Recycling Used Rinse Water
Using Reverse Osmosis on Standard (Iron-phosphate) Washer

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The Powder Coating Industry demands a high volume of high purity water to support production. High purity water is used to clean and rinse parts. Simultaneously, there is also a need to reduce the total volume of wastewater from the manufacturing facility. As companies begin to find out that many of their waters can be reused internally by containing them and then repurifying them, they are also finding that the process involved is so simple that it is often cost effective for them to reclaim the water. This is particularly true when membrane processes are used to treat water because the recovery of water for reuse is extremely high, typically 80% to 95%.

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WATER USE REDUCTION... is becoming essential to the powder coating industry. The reduction in consumption has been accomplished through reuse and reclaim processes that have resulted in a lowered total amount of water consumed. Water use reduction, if implemented correctly, translates to a reduction in cost. However, this COST SAVING is only one reason to reduce water usage. A growing customer demand for industrial environmental responsibility has prompted several companies to develop environmental management systems(EMS) and to become International Organization for Standardization(ISO)14001 certified. Certification to the ISO 14001 standard is partly based on the requirements for a company's EMS to identify the environmental aspects derived from their operations, set objectives and targets to minimize significant aspects, and commit to continual improvement. Reduction of water use has benefited companies in many ways, including a reduction in cost, increased efficiency of operations, and reduction in use of natural resources in an environmentally conscious community. Wastewater discharge can be reduced significantly by the elimination of an unneeded pre-rinse step, or by counterflowing rinse baths and then recycling the used rinse water and reclaiming the reverse osmosis concentrate stream for reuse.

TREND TOWARD WATER REUSE... Whatever the case, wastes and wastewaters are generated from the use of pretreatment washers that must be contained, managed, and appropriately disposed. The costs associated with these processes are no longer trivial. They are significant production costs. No longer is water an inexpensive commodity to be taken for granted by the industry. The first step in management of any water or wastewater is AWARENESS. As companies begin to find out that many of their waters can be reused internally by containing them and then repurifying them, they are also finding that the process is so simple that it is often cost effective for them to reclaim the water. This is particularly true when membrane processes are used to treat water because the recovery of water for reuse is extremely high, typically 80% to 95%. The practice of conservation is new to the industry, however, it is becoming a way of life. New facilities are being constructed with water conservation, recycle, and reuse engineered as part of their design. It is anticipated that this will continue into the future.

PURIFYING WATER WITH REVERSE OSMOSIS

Many pretreatment systems used in the powder coating industry rely on reverse osmosis and deionization technologies for water treatment. However, RO is replacing DI as the technology of choice for many coaters. As in all developing technologies, many have interpreted the role RO treatment should play and what it's interaction with existing technologies should be. In particular, one school of thought considers RO a competitor of ion-exchange technology; many references to comparisons of the two treatment methods can be found in literature of the past two decades. Regardless, the market penetration of RO technology in the front end of water systems is an instructive recent example of the current trend toward the replacement of ion-exchange operations by continuous membrane processes.

RO is a relatively new technological development; the first commercial RO systems date to the 1970's. In the years since then, the technology has matured. Today's systems represent viable methods for reducing the concentration of materials dissolved in water. The technology has found application in widely diversified fields including drinking water, fruit juices, treatment of wastes, and production of high purity process water for use in numerous industrial applications.

Shown here is a reverse osmosis reclaim system at Tuthill Transport Technologies, Brookston, IN. The system includes (4) 1500 gallon storage tanks, activated carbon filter, duplex water softener, and a 10,000 gal/day Reverse Osmosis machine. The used rinse water is continuously circulated through the equipment and the purified water is then sent back out to the washer. 90% of the water is recycled and the final 10% goes to an evaporator. The system offers ZERO DISCHARGE and complies with local regulations.

RO technology uses a high pressure pump to force water through a semipermeable membrane made from thin film composite plastic. Water molecules are small enough to pass through the membrane (called permeate), leaving behind the larger metal ions and mineral salts (called concentrate). A reverse osmosis machine can remove 97% to 98% of the total dissolved solids (TDS) found in the incoming feedwater.(See Table 1). The ratio of permeate flow rate to feedwater flowrate is known as the recovery rate of the RO machine. The more recovery, the more salts are concentrated in the waste concentrate stream. A recovery rate of 66% means we will concentrate our waste stream by 3 times; 75% will be 4 times; and 80% will be 5 times.

