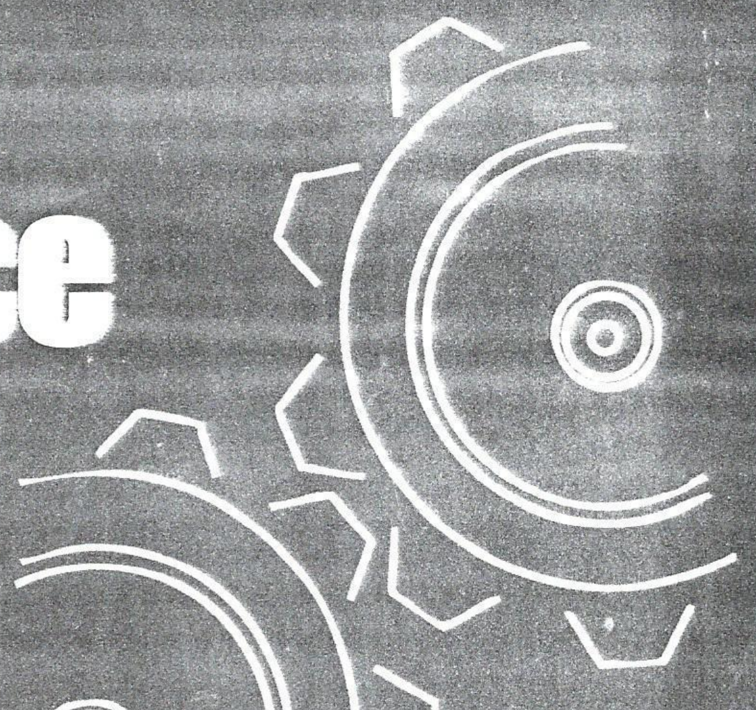
Industrial Wastes Technical Conference



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WATER AND WASTEWATER TREATMENT, CONSERVATION, AND REUSE IN AN INTEGRATED CIRCUIT PACKAGING PLANT

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ABSTRACT

Facilities that package integrated circuits utilize high purity, 18 megohm-cm resistivity, water in the process operations of cutting and grinding integrated circuits prior to encapsulation packaging. Wastewater produced by these process steps is contaminated by suspended solids, surfactants, and, on occasion, heavy metals.

ProChemTech was retained by an integrated circuit packager to design and supply the water and wastewater systems for a new plant to be constructed in the Phoenix, AZ, area. Client instructions were to conserve use of fresh water, reduce wastewater discharges to a minimum, and minimize use of hazardous chemicals. Integration of the facility water purification, wastewater treatment, and cooling water systems at the design stage has resulted in an overall plant water system design that reuses reject from the water purification system as cooling tower makeup, operates the cooling towers with zero blowdown, and treats for process reuse over 95% of the generated wastewater.

Innovative concepts in the water purification system include use of softened water feed to the primary reverse osmosis unit, replacement of the standard separate bed ion exchange unit with a second stage of reverse osmosis purification, and reuse of second stage reverse osmosis reject and treated wastewater as components of primary reverse osmosis feed water. New technologies used in zero blowdown operation of the cooling tower system include use of primary reverse osmosis reject and softened water as makeup, sidestream filtration, and specialized chemistry to allow operation at total dissolved solids values up to 40,000 mg/l with acceptable control of corrosion on system components.

The wastewater treatment system utilizes a combination of innovative chemistry combined with an inclined plate clarifier and microfiltration to produce an effluent acceptable for use as primary reverse osmosis unit feed water.

KEYWORDS

reuse, recycle, integrated design, microfiltration, semiconductor

INTRODUCTION

ProChemTech (PCT) was requested by an integrated circuit packaging firm (client) to design and supply the water and wastewater systems for a new plant to be constructed in the Phoenix, AZ area in 1997. Given that the Phoenix area is located in a desert and much of the water supply is imported, reuse and recycle of process wastewater was a high priority in the overall system design. The following specific objectives were provided by the client for this project:

- design flow of 75.7 lpm (20 gpm) product water with a resistivity of 18 megohm-cm
- minimize fresh water use via recycle/reuse/zero blowdown
- minimize discharge of plant process wastewater
- minimize use of hazardous chemicals in the water and wastewater treatment processes

The plant was to be equipped with a 1,512,000 kcal/hr (500 ton) average load cooling tower system for HVAC and process cooling with fresh water supplied by the City of Chandler, AZ. Data on the Chandler water supply, which is obtained from a mix of local well, Salt River Project, and Central Arizona Project waters, showed that chemistry of the supply water was variable, but could be described on average as being hard with high alkalinity and dissolved solids. Table 1 notes some relevant average parameters for this water.

