APPENDIX 5.15E

Overview of Considerations for Zero Liquid Discharge System

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OVERVIEW OF CONSIDERATIONS FOR ZERO LIQUID DISCHARGE SYSTEM

Background:

In combined cycle power plants circulating cooling water system is typically the major user of make-up water that must be supplied from the outside sources. The amount of make-up water to the circulating cooling water equals losses due to evaporation and blowdown from the cooling system. This blowdown is typically the largest source of wastewater requiring disposal to a Publicly Owned Treatment Works (POTW) or to a receiving body of water. The other major source of water consumption is for generating steam in heat recovery generators (HRSGs) needed to produce electricity from steam turbine generators. The steam, at the end of thermal cycle in steam turbines, is condensed in air or water cooled condensers and treated in deionizers to remove dissolved impurities for reuse as HRSG make-up water. During warmer weather with low humidity conditions, steam may also used for boosting power (power augmentation) in combustion turbines that drive the main electrical generators but the steam required for power augmentation is lost to atmosphere along with products of combustion. This loss constitutes the next largest proportion of the water consumed at combined cycle power plants. Among other significant losses are water lost to atmosphere and as blowdown in evaporative coolers that are needed to cool the inlet air to combustion turbines when operating during hot ambient air temperature and low humidity conditions. Water in the form of steam is also lost due to leaks from HRSGs, HRSG blowdown tank cooling, steam turbines, etc., that must also be made up continuously.

At Carlsbad Energy Center Project (CECP), the bulk of make-up water for HRSGs are obtained by demineralizing the City of Carlsbad reclaimed water in a reverse osmosis (RO) system followed by a deionizer unit. Air cooled condensers are used for condensing steam from steam turbines thus eliminating the need for make-up to circulating cooling water.

The reclaimed water quality contains undesirable contaminants and must be treated on-site to produce high purity water for the HRSGs and process use. An RO system produces a continuous stream of concentrated waste (reject stream) that must be continuously discharged to a POTW, to a receiving body of water, or to a zero-liquid discharge (ZLD) system. The reject stream generally contains all constituents of the reclaimed water that is processed through the RO system, but in a concentrated form. Table 5.15F-1 shows the anticipated constituents of the City of Carlsbad reclaimed water that must be treated by the RO / deionization units and those of the reject stream that must be discharged.

The Carlsbad Energy Center Project (CECP) is mandated by California Code Title 22 to use reclaimed water available from the City of Carlsbad for all of its process and make-up water uses.

Table 5.15F-1

WQ Parameters	**Unit**	**City of Carlsbad Reclaimed Water**	**RO Reject Water**
Boron	ppm	0.4	1.30
Cadmium	ppm	0.005	0.02
Chromium (T)	ppm	0.005	0.02
Copper	ppm	0.01	0.03
Iron	ppm	0.12	0.39
Lead	ppm	0.005	0.02
Manganese	ppm	0.087	0.28
Nickel	ppm	0.01	0.03
Silver	ppm	0.01	0.03
Zinc	ppm	0.02	0.07
pH	Units	7.19	6 to 9
O&G	ppm	N/R	N/R
PCBs	ppm	N/D	N/D
BOD5	ppm	4	13.03
TSS	ppm	1.4	4.56
Bicarbonate	ppm	177.5	?
Calcium	ppm	71	231.36
Magnesium	ppm	30	97.76
Sodium	ppm	200	651.72
Chloride	ppm	263	857.02
Sulfate	ppm	182	593.07
VSS	ppm	1.3	4.24
TDS	ppm	922	3004.45
Conductivity	microS/CM	1619	5275.71
Turbidity (Daily Max)	NTU	0.5 to 2.6	7.8 max
Coliform (7-day median)	cfu/100 ML	<2.8	8.4 max
Chlorine Residual	ppm	3.7 to 14.3	<1.0
Total Toxic Organics (TTO)	ppm	N/D	N/D

Wastewater Treatment and Disposal:

Any wastewater discharge from the CECP project to the nearest receiving body of water, the Pacific Ocean, is restricted by the California Department of Environmental Protection and other regulatory agencies. Three viable options considered are discharge to a POTW, or to an evaporative basin, or to a ZLD system.