Table 1: Specific conductance, resistance, and approx. electrolyte content.

Specific Condutivity in Micromhos	Specific Resistance in Ohms	Approximate Electrolyte Content, .ppm (NaCl)
0.1	10,000,000	0.04
0.2	5,000,000	0.08
1	1,000,000	0.4
2	500,000	0.8
4	250,000	1.6
6	166,000	2.5
8	125,000	3.2
10	100,000	4
20	50,000	8
30	33,333	14
40	25,000	19
50	20,000	24
60	16,666	28
70	14,286	33
80	12,500	38
90	11,111	43
100	10,000	50
200	5,000	100

CLEANING RO MEMBRANES... Many advances in the water treatment industry have led to the success of the RO machine. Several water treatment equipment manufacturers have focused on engineering and research. These companies don't accept the industry premise that RO membranes are disposable items. These companies' attitudes are bolstered by dozens of patents, several of which deal with machine design and the process of membrane cleaning. This technology administers cleaning agents to the feed and permeate sides of the membranes. The cleaning agents remove scale and biogrowth from the membranes which might restrict the flow of water.

Because the thin film composite membranes are pH resistant and mechanically durable, many manufacturers use a combined pH- and osmotic-driven process to affect cleaning. This makes cleaning quick, safe, simple, and reliable. It also creates a preventive process so that the entire membrane surface is recovered with each cleaning. For an experienced operator, the total cleaning time takes one hour. The cleaning process restores the membrane to it's original flux rate and diverts the system's permeate water to drain, which flushes out debris before placing the RO machine back in service. The clean-in-place system restores the membranes to their original flux rate and sustains membrane life and performance. RO membranes come with manufacturers warranties and can last as long as 6 to 8 years if maintained properly. Membranes need to be replaced when permeate flow rate drops 15 to 20 percent or when cleaning no longer restores the original flow rate.

UNDERSTANDING AN OLD DESIGN FIVE STAGE WASHER

The old typical five stage washer system(shown in Figure 1.0) uses a traditional deionizer for spot-free final rinse, and simply uses utility grade city water for the intermediate rinses. Stage 1 uses 140F hot alkaline cleaner to remove cutting oils and degrease the parts. Stage 2 is an ambient temperature city water rinse, which will continuously overflow to drain in an effort to keep the impurities (carryover from Stage 1) purged from the rinse water bath. Stage 3 is a surface preparation using 130F hot iron-phosphate chemical solution. Stage 4 is another ambient temperature city water rinse, also overflowing continuously to drain. Stage 5 uses a traditional deionizer for spot-free final rinsing of the parts prior to painting. A 5 to 10 gal/min. flow rate of fresh DI water passes through the last set of spray nozzles and will then continuously overflow to drain. This once-through DI design provides adequate final rinse water quality in the range of 200,000 ohm to 500,000 ohm resistivity. One problem with this design is that the load capacity on the DI equipment is equal to the TDS concentration in the raw city water being treated. Frequent regeneration and maintenance are required for the once-through DI system to work properly.