Table 1 **City of Chandler, Typical Water Analysis Data**

pH su	7.9	total alkalinity mg/l	132
calcium mg/l	138	sulfate mg/l	73
magnesium mg/l	67	chloride mg/l	136
sodium mg/l	90	silicate mg/l	8
dissolved solids mg/l	460	fluoride mg/l	0.5

METHODOLOGY

Typical practice in similar projects would have the client retain a consulting engineer, who would then deal with several different designers/suppliers for each water or wastewater system in the new plant. Thus one supplier would be responsible for the high quality water system, another for the wastewater system, a HVAC contractor for the cooling system, and yet another vender for the cooling water chemistry program. This approach will not result in an overall optimum system design due to the difficulty in integrating the differing technologies of multiple suppliers.

A major management innovation on this project was placement of the design and supply of the entire plant water and wastewater system with a single supplier. By proceeding in this fashion, a completely integrated design resulted which could exploit new technology in one area, such as high dissolved solids treatment chemistry in cooling towers, to reuse a wastewater stream from another area, the primary reverse osmosis (RO) unit.

High Quality Water

Traditional design of an 18 megohm-cm water supply system would utilize carbon filtration, pH adjustment, RO, separate bed deionization, and mixed bed deionization to achieve the required quality. Such a system would, however, produce a substantial wastewater flow, consisting of carbon filter backwash, RO reject, and deionizer regenerate; and utilize hazardous acid and caustic solutions in its operation.

The wastewater produced by such a treatment train would be very high in hardness and/or dissolved solids, and thus not easily recycled or reused. Since it was obvious that a traditional design would not satisfy our client's objectives, we reviewed the basis for design and looked for alternative means of obtaining the same result.

Carbon filters are commonly used to remove oxidizers, mainly chlorine, from city water sources to protect downstream units, such as ion exchange resin, from oxidation. Such filters must be routinely backwashed, which generates a wastewater stream, and they are rather costly to install and maintain. An acceptable alternative is to merely inject a small amount of a reducing agent, sodium metabisulfite solution, into the inlet water to chemically destruct any oxidizers present. This process produces no wastewater and adds a minimal amount of dissolved solids to the input water.

Acid is utilized for pH adjustment of RO feedwater in order to prevent scale formation in the unit due to concentration of salts in the reject stream. Softening of the inlet water to the RO unit accomplishes the same thing, prevention of scale formation, and permits both higher RO recoveries and reuse of the RO reject water as cooling tower makeup.

A separate bed deionizer serves to further reduce the level of dissolved solids in the water prior to final polishing using mixed bed units. Replacement of the separate bed deionizer unit with a second stage of RO treatment is technically feasible and eliminates production of very high dissolved solids regenerate wastewater. Reject from the secondary RO unit is of a quality to be reused as a component of the feedwater to the first, or primary, RO unit.

Both the primary and secondary RO units are designed to be capable of operating on inlet waters that vary from 100% soft water makeup to the designed 95% wastewater recovery. The major change in unit operation when switching from one water source to the other is the operating pressure of the primary RO. Operation on 100% soft water requires a pressure of 12 kgscm (172 psi), while operation using 95% recycle results in an operating pressure of 19.4 kgscm (134 psi). Operation with 95% recycle also lowers the dissolved solids content of most of the water streams in the system.

Table 2 summarizes some relevant parameters for the RO units while operating on 100% soft feedwater and 95% recycle.

