Retrofit of a California Coastal Desalination Plant: Add Technology, Lower Costs

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***Abstract*- California's largest municipal drinking water seawater desalination facility is located in the city of Marina on Monterey Bay. The plant produces about 1000 m^3/d (~300,000 gallons) of potable water in compliance with California primary drinking water standards. Although only seven years old, the plant does not meet the economic needs of the operator in light of the increased electrical costs in California. To take advantage of reduced weekend electricity rates, the plant is operating Thursday through Monday with product water costs about \$2.40 /m^3. In 1996-1997, when electricity rates were significant lower, the plant operated seven days a week and product water costs were \$1.40 /m^3. By adding several technologies during a retrofit of the facility, Oases is able to lower operating costs by 64%. Key technologies employed include installation of a state-of-the-art pressure exchange system to recover energy, high-efficiency pumps, removal of the plant from local electrical grid and utilizing natural gas fired microturbines with heat recovery. Planned future improvements include incorporation of plasma chemical reactor ozone generation technology for pre-treatment of seawater and wireless SCADA coupled with predictive diagnostic software. The retrofit will allow production of potable water for less than \$0.60/ m^3 or about \$740 an acre-foot. Without debt service on the original plant, the retrofit costs are only \$0.49/ m^3 (about \$600 per acre-foot).**

I. INTRODUCTION

Many municipalities along the California coast are seriously considering or planning to build desalination facilities (Table 1). Among the factors which are currently stimulating the reconsideration of ocean desalination in California are regional water supply planning for new and secure sources of water, and realization that extended droughts are part of the natural hydrologic cycle in semi-arid California.

Until recently, desalination was opposed due to perceptions that plant construction, operation and product water are expensive and that unacceptable pollution is caused from the discharge of brine byproduct during the desalination process.

The Marina Coast Water District owns and operates California's largest municipal drinking water seawater desalination facility in Marina on Monterey Bay. The District provides water for the City of Marina, a community of about 18,500 people, and is responsible for developing new water sources for the Fort Ord Reuse Authority over the next several years. This facility is an important step in diversifying the District's water sources.

The reverse osmosis (RO) seawater desalination plant produces approximately 1000 m^3/d (~300,000 gallons per day) of potable water in compliance with California primary drinking water standards. The plant utilizes beach wells for seawater intake and discharge of concentrated seawater.

TABLE 1
PROPOSED DESALINATION PLANTS ALONG THE CALIFORNIA COAST.

Proponent/Location			
Max. Capacity (m^3/d)	Tech.	Source Water	Status
Cambria Community Services District/ San Simeon			
1,628	RO	Well	Planning
Cannery Row Marketplace/ Monterey			
19	RO	Ocean	FEIR certified by City of Monterey
City of Sand City			
103	RO	Well	Planning
City of Santa Cruz/ Santa Cruz			
9,463	RO	Ocean	Plan being assessed
Long Beach/ Haynes Generation Station			
1,136	2-NF	Ocean	Design/construction
Long Beach			
34,065	2-NF	Ocean	Initial planning
Los Angeles Department of Power and Water/ Playa del Rey			
45,420	RO	Ocean	Planning, 2010 target
Metropolitan Water District of Southern California			
18,925		Ocean	
Monterey Bay Shores/ Monterey County			
76	RO	Well	Not likely, backup plan
Monterey Peninsula Water Management District/ Sand City			
~28,388	RO	Well	Preliminary work on EIR
Municipal Water District of Orange County/ Dana Point			
102,195	RO	Ocean	Working on DEIR
Poseidon Resources/ Huntington Beach			
189,250	RO	Ocean	DEIR 2006 target
San Diego County Water Authority/ Carlsbad			
189,250	RO	Ocean	Feasibility study completed; 2007 target
Sterling Hotel/ Sand City			
68		Well	
Santa Cruz County Sanitation District			
~32,173			Planning
U.S. Navy, North Island Naval Air Station/ San Diego			
2,650		Well	
West Basin Municipal Water District/ El Segundo			
75,700	RO*	Ocean	Pilot project on-line (20 gpm); 2008 target

Source: California Water Desalination Task Force [1]
Note: RO is reverse osmosis, 2-NF is two-stage nanofiltration, RO* is reverse osmosis with nanofiltration.