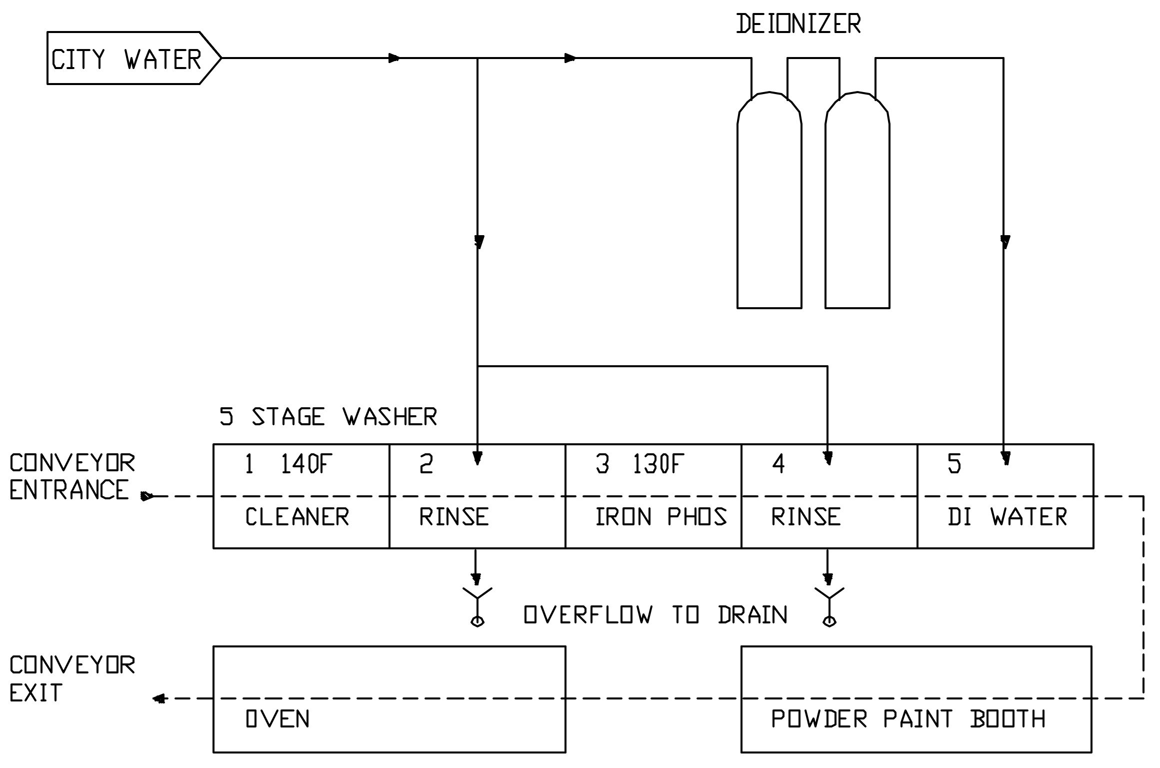


FIGURE 1.0 OLD FIVE STAGE WASHER

CONSIDER THIS EXAMPLE CALCUALTION... of a typical old five stage washer with purified water on the final rinse only. City water with 400 mg/L of TDS is used for continuous overflow rinses in Stage 2 and Stage 4. The overflow rates must be maintained at approx. 3 gal/min. to keep the rinse water clean. However, we know that the TDS in Stages 2 & 4 will never be less than 400 mg/L in this manner. By using RO water (10 mg/L TDS) for rinsing, we can substantially reduce the overflow flow rate until the operating TDS of Stage 2 and Stage 4 are somewhere within the range of 50-100 mg/L. This is monitored automatically or by an operator with a handheld TDS meter. In most instances, overflow rates can be reduced by as much as 50% to 60%. This means you produce less wastewater.

Now let's look at the "heated" Stages. Stage 1 and Stage 3 lose water from carryout losses and from evaporation. If Stage 1 has 2,000 gallons of alkaline cleaner, and it requires 500 gal/day of makeup water from evaporative losses, then let's assume a gallon of water contains (4) liters as follows:

500 gal/day x (4)L/gal x (400)mg/L= 800,000 mg = 800 grams of dissolved salt

800,000 mg added to our bath of 8,000 L (2,000 gallons) 100 mg/L rise in TDS for Stage 1 each day! This is approx. 2 lbs. of salt! This causes a corresponding change in conductivity of the bath. You can see that after 1-2 months of operation, the TDS content of the bath will have increased by 2,000 mg/L just from the dissolved solids in our raw city water makeup.

If conductivity is the parameter (which we monitor to drive the chemical feed pump for the alkaline cleaner into Stage 1) then, it becomes literally impossible to control the TDS. Eventually, Stage 1 must be dumped, refilled and recharged with new chemical, and we start over. If we were to use 10 mg/L reverse osmosis water for makeup in this example, we eliminate 98% of the raw city water TDS buildup and now the effect of "fighting against the chemistry" has been significantly reduced.

MANY IMPROVEMENTS HAVE BEEN MADE to the old system design in recent years.(See Figures 2.1-2.4) This includes replacing the final rinse water with a reverse osmosis water system; which not only provides spot-free final rinse water quality, but does this more efficiently and less costly than the traditional deionizer. The continuous overflow to drain from the rinse stages can be reduced and sometimes even eliminated when using RO water for the rinse baths.

The following four system designs have evolved from each other. They offer cost savings and other operating advantages over the once-through DI system.