Table 2 **Primary and Secondary RO Unit Data**

Parameter	**Primary RO**		**Secondary RO**	
	soft	recycle	soft	recycle
Operating pressure kgscm	12	9.4	10.9	10.9
Stages	2		1	
Square Meters Membrane				
Stage 1	129.5		129.5	
Stage 2	51.8			
Type Membrane	TFC		TFC	
Feed lpm (gpm)	112 (29.6)		84 (22.2)	
Reject lpm (gpm)	28 (7.4)		8.4 (2.22)	
Permeate lpm (gpm)	84 (22.2)		75.7 (20.0)	
% Recovery	75		90	
Feed DS * mg/l	540	123	16.3	4.9
Reject DS * mg/l	2187	488	189	44.6
Permeate DS * mg/l	16.3	4.9	1.3	1.9

*** Dissoved Solids**

Complete elimination of sulfuric acid and sodium hydroxide use in the plant is achieved via use of exchange mixed bed deionizers, where the regeneration of the mixed bed exchange tank is done off-site. Use of such exchange tanks is possible as the effluent from the secondary reverse osmosis unit has a dissolved solids content of 1.9 mg/l. With this level of dissolved solids about 1,326 kl (360,000 gallons) of water can be polished by a typical 0.11 cu m (4 cubic foot) capacity mixed bed exchange tank, giving about twelve days operation between tank exchanges.

Figure 1 is a schematic block diagram of the final design for the high quality water portion of the project.

Wastewater

The high quality water produced by the proceeding train is used as cooling and rinse water during the diamond saw cutting of individual integrated circuits from the large discs on which they are fabricated. Rinse water is used as supplied, while cooling water is often pH adjusted by introduction of carbon dioxide gas with a small amount of non-ionic surfactant, less than 5 mg/l, added for improved surface wetting. Both rinse and cooling water use is one pass to minimize solids retention on the integrated circuits. A wastewater sample obtained from a similar operating plant gave the following results upon analysis.

Table 3 **Wastewater Sample Results**

turbidity (ntu)	155
silicon (mg/l)	7.0
suspended solids (mg/l)	15

While most integrated circuits produced today do not have significant levels of heavy metals present, resulting in basically heavy metal free cutting wastewaters, some high performance semiconductors are based upon gallium arsenide, which when processed contaminate the water with arsenic. A recent development by IBM, replacing the aluminum circuit paths in integrated circuits with copper, will result in a significant amount of copper being added to the wastewater when such products are processed. Since it is likely that heavy metals will be present in future process wastewaters, the design of the wastewater treatment system had to provide for their removal.

Based upon our research and operating experience with such systems, we selected a wastewater treatment train consisting of an inclined plate clarifier followed by microfiltration. The inclined plate clarifier would initially serve as the primary solids removal device prior to the microfilter and serve to recycle the reject from the microfilter. In the event that heavy metals are introduced into the products being packaged, the clarifier unit is designed for use of precipitation chemistry for their removal. A proprietary chemistry based upon modified polyaluminum compounds, which minimize addition of dissolved salts to the treated wastewater, has been devised for this process step. Several operating systems have demonstrated the ability of this chemistry to remove arsenic, lead, and copper from various wastewaters, including those produced by gallium arsenide crystal production.

Inclined plate clarifier design was based upon a flow rate of 9.5 lpm/sq meter (0.25 gpm per square foot) of projected plate surface area. Careful attention was given to the areas of mix tank geometry (square dimensions), mixing energy ((0.2 kw/1000 l (1 hp/1000 gallons capacity)), plate pack influent entry, and effluent weir placement and geometry. Glazed flat fiberglass plates with plastic fasteners and PVC spacers were specified to minimize corrosion and deposition problems in the plate pack itself. The three specified mix tanks, clarifier, and clear well were produced as a single unit. Chemical feed systems were specified as retrofits to be installed if needed in the future.

The microfilter was designed to use a new PVDF membrane, series J, developed by Desalination Systems of Vista, CA. This membrane has been used in a spiral wrap configuration in several microfilter units for removal of suspended solids from waters and wastewaters with excellent results. Due to its composition, it is very resistent to fouling and chemical degradation. Based on past performance, a microfilter unit constructed with a total of seven Desal 10 cm (4") dia. X 102 cm (40") length series J spiral wrap membrane assemblies was specified to provide a maximum permeate flow of 75.7 lpm (20 gpm) at an operating pressure not to exceed 7 kgscm (100 psi). This unit has a total active membrane surface area of 62.4 sq m (672 sq ft) with a particle size cutoff of 0.4 micron.