A. Background

Along with other urban and agricultural water suppliers in the Salinas Valley, the Marina Coast Water District relies on the Salinas Valley Groundwater Basin as a primary source of water. The history of groundwater extraction throughout the Salinas Valley has resulted in overdraft of groundwater. This condition has resulted in seawater intrusion into two of the three aquifers underlying the coastal portion of the Salinas Valley, rendering some groundwater in those aquifers unfit for use. Efforts are underway to address this issue on a regional scale. Planned reclamation projects include replacement of groundwater for use in agricultural irrigation in coastal areas with recycled water.

B. The Facility

The plant utilizes a conventional beach well for seawater collection. The well is located < 100 m inland from the high tide line and draws water from the shallow dune sand aquifer. By using a beach well, the need for extensive pretreatment is minimized. Filtration through beach sands removes much of the suspended material in the seawater.

A subsurface pipeline conveys the feed water, primarily saline groundwater (23,000 ppm TDS) to the desalination plant, where RO membranes are used to desalinate the water.

The brine stream (43,0000 ppm TDS) is injected into the shallow dune sand aquifer in a conventional well, where it blends with native groundwater and ultimately diffuses into the surf zone.

II. THE CHALLENGE

Although only seven years old, the plant does not meet the economic needs of the operator in light of the increased electrical costs in California. To take advantage of reduced weekend electricity rates, the plant was operating Thursday through Monday with product water costs about \$2.40 /m^3. In 1996-1997, when electricity rates were significant lower, the plant operated seven days a week and product water costs were \$1.40 /m^3.

Primary objectives of the retrofit were to reduce peak electrical demand of the plant, reduce the cost of product water by a significant margin, achieve a short return on investment period, allow accommodation of future R & D (further reducing product water costs), and enhancing the life cycle of the plant.

III. TECHNICAL SOLUTION

The technical solution to meeting the above requirements included design and installation of pressure exchange devices, installing high-efficiency pumps, removal of the plant from local electrical grid power and utilization of natural gas fired micro turbines with heat recovery.

A. Pressure Exchanger

Energy costs represent about 75% of the RO plant operating costs. By installing pressure exchangers to capture the pressure on the reject stream, energy is transferred from the reject stream directly to the feed stream. The direct connection allows very efficient energy transfer on the order of 95%. The use of a booster pump pump compensates for the slight pressure loss through the energy recovery device. Energy consumption below 2 kWh/m^3 is attainable with pressure exchangers [2].

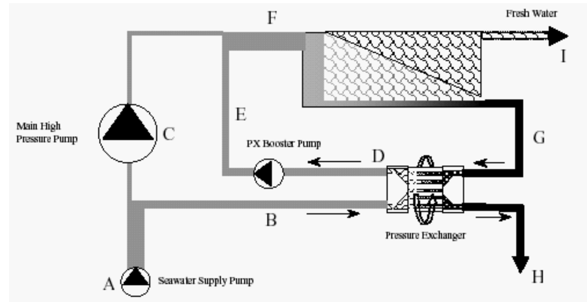

Fig. 1. Simple Pressure Exchanger Diagram. From MacHarg [2].

This configuration (Fig. 1) allows for reduction in size of the main high-pressure pump. Additionally, significant energy savings can be realized by lowering recovery of product water. Lower recovery rates in RO system yield better water quality results. Additional benefits include reduced (or eliminated) costs for pretreatment and antiscalant chemicals, more efficient membrane utilization, and improved operations.

B. Off Grid Power

The plant was switched from the local electrical grid connection to natural gas fired microturbines. The substitution of local grid power provides a more reliable and less expensive source of electricity. Peak energy demand is reduced by 10-15%.

C. MicroTurbines

Micro turbines were selected because they permit small desalination plants to produce clean on-site power, independent of the grid, using natural gas, diesel, and various other fuels. Heat exchangers capture reject heat, apply it directly to stream of incoming seawater. This enables increased flux through the RO membranes.

D. Ozone Treatment

Plans are to use a Plasma Chemical Reactor to generate ozone directly from ambient air. Test have verified 60 g per hour of ozone at concentration greater than 2% by weight while consuming less than 1.5 kW average power. It is anticipated that concentration and contact time requirements would comply with US EPA specifications as outlined in Alternative Disinfectant and Oxidants Guidance Manual. Test are planned to verify anticipated effects of disinfection, inorganic pollutant oxidation, organic micro pollution oxidation and reduction of pretreatment chemical demands.