At CECP, the circulating cooling water system has been replaced with air cooled condensers and therefore a major source of cooling water blow down has been eliminated. The only wastewater stream that needs to be discharged to the POTW, evaporative basin or to a ZLD system is the reject stream (56 million gallons/yr) from the RO treatment process after taking into consideration that blow down from HRSGs and evaporative coolers and plant wastes are recycled and reused.

Discharge to a POTW:

The RO system reject stream will be pretreated and monitored for compliance with the Encina Wastewater Authority Pretreatment Ordinance. The reject stream will be connected to an on-site 12-inch sewer line approximately 1,100 feet long and connecting to the City of Carlsbad Sewer System immediately west of the CECP site. It is estimated that the peak and annual average discharge rates will be 290 GPM and 107 GPM respectively. The characteristics of the wastewater discharge are shown in Table 5.15F-1 above.

A discussion with the City of Carlsbad Engineering and Planning Officials indicate that sufficient capacity exists at the Encina Wastewater facility to accept the discharge from the CECP. Project analysis indicates that the discharge will meet the Encina Wastewater Authority Ordinance and the USEPA Categorical Pretreatment Standards (40 CFR Part 423).

Discharge to ZLD System:

A. Evaporative Basin:

The least technically challenged method of achieving zero-liquid discharge is to discharge the wastewater into a solar evaporative basin. A dry basin is excavated after several cycles of solar evaporation and the dried solids are disposed off-site. The thermal energy required for evaporation is avoided. However, there is no recovery of evaporated liquid for reuse.

In the San Diego region, the annual evaporation rate (approximately 82.2 inches/yr.) exceeds the annual rain fall (approximately 10.3 inches/yr.) and therefore it is entirely feasible to use evaporative basins to dry plant wastewater streams subject to availability of land inside the plant premises or off-site. A shallow evaporative basin, properly lined to prevent leakage to the ground, and berm, approach road, operation and maintenance shed will require approximately 40 acres of land. The basin would be divided into two or more cells to allow periodic removal of dried solids while the other cells would be receiving the waste stream. The total area of the CECP site is only 23 acres. The entire existing Encina site is 130 acres, but is densely occupied by existing or proposed facilities and there is insufficient space for such an evaporative basin. Construction of an evaporation basin on site, therefore, was ruled out from alternative analysis. Similarly, construction of a basin off-site was also ruled out because of ownership or availability issues.

B. Mechanical ZLD System

ZLD water management systems for power generating stations have historically been applied in areas that are deficient in water supply, remote from suitable receiving streams and/or at projects prohibited from discharging to streams, POTWs or large/small bodies of water. Other factors that favor of mechanical ZLD system are unavailable of land or when it is too costly or areas that have net positive annual precipitation. ZLD systems are employed to dispose of wastewater as much as possible by mechanical evaporation. Evaporator distillate can be recovered for further use such as make-up water for the HRSGs and other plant process.

A mechanical ZLD system was investigated as a possible wastewater management alternative to discharging the RO reject stream to the City of Carlsbad (Encina Wastewater Authority) POTW, should the discharge to the POTW become unfeasible due to technical, regulatory, economic or other reasons. No other liquid streams discharged to the POTW or ZLD system are planned, except in the case of emergencies. The deionizers, when regenerated, produce acidic and caustic waste streams, will be regenerated off-site. Other sources of wastewater that have been eliminated are blow downs from evaporative coolers and miscellaneous plant wastes. These streams are recycled to reduce water consumption as well as direct discharge to the ZLD system. These waste minimization measures are paramount to achieving economy of design, minimizing resource consumption and reducing environmental impacts.

For producing steam and miscellaneous process uses, CECP will be using the reclaimed water from the Encina Wastewater Authority, City of Carlsbad. This use is mandated by the State of California Title 22 Requirements. The reclaimed water will be processed in a RO system to primarily remove dissolved solids. The RO process continuously generates a wastewater stream (reject stream) high in concentrated solids that must be disposed off. As an alternate to disposal via the POTW or surface waters, the ZLD system was investigated because it eliminates wastewater discharge by evaporation and recovers condensates for reuse.