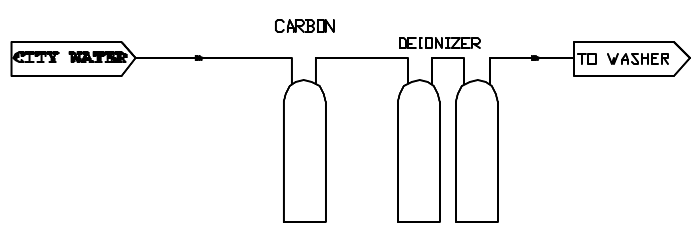


FIGURE 2.1 SINGLE PASS DI

Figure 2.1 Single Pass DI. This is a large capacity single DI unit with a carbon filter, and often has a optional waste neutralization tank for the regenerant chemical. The system can run for 8-16 hr/day with a single Dl and can regenerate it's capacity during off-peak hours. This system has the lowest capital cost among systems but is much less efficient than other systems. This was the standard design 30 years ago.

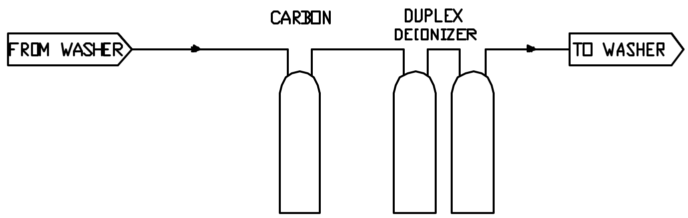


FIGURE 2.2 RECIRCULATED DI

Figure 2.2 Recirculated DI. This is a duplex DI system for continuous 24 hr operation. The used DI rinse water recirculates back through the carbon filter and deionizer. Built-in resistivity monitors automatically initiate the regeneration sequence. In the recirculation mode, the DI water will approach 1.5 million ohms. This design saves on chemical costs and recycles water. However, there is added cost with the second DI unit. Makeup water into the recirculation loop is the only load on the capacity of the DI units.

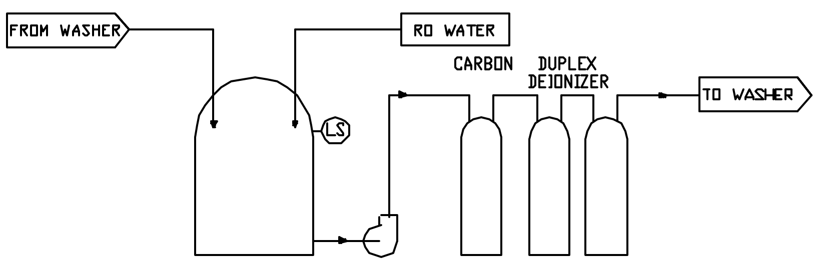


FIGURE 2.3 RECIRCULATED DI W/RO MAKEUP

Figure 2.3 Recirculated DI w/ RO Makeup. This system includes a single or duplex DI unit with a small receiving tank added into the recirculation loop. In this loop, the water level is maintained in the receiving tank by adding RO makeup water. The RO removes 98% of the makeup TDS, thereby reducing the regeneration frequency of the DI that much more. This is the most efficient system design for high volume DI water usage and high rinse water flow rates.