Figure 2 is a schematic block diagram of the final design for the wastewater portion of the project.

Cooling Tower
With the fresh makeup water available, the cooling tower in this plant would typically be operated at three cycles of concentration with anti-scalant chemistry. Such operation would result in generation of 25,121 lpd (6,637 gpd) of blowdown to be discharged and require 75,363 lpd (19,911 gpd) of fresh makeup water.

However, cooling towers using softened makeup water can be operated with no intentional blowdown, reducing the amount of water needed, and wastewater generated, by the plant. Basically, the cycles of concentration in the cooling tower system are increased to the point where windage from the cooling tower equals the blowdown rate. At this point zero blowdown is achieved. Typically, the zero blowdown point is reached between 10 to 20 cycles of concentration in standard cooling towers.

Operation of the client's cooling towers at 20 cycles, using secondary RO reject with no wastewater recycle operation as 100% makeup, could result in worst case dissolved solids values as high as 37,560 mg/l. Normally, cooling towers are not operated with softened makeup water at such high dissolved solids values due to the extreme corrosivity of the water. We have found that by application of specific water treatment chemistry, the corrosivity of such cooling waters can be controlled to acceptable levels. Bypass filtration, using cartridge type filters with cleanable elements, is also required to prevent buildup of suspended solids in the cooling tower with subsequent underdeposit corrosion.

Application of this new technology to operate cooling towers with soft water makeup and dissolved solids levels of up to 40,000 mg/l permits reuse of the primary RO reject as cooling tower makeup, with supplemental makeup provided by the water softener as needed. Reuse of the RO reject and operation of the cooling tower with zero blowdown substantially decreases the plant wastewater discharge and use of fresh water.

Specific equipment provided for zero discharge operation of the cooling tower consisted of a makeup proportional chemical feed system, to ensure proper inhibitor dosage, and a cartridge type bypass filter sized for one turnover per day.

Figure 3 is a schematic block diagram of the final design for the cooling tower portion of the project.

RESULTS

Returning to the objectives set by the client at the start of this project the following results were obtained:

- A system has been designed to provide 75.7 lpm (20 gpm) of 18 megohm-cm resistivity water using Chandler city water as the source.

- Fresh water use has been minimized by reuse of primary RO reject as cooling tower makeup, recycle of secondary RO reject and treated wastewater, and zero blowdown of the plant cooling tower. At the design high quality water use rate of 75.7 lpm (20 gpm), with 95% recovery of wastewater, water softener production will amount to 55,742 lpd (14,727 gpd) broken out as 45,833 lpd (12,109 gpd) for primary RO feedwater and 9,909 lpd (2,618 gpd) for additional cooling tower makeup. Input fresh water will thus total 57,884 lpd (15,293 gpd), with the majority of it, 50,242 lpd (13,274 gpd), ultimately consumed by the cooling tower system.

  Wastewater discharged from the cooling tower has been reduced from 25,121 lpd (6,637 gpd) to 0 lpd (0 gpd), while fresh water makeup requirements have been reduced from 75,363 lpd (19,911 gpd) to 9,909 lpd (2,618 gpd) via reuse of the primary RO reject as makeup in place of fresh water.

- Discharge of wastewater has been substantially reduced. The only wastewater discharged from the entire system is the softener regeneration wastewater at a calculated volume of 38.4 l/1000 l (38.4 gal per 1000 gal) of soft water produced. Based on this data, the total daily process wastewater discharge from the system as designed amounts to 2,142 lpd (566 gpd).

- Hazardous chemical usage has been essentially eliminated as to treatment of water and wastewater. In place of sulfuric acid and sodium hydroxide, both hazardous chemicals, a solution of sodium metabisulfite and common salt has been used.

