

# DESIGN/OPERATING EXPERIENCE ON A UTILITY BOILER WASH TREATMENT SYSTEM

JOSEPH M. SUTTON AND GARY R. VEERKAMP

Pacific Gas and Electric Company  
San Francisco, California

## ABSTRACT

On November 8, 1985, the surface impoundments at Pacific Gas and Electric Company's (PG&E) Contra Costa Power Plant were closed to further use. This left the plant with no means to handle the approximately 250,000 gal of boiler waste water generated per year. This paper discusses design, construction, and start-up experience of the substitute treatment system. This system converts the waste water into 10-12 cu yd of solid waste, and water that is discharged under an existing National Pollutant Discharge Elimination System (NPDES) permit. PG&E interaction with regulatory agencies, and start-up problems and their resolutions are also discussed.

## INTRODUCTION

This paper describes a unique design for a hazardous waste treatment facility that removes Pacific Gas and Electric Company's (PG&E) Contra Costa Power Plant from the Environmental Protection Agency's (EPA) list of hazardous waste storage sites. It is a permitted facility that was designed, constructed, and started up in 11 months. Its traditionally unorthodox method of handling metal cleaning wastes provides a cost-effective tool for implementation of a hazardous waste minimization program. This paper describes system design and the impact on this design of current

and proposed legislation. Start-up problems and solutions are discussed in detail. Proposed enhancements to the treatment facility are also reviewed.

## LEGISLATIVE BACKGROUND

On September 28, 1984, the EPA Region IX formally requested that PG&E prepare a Resource Conservation and Recovery Act (RCRA) Part B permit application for its two hazardous waste storage ponds at Contra Costa Power Plant. These ponds were used to store boiler acid cleaning waste water and air preheater/fireside washes for evaporation. On December 8, 1984, Title 23, Subchapter 15 of the California Administrative Code was enacted, defining construction and siting requirements for new and existing hazardous waste surface impoundments. The ponds did not comply.

After review of Title 23, California's Toxic Pits Clean-Up Act and EPA requirements, PG&E decided to close the impoundments because of the uncertainties in obtaining permits for their continued operation, even after expensive modifications. The ponds were closed to further use in November 1985 (Boiler 9 was scheduled to be cleaned September 1986).

RCRA requires that generators of hazardous wastes certify that they have a hazardous waste quantity and

toxicity minimization program in place, and that disposal methods minimize the threat to human health and the environment. The new treatment system was designed and constructed to this requirement and resulted in a permitted boiler waste handling system which is not common in either the utility industry or the PG&E system.

Design coordination with the regulatory agencies was essential to timely permit approvals. In this case, the operational permitting agency was the California Department of Health Services (DHS). DHS and PG&E mutually agreed on an operation plan that describes operating procedures and limitations, testing requirements, and establishes performance standards for the treatment system.

## STATEMENT OF DESIGN PROBLEM

PG&E established a design requirement that no hazardous wastes would be "stored" or otherwise left on-site. This would remove the plant from the EPA's list of hazardous waste storage sites. Retrofit costs for compliance with Title 23 of the California Administrative Code (which establishes design and construction requirements for surface impoundments) directed PG&E to this design basis. For siting and construction requirements outside California, the July 14, 1986, Final Rule, Waste Management System and Standards for Hazardous Waste Storage and Treatment Tank Systems (51FR25422, *Federal Register*, Vol. 51, 25422) provides a strong indicator of requirements future federal legislation will impose on surface impoundments.

Also influencing the design were "operational" restrictions imposed by DHS in its permit to operate. With these design requirements established, design goals evolved to include:

- (a) No permanent tanks.
- (b) Treated water must meet NPDES discharge limits for pH and metal concentrations.
- (c) The solid waste must be sufficiently dry to meet land disposal requirements.
- (d) Start-up duration minimization and operational simplicity should be a major objective.
- (e) Project costs must be minimized.
- (f) Flanged connections would be avoided to the extent practical.
- (g) Piping would be above grade (and permanent).
- (h) The berm would be coated with a tough, chemical resistant epoxy grout.
- (i) The transfer areas (Fig. 1) would include spill containment.

(j) Before discharge, the treated water would be analyzed by an independent lab to demonstrate conformance with the plant's NPDES discharge permit and the operation plan.

## DESIGN OPTIONS AND CONSTRAINTS

A brief description of the boiler cleaning process is necessary before discussing design options.

There are ten boilers serving seven units at Contra Costa Power Plant. They include three 110 MW units with two headered boilers each (Group I), two 110 MW units with single boilers (Groups II and III), and two 330 MW units with single boilers (Group IV). The boilers in these groups are acid cleaned once every 7 years, 5 years, and 2 years, respectively.

All ten boilers at Contra Costa are gas/oil fueled. Depending on the percentage of oil burned in a year and unit capacity factors, an acid clean and air preheater/fireside wash can occur from one to nine times per year. A cleaning generates 150,000 gal of acid wash and 100,000 gal of air preheater wash waste water. Based on projected future gas/oil splits and operating hours, acid cleans were assumed, on the average, to occur one and a half times annually, and air preheater/fireside washes three times annually. (These frequencies were utilized for comparing the economics of the various design options.) As a result, the treatment system was sized to temporarily store and subsequently treat 250,000 gal of waste water.

The chemical fill consists of a 5% hydrochloric acid solution with 0.25% corrosion inhibitors, 0.5% ammonium bifluoride, and 0.5% thiourea. (Boilers 7 and 8 may involve a second phase of cleaning with addition of 1.0% ammonium hydroxide and 0.6% sodium bromate.) A typical chemical cleaning consists of approximately 50,000 gal of chemical cleaning solution fill, soak and drain, followed by two 50,000-gal distilled water rinses.

Given the type of acids used and the distilled water flushes at the end of the cleans, carbon steel was deemed an acceptable material for this system. Exceptions to this will be noted as the design is discussed in more detail. Sample constituents pertinent to the plant's NPDES permit are listed in Table 1. Table 2 lists constituents in typical drain and treated samples.

The waste streams, which had previously been routed to the evaporation ponds, are considered hazardous (pH is less than two), and heavy metal concentrations often exceed STLC/TTLC limits (soluble threshold limit concentrations/total threshold limit concentrations). Iron concentrations had to be reduced

**TABLE 1 WASTE WATER AND TREATED WATER ANALYSIS AS APPLIED TO THE DISCHARGE PERMIT**

	Boiler Waste Water	Treatment System Filtrate	Limit*	
			STLC	TTLCL
Chromium, mg/L	.73	< .01	560	2,500
Copper, mg/L	20.00	.25	25	2,500
Lead, mg/L	.57	< .05	5	1,000
Nickel, mg/L	3.90	< .05	20	2,000
Vanadium, mg/L	1.90	< .05	24	2,400
Zinc, mg/L	33.00	< .05	250	5,000
Iron, mg/L	2600.00	.32	-	-

\*California Title 22

to comply with the plant's NPDES discharge permit.

PG&E has considered various options for handling the waste streams at its fossil units. These include:

- (a) Rebuild the evaporation ponds to current permitting status.
- (b) Contract clean and treat (on-site or offsite).
- (c) Construct a treatment facility on site (which itself involves various suboptions).

**Option 1: Rebuild the Evaporation Ponds**

As previously noted, this was not a viable option for Contra Costa Power Plant. The siting requirements imposed by Title 23 of the California Administrative Code made this option impractical.

**Option 2: Contract to Clean**

Contracting to clean involves annually contracting for turnkey treatment and waste disposal. Complications include defining a performance guarantee and chain of custody procedures.

Contract treatment costs are typically per gallon of effluent. In this service territory, costs can range from \$0.80 to \$1.60/gal. Assuming one and a half chemical cleans and three washes per year, costs of up to \$840,000 annually are realistic.

**Option 3: Construct a Treatment Facility**

The on-site treatment facility selected (Fig. 1) consists of above-grade piping, pump systems, and treatment equipment. The waste water is routed from the boiler drains to temporary (rented) storage tanks located in a bermed area. In route, caustic is injected to neutralize the effluent and initiate precipitation of the

**TABLE 2 TYPICAL WASTE WATER AND FILTRATE ANALYSIS**

Parameter	Typical Boiler Waste Water (As Drained) mg/L	Typical Filter Press Filtrate mg/L	
		STLC	TTLCL
Antimony (sb)	< .01	< 0.1	< 0.1
Arsenic (As)	0.014	< 0.01	< 0.01
Barium (Ba)	.8	< 0.1	< 0.1
Beryllium (Be)	< 0.01	< 0.005	< 0.005
Cadmium (Cd)	< 0.01	< 0.005	< 0.005
Chromium (Cr)	0.73	< 0.02	< 0.02
Cobalt (Co)	0.47	< 0.1	< 0.1
Copper (Cu)	20.0	< 0.05	< 0.05
Lead (Pb)	0.57	< 0.1	< 0.1
Mercury (Hg)	0.0004	< 0.0004	< 0.0004
Molybdenum (Mo)	0.1	< 0.1	< 0.1
Nickel (Ni)	3.9	< 0.05	< 0.05
Selenium (Se)	0.007	< 0.005	< 0.005
Silver (Ag)	0.02	< 0.01	< 0.01
Thallium (Tl)	< 0.1	< 0.1	< 0.1
Vanadium (V)	1.9	< 0.2	< 0.2
Zinc (Zn)	33.0	< 0.01	< 0.01
Chromium <sup>+6</sup> (Cr) <sup>+6</sup>	0.02	< 0.02	< 0.02
Manganese (Mn)	18.0	0.6	0.6
Iron (Fe)	2600.0	.32	.32
pH	1.0	7.5	7.5
TSS	88.0	22.0	22.0

metal ions. The precipitates are filtered into a cake and dropped into a dumpster (rollaway) for disposal by others at a Class I land disposal site. The treated water can subsequently be discharged to plant outfall per the plant's NPDES discharge permit.

Installation of permanent tanks would have resulted in the site being classified as a hazardous waste permanent storage facility. Therefore, rental tanks are used to temporarily store the waste water prior to treatment. Other rental tanks are used to temporarily store treated water while testing for compliance with discharge requirements. The tank rental costs for the life of the system are competitive with a comparable permanent tank installation and are consistent with PG&E's goal of being removed from the EPA's list of land disposal (surface impoundment) sites.

This option had a total direct cost (from design through startup) of approximately \$1.7 million. The levelized annual revenue required over 20 years is approximately \$415,000. This mechanical treatment system is discussed in detail on the following pages.

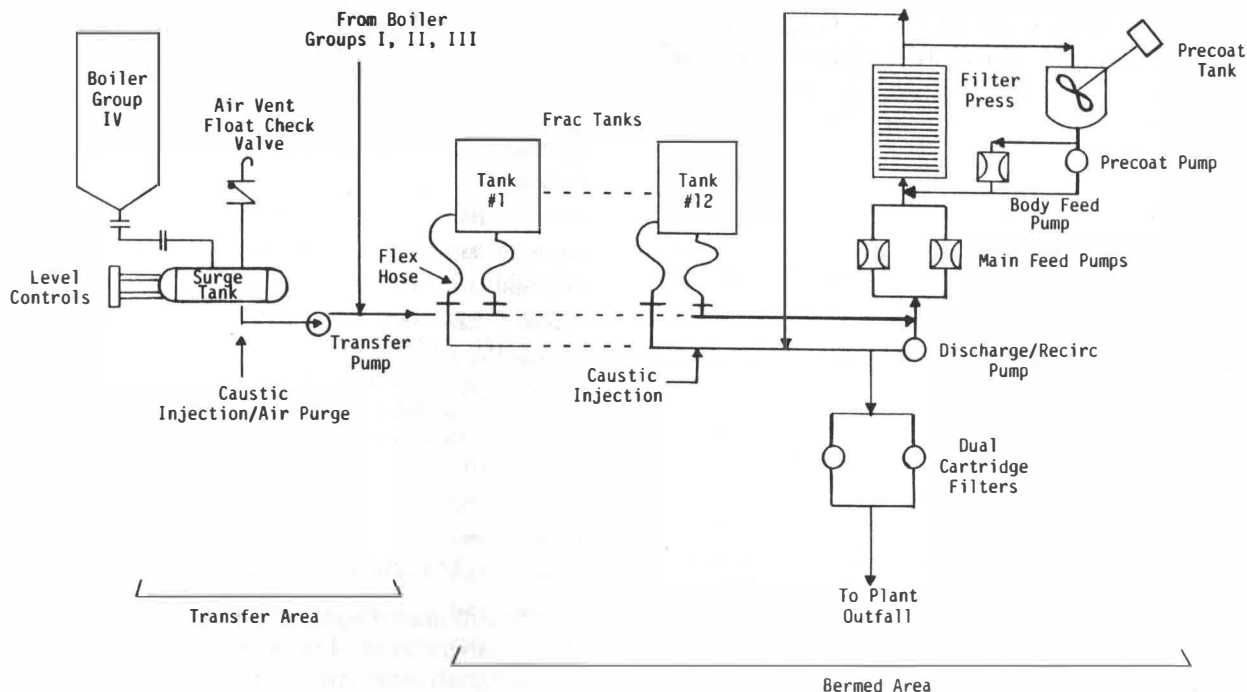


FIG. 1 TREATMENT SYSTEM

Problems encountered with solutions are also discussed.

### SYSTEM DESIGN OVERVIEW

As shown in Fig. 1, a straightforward design evolved that includes, in essence, boiler transfer equipment and ancillary treatment hardware. Each boiler group has a transfer system consisting of a surge tank, centrifugal transfer pumps, and caustic injection taps. The surge tanks are approximately 1100 gal and are equipped with level indication and controls for the automatic pump starts. Caustic is injected during boiler draining to raise pH and precipitate metals.

Waste water draining from the boiler to the surge tank is pumped to a bermed area sized to contain 12 rental tanks and a filter press housed in a structure elevated above a drop box (see Fig. 2). The tanks, headered together, supply the waste water to air driven diaphragm pumps that feed the filter press. Filtrate from the press is temporarily stored in spare rental tanks.

### FILTERING OPTIONS

The type of filtration device selected is critical to the success of the treatment process and will influence the balance of system equipment requirements. Various devices were considered. Options were evaluated based on filtration efficiency, cake dryness, and cost.

Since metal hydroxides tend to blind filters and thus do not lend themselves to efficient moisture separation, solid waste land disposal can be jeopardized. Given the goals of operational simplicity and cost minimization, it was necessary to achieve sufficient cake dryness while minimizing support equipment. The use of a filter aid [ash or medium grade diatomaceous earth (D.E.)], along with the abrasive nature of the solids entrained in the air preheater/fireside washes, led to a desire to minimize moving parts.

A plate and frame filter (filter press) was selected because of its relatively low cost, simplicity of operation, and high filtration efficiency. It requires precoat- ing to prevent blinding the filter medium. Filtering