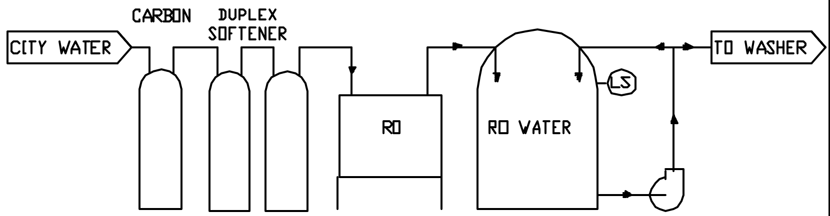
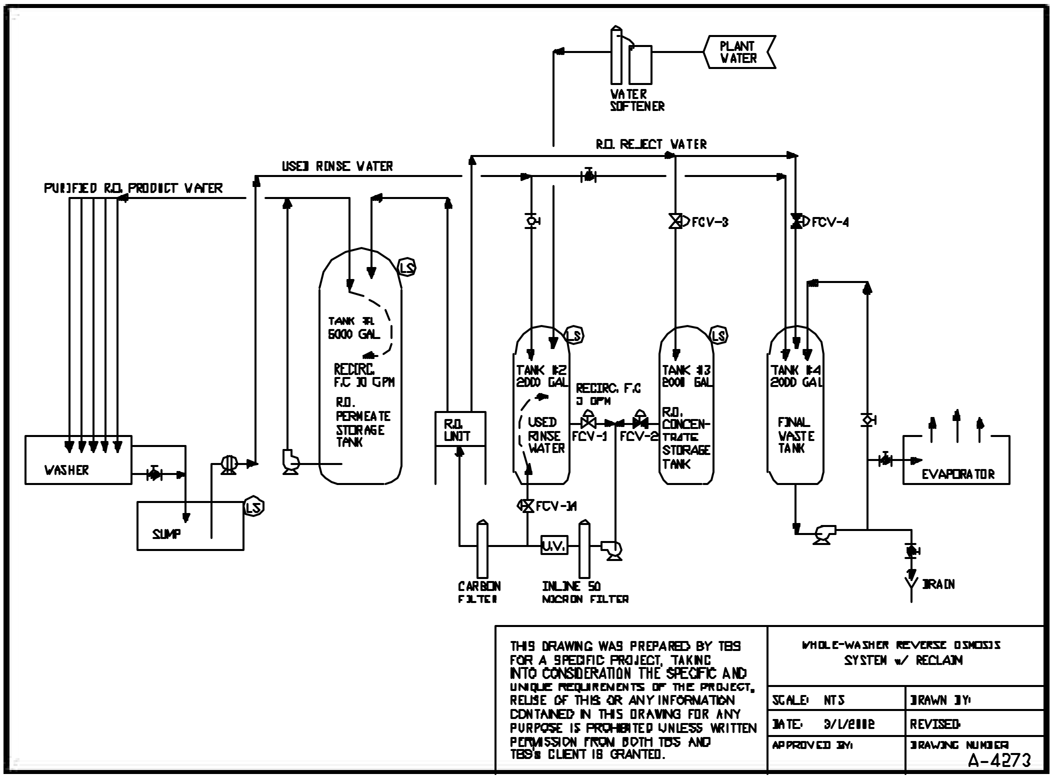


FIGURE 2.4 REVERSE OSMOSIS SYSTEM

Figure 2.4 Reverse Osmosis System. In this system the RO unit is the primary roughing unit. It removes 98% of the raw water TDS, no matter what the incoming TDS is, and the RO water is stored in a relatively large volume storage tank. This stored RO water is then sent out to the washer for fast fill, makeup, and spot-free final rinse. This RO system design has become the most common water treatment system used for washers in recent years.

RECYCLING THE RINSE WATER

Recycling the rinse water requires that we separate the “used” rinse water into a bulk storage tank so that we may repurify it. This stored water can now be continuously circulated through a series of filters, each specifically designed to remove certain impurities such as iron, mineral hardness, chlorine and organics, turbidity and supended colloidal particulates, and dissolved salts. Drawing No. A-4273 shows the whole washer reverse osmosis system design. The system is similar to the reverse osmosis system discussed previously. With the simple addition of (2) more storage tanks, we can now separate and recycle the used rinse water (returned from the washer) and reclaim the concentrate waste stream from the RO machine for reuse. In this manner, all water going out to the washer is purified RO water (Tank #1), and all “used” rinse water (Tank #2) returned from the washer must again pass through the RO equipment. The concentrated salts from the RO reject stream are also collected (Tank #3) and passed through the RO machine one more time.



By adjusting the recovery rate of the RO machine to approx. 66%, we can recycle and reuse up to 90% of the rinse water being used on the five stage washer. Typically, the final 10% is sent through an evaporator or other means of disposal when ZERO DISCHARGE requirements must be met. This system design works well when the used rinse water is not allowed to exceed 200 mg/L concentration. Our final concentrate to the evaporator will then stay below 800 to 1,000 mg/L, which in many instances can be cleaner than the raw (city water) which we started with.

The used rinse water will contain trace amounts of contamination, including oil and grease, dissolved salts and chemical used in Stage 1 and Stage 3, and suspended colloidal particulates. Since we want the RO machine to only remove the dissolved salts, we must pre-treat the "used" rinse water to remove everything else prior to the RO. Iron is present in Stage 2 from the surface etching of steel parts in the previous Stage 1. Iron is also present is Stage 4 from the iron-phosphate carryout from Stage 3. (See Table 2).