CONCLUSION

The superior systems integration possible with a single designer/supplier permits new concepts in water and wastewater treatment, and cooling tower treatment chemistry, to be easily applied to design of entire plant water systems. This integrated approach results in superior designs which provide substantial decreases in both fresh input water and process wastewater discharges.

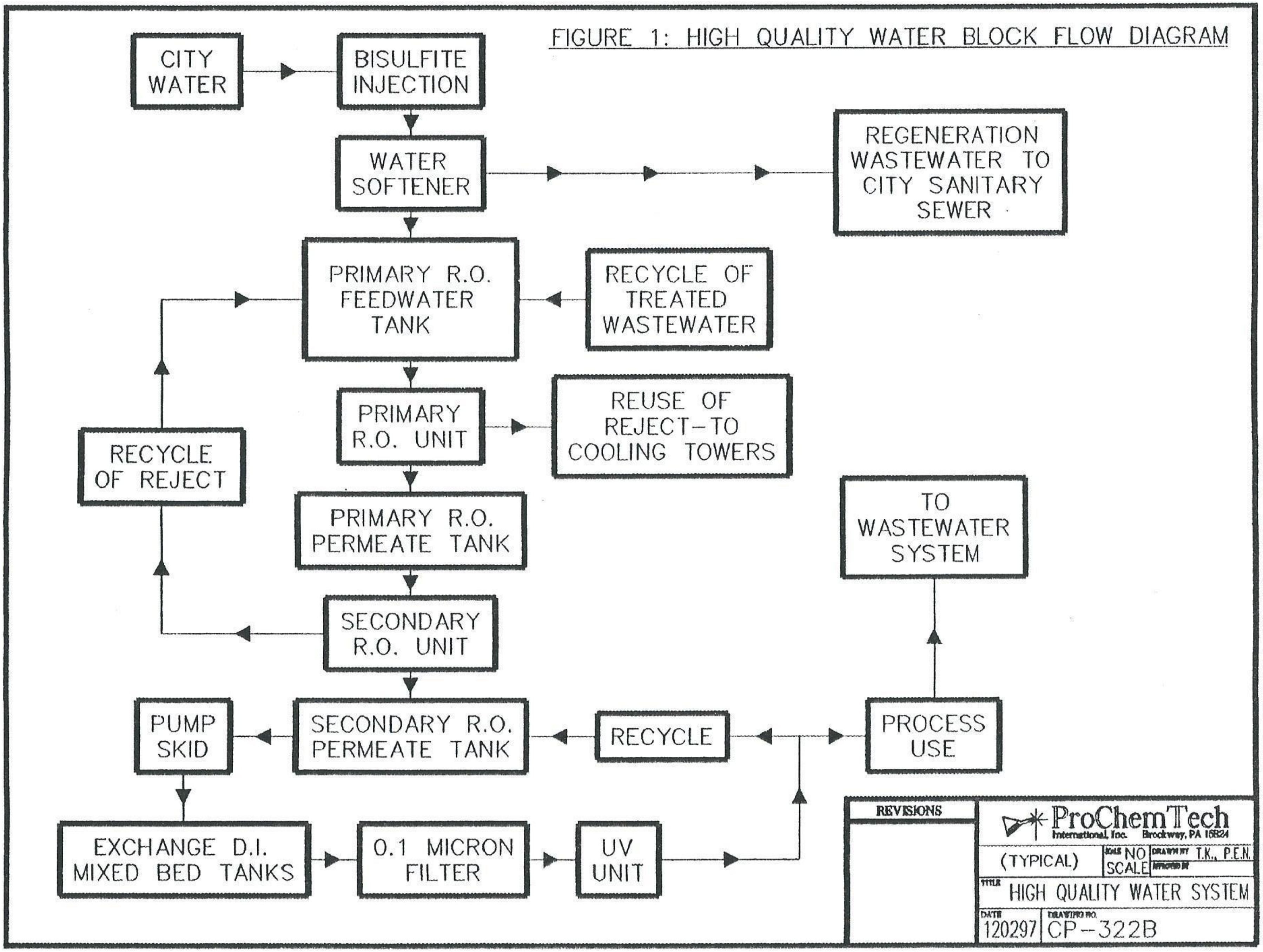


FIGURE 1: HIGH QUALITY WATER BLOCK FLOW DIAGRAM