A ZLD plant under consideration has two components, a mechanical evaporator that concentrates wastewater into a liquid stream containing concentrated constituents of the wastewater being treated, and a brine concentrator or a crystallizer to achieve true zero-liquid discharge. The evaporator produces condensates that can be reused in the power plant together with a concentrated stream containing mineral salts and other minor constituents normally present in the wastewater. This stream can be dried in brine concentrators/crystallizers. The dried solid is normally non-hazardous and is sent off-site for disposal.

Mechanical evaporators consume a significant amount of energy in the forms of electricity or low pressure steam. Depending upon the type of evaporator, the electrical consumption in a vapor compression type could range 70 to 90 KWHr per thousand gallons of feed. A single effect steam-driven evaporators could consume 10 times more energy that must be supplied from the power plant. In the vapor compressor type, the condensate recovery could be as high as 95 percent and overall reclaimed water consumption could be reduced by nearly 25 percent. The recovery of condensate in a steam-driven evaporator would require a large quantity of cooling water that is not available at the CECP site. Considering steam availability at 5 - 6 bar (g), approximately 13 tons/hr of steam and corresponding cooling water flow of 2800 gpm will be required to operate.

The ZLD evaluated for CECP is a fully integrated automated system incorporating a Mechanical Vapor Compression Brine Concentrator (BC) and a Forced Circulation Crystallizer (FCC) system. The system concentrates reject stream from the RO system in the brine concentrator and later evaporates it in the FCC into nearly dry salt for off-site disposal. The high purity distillate from the brine concentrator is blended with permeate from the RO system to increase the yield and the blended water is further processed in the ion-exchange system for boiler water make-up and other process uses.

The ZLD process concentrates the RO reject to nearly 50% solids and recovers nearly 90% of the reject as condensates for plant reuse. The concentrated stream containing 50% solids can be further dewatered in a belt filter press unit to deliver dewatered salt cake with about 10% - 20% moisture content. This salt cake can be disposed of for landfill, while the filtrate from the belt filter press is recycled back to the forced FC evaporator. As an alternative to the belt-press, the concentrated stream can be dried on solar evaporative beds.

Chemicals required for treating the influent (RO reject) stream are sulfuric acid and small amounts of scale inhibitors. Annually cleaning chemicals are used for removing scales built upon the ZLD components. Cleaning chemicals and wash downs are collected and disposed off-site.

Electrical power is required to run a vapor compressor that compresses vapor generated in the brine concentrator. The compressed vapor is hot and is used to evaporate waste stream being treated. The vapor flows to the shell side of the brine concentrator and is condensed on the outside of the tubes and is pumped out of the system for process use. A small amount of carbon dioxide is vented from the deaerator to the atmosphere as a result of acidification of the influent. An external source of steam can be used for in place of the vapor compressor but will also require an external source of cooling water to cool the vapor into condensates.

The design of a successful zero-liquid discharge management system is complex as much as it difficult to operate. The system is prone to scaling requiring at least an yearly complete shutdown. It is also an energy intensive operation that deprives the power plant of the energy that should be delivered to the power grid. The ZLD units are designed for automatic steady state operation requiring little operator attention. The ZLS system under consideration for CECP is much more expensive to build and operate compared to discharging to the POTW by a factor of over 4 to 1 despite taking credit for reduced reclaimed water consumption and condensate reuse.

Conclusions:

The following conclusions can be made regarding ZLD and non-ZLD systems:

1.	Area required for ZLD installation:	175-ft X 50-ft
2.	Power requirement for ZLD system:	3.9 million KwHr/Yr
3	Reclaimed water consumption for ZLD system	366 AFY
4.	Reclaimed water consumption when discharging to POTW	516 AFY
5.	Reduction in reclaimed water consumption when operating ZLD system	150 AFY
6.	Non-hazardous solids for off-site disposal	700 TPY
7.	Avoided POTW fees when operating ZLD system	$146,300/Yr
8.	Avoided reclaimed water fees when operating ZLD system	$109,200/Yr
9.	O&M cost of a ZLD system	$2,863,000/Yr
10.	O&M cost of a non-ZLD system	$634,000/Yr

Use of a ZLD system is economically unsound and sewer disposal is adopted for this project.