Ozone pretreatment of seawater, does not reduce power consumption. It can, nevertheless, lower the cost of product water by as much as 30 percent. The cost reduction is a consequence of elimination of chemicals in pretreatment and associated costs for their purchase, storage, permitting and training of personnel who handle them. Ozone is also an effective anti-scalant. This latter effect is apparently due to the reduction of organic materials that seed soft scale nucleation. The oxidation of the organic materials, together with the increased flow of the seawater and brine, (due to lower recovery rates dictated by the optimum operating point of the pressure exchanger) results in eliminating the need for any chemical pretreatment. This has very positive environmental benefits relative to the brine discharge into the ocean.

E. Wireless Communication

Wireless communication between sensors, motor controllers, valve actuators, and power controllers enables the rapid installation and integration of desalination system modules. Modular expansion of a system is more efficient due to the inherent "master-slave" communications architecture of the wireless protocol.

Concern over the vulnerability of internet-based SCADA for infrastructure systems is growing as documented cases of unauthorized manipulation of such systems by potentially hostile individuals or groups is being collected. New, robust, broadband communications paths will be employed by these wireless SCADA systems. The burden of high performance software and computers to accomplish predictive diagnostics is placed on the centralized receive end of the wireless SCADA network. Eventually, the facility will operate by secure wireless communication

IV. THE BENEFITS

A. Economic Benefits

By adding several technologies during the retrofit of the facility, Oases is able to lower operating costs by 64%. Key technologies employed included installation of state-of-the-art pressure exchangers to recover energy, installation of high-efficiency pumps, removal of the plant from local electrical grid and utilizing natural gas fired microturbines with heat recovery.

Planned future improvements include incorporation of plasma chemical reactor ozone generation technology for pre-treatment of seawater and wireless SCADA coupled with predictive diagnostic software. The retrofit will allow production of potable water for less than \$0.60/ m^3 (about \$740 per acre-foot) including debt serve. The cost of product water, minus debt service on the original desalination facility, is only \$0.49/ m^3 (about \$600 per acre-foot). For comparison, unit costs of water for several major international desalination plant are provided in Table 2.

TABLE 2
COST COMPARISON FOR
RECENT LARGE SEAWATER REVERSE OSMOSIS FACILITIES

	Tampa	Trinidad	Larmika (Cyprus)
Capacity (m^3/d)	95,000	108,000	40,000
Salinity (ppm)	26,000	34,000	35,000
Capital Costs (\$ million)	94	120	40
Selling Price (\$/m^3)	0.55	0.73	0.82
Developer	Poseidon	Ionics	IDE
Terms (years)	30	20	10

Source: [3]

Anticipated retrofit savings include reduction in peak electrical demand. The current peak demand is 229 kW while the post retrofit demand will be 83 kW, a reduction in 146 kW. Additional savings include reduction in manpower on site and reduction of chemical consumables. We anticipate that the mean time between failures will increase while the mean time to repair will decrease.

B. Environmental Benefits

The retrofit design discharges less concentrated brine into the beach wells. System operations are optimized so that recovery rate of water flushed through system is approximately 36% instead of current 50%. The discharge volume increases, but total dissolved solids per unit volume is significantly lower.

In the injection wells, the brine is further diluted by the shallow aquifer which flows into the adjacent intertidal and surf zone. To date, monitoring of the brine discharge has not detected any impact to marine life.

IV. DISCUSSION

Water districts, especially on the West Coast, are investigating seawater desalination to augment their water supplies, especially along the west coast. Technologies under development will allow for ultra-efficient seawater desalination and return of seawater concentrate in an environmentally acceptable manner to satisfy the requirement for safe, secure and sustainable water.

Oases advocates distributed generation of water by construction of several smaller desalination facilities per region, rather than a single large central facility. New construction techniques allow for more rapid construction at lower cost. The resultant facilities will have a smaller ecological footprint and provide more security for source reliability.

ACKNOWLEDGMENTS

Part of this work is a continuing effort to develop technology including the Plasma Chemical Reactor Ozone Generator under a Cooperative Research and Development Agreement between Battelle Memorial Institute, Kharkov Institute of Physics & Technology (Ukraine) and US Department of Energy.

REFERENCES

[1] Center for Collaborative Policy, California State University, Sacramento, "Desalination Task Force, Desalination Issues Assessment Report," Draft of May 29, 2003.
[2] J.P. MacHarg, "Exchanger Tests verify 2.0 kWh/m^3 SWRO Energy Use," *International Desalination and Water Reuse,* vol. 11/1, 2001.
[3] E.R. Jankel and L. Henthorne, "An Update on Recent Advances in Reverse Osmosis Cost Reductions," Conference on the Global Expansion of Desalination, June 30, 2000.