FIGURE 2: WASTEWATER BLOCK FLOW DIAGRAM

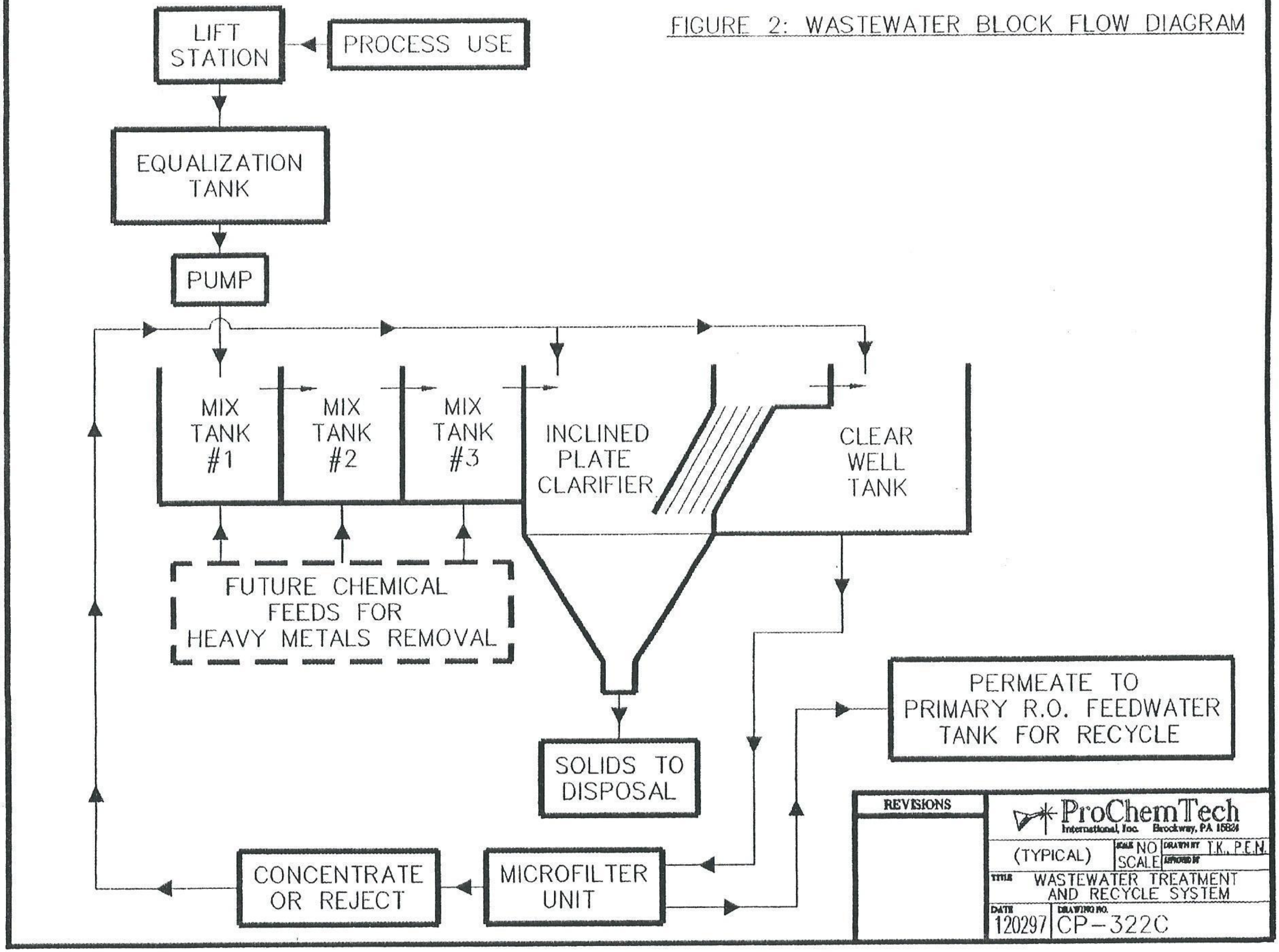
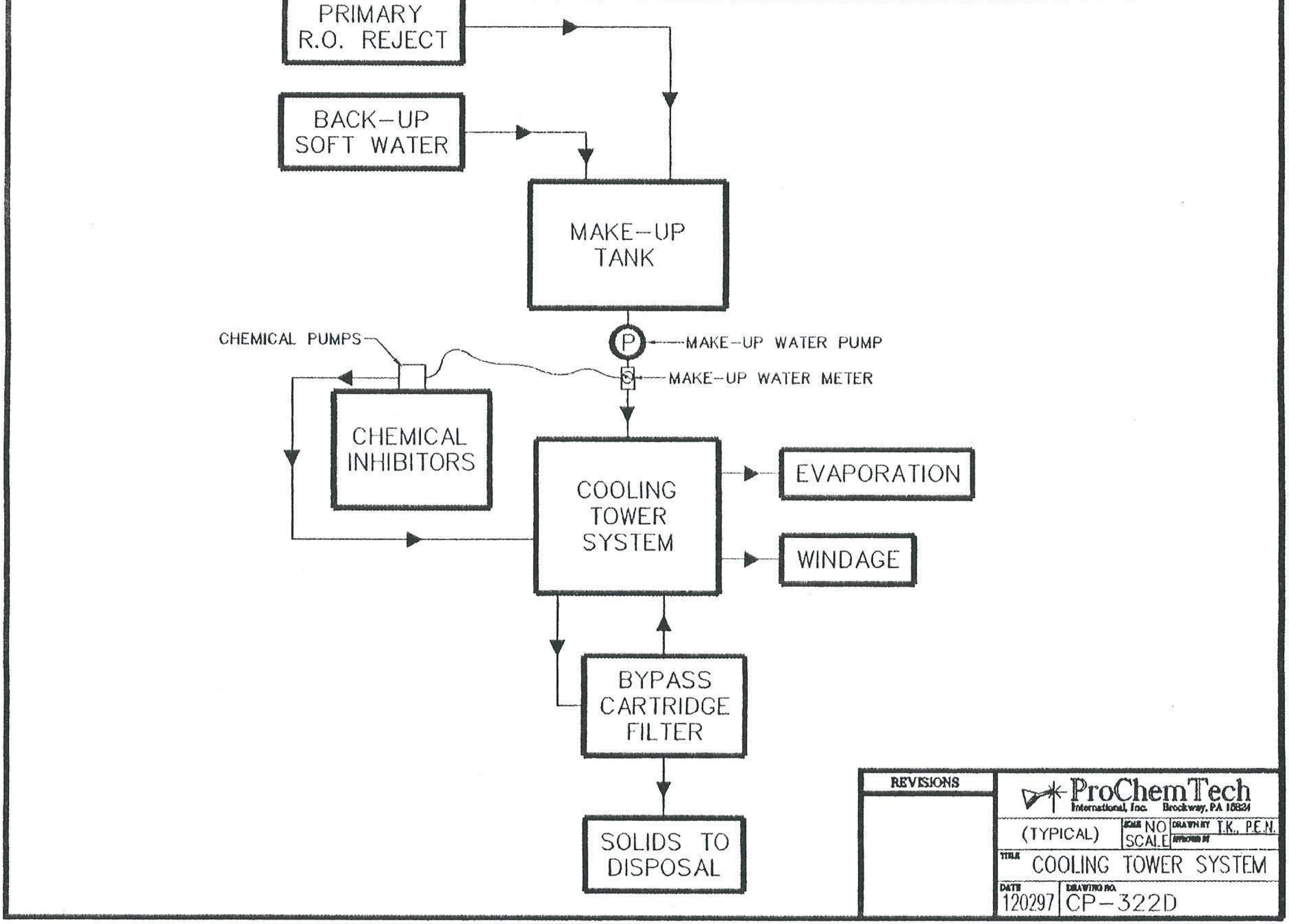
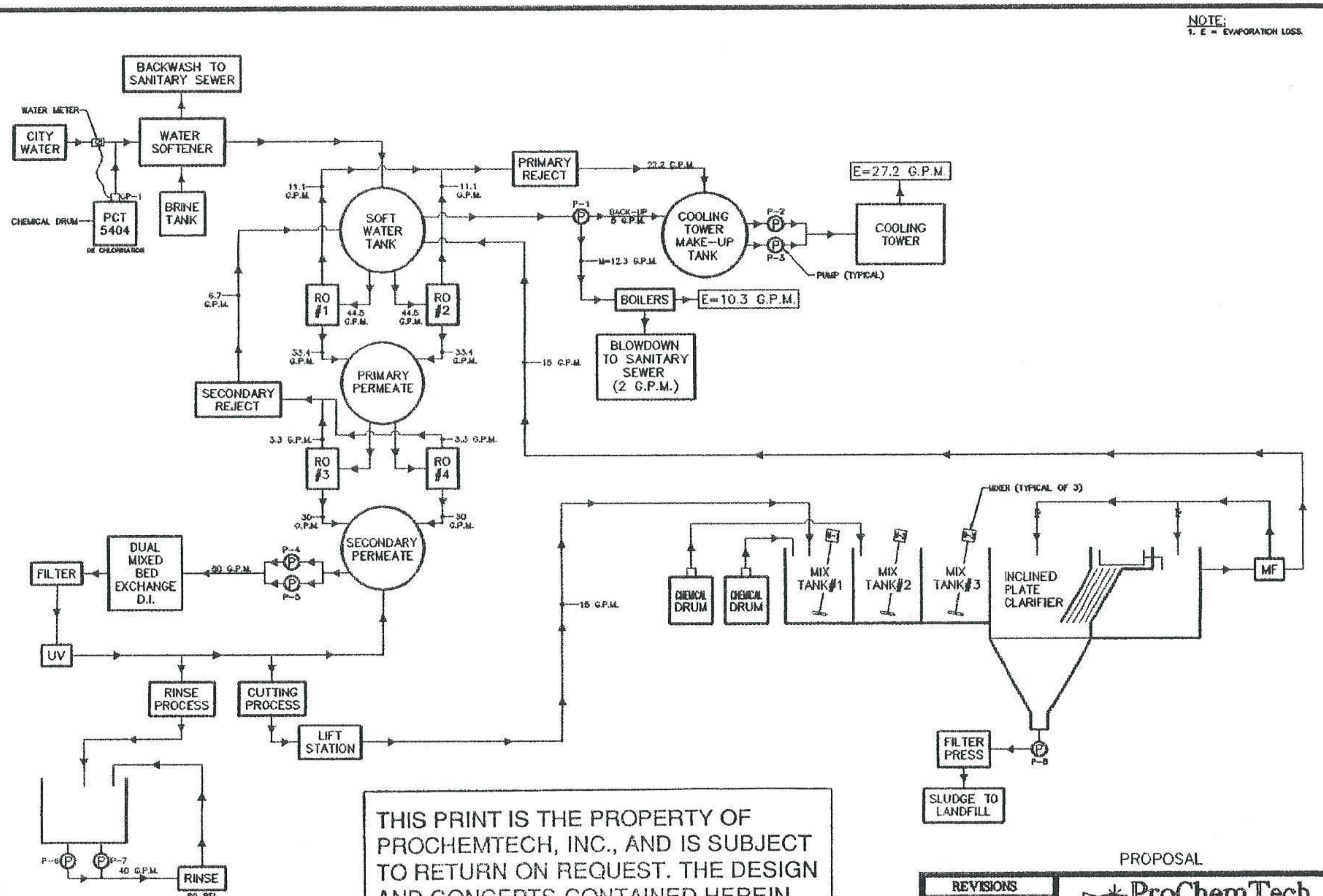


FIGURE 3: COOLING WATER SYSTEM BLOCK FLOW DIAGRAM





PROPOSAL

REVISIONS	ProChemTech International, Inc. Brockway, PA 15824		
	AMKOR ELECTRONICS, INC. CHANDLER, ARIZONA	SCALE NO SCALE	DRAWN BY T.K., T.C., P.E.M. APPROVED BY
	TITLE WATER SUPPLY AND REUSE SYSTEM		
	DATE 060198	DRAWING NO. CP-370	