and there was an immediate negative impact on the system. First, the Duraflow membranes flow slowed down and the system required chemical cleaning every day. Second, the filtrate flow from the microfilter began to foul the RO and we had to shut down the DFM feed, stop recycling water and use city water in the factory. Immediately, upon switching back to the Duraflow products the problems went away.

"The Duraflow Microfiltration System is what makes this process work. It is truly the state of the art for recycling industrial waste water."