Table 2 – Iron Content of Rinse Water – Low Carbon Steel Parts

	Washer 1 Stage 2, 4		Washer 2 2, 4		Washer 3 2, 4		Washer 4 2, 4		Washer 5 2, 4		Washer 6 2, 4	
TDS Mg/L	290	110	1500	235	217	40	200	21	155	75	185	50
Fe Mg/L	2.0	5.0	12	9.0	2.0	1.5	6.0	0.8	1.5	1.5	0.8	0.5

- actual data from (6) difference five stage washers all running low carbon steel parts;
- Feb. 2002 though Oct. 2002 by TBS.

The iron will foul the Reverse Osmosis membanes and can be easily removed using a traditional water softener which is modified to use ion-exchange resin specifically designed to remove higher concentrations of dissolved iron. The water softener then uses iron-out style salt to recharge it's capacity, together with routine application of resin cleaner to strip off the collected iron. Oil & grease and organic molecules are adsorbed by an activated carbon filter which will also physically filter suspended particulate down to approx. 50 micron particle size.

OPERATING DATA FOR A REVERSE OSMOSIS RECLAIM SYSTEM

Table 3 shows actual operating data taken from an RO reclaim system which runs at 10 GPM continuous flow rate. The system starts with relatively dirty rinse water and runs for 4 hours. After 4 hours, we see that the differential pressure across the activated carbon filter and the 5.0 micron filter begin to rise from less than 1.0 psid to 2.0 psid. This gives an indication as to how often we must backwash the AC filter to reduce pressure drop. The 5.0 micron filter cartridge must be replaced when pressure drop exceeds 5.0 psid. The TDS of the used rinse water feeding the RO machine and the TDS of Stage 2 both decrease. As the TDS of the returned water decreases, then the RO permeate also improves (conductivity decreases).

Table 3. Operating Data Of An RO Reclaim System

Time	AC Filter	Gallons Remaining	Feedwater TDS	5 Micron Filter
11:30	<1 psid	14,620	674 mg/L	<1 psid
12:15	1.0	14,099	485	1
12:45	1.5	13,755	405	1
14:15	2.0	12,580	239	2
14:45	2.0	12,180	191	2
15:15	2.5	11,850	122	2

Conc. Flow	Permeate Flow	Permeate Cond.	RO Tank TDS	Stage 2 TDS
3.5 GPM	7.0 GPM	10 micromho	28 mg/L	220 mgL
3.5	7.2	8	24	185
3.5	7.3	7	19	172
3.3	7.4	6	11	141
3.3	7.5	5	9	136
3.3	7.6	5	8	131

Notes: 1) Backwash AC filter @ 5 psid.
2) Change 5.0 micron filter cartridge @ 5-8 psid.
3) Use minimum recirc.flow rate to maintain constant (100 mg/L) TDS in Stage 2.

There are many mechanical problems to watch for, which can throw the RO reclaim system out of balance. These include washer spray nozzles misaligned or missing, backspray and overspray can introduce so much contaminant into our recirculated RO rinse water baths and cause the system to overload. Excessive oil and grease, poor design drip pans, large parts with hidden cavities containing carryout chemical, and severe iron fouling can all present problems. Field sampling certainly can identify these potential situations, and project planners can incorporate specific filters to remove problem contaminants.

MANY PROJECT PLANNERS AND DESIGNERS DON'T THINK ABOUT WATER QUALITY for a finishing line until late in the design process. Nonetheless, awareness of water quality for pretreatment is increasing as more information becomes available about contaminants and their various water supplies. Water quality is becoming a primary design criteria for multistage washers, just as energy efficiency is the primary driver in designing HVAC systems. This has created the need to apply whole-washer treatment approaches to new systems. This includes recycling the used rinse water and simultaneously reducing the volume of wastewater from the manufacturing facility.

IN SUMMARY, the advantages of using reverse osmosis technology have been discussed here together with incorporating RO into a new system design which allows up to 90% of the used rinse water to be recycled. The "whole-washer RO with reclaim" concept offers the following advantages:

*Recycles 90% of rinse water.

*Reduces dumping and recharging chemical stages with new chemical.

*Eliminates sludge and scale buildup on heat exchangers.

*Provides a spot-free final rinse.

*Increases finish quality by increasing powder adhesion.

The practice of conservation of water is new to the industry, however, it is becoming a way of life. New facilities are being constructed with water conservation, recycle, and reuse engineered as part of their design. It is anticipated that this will continue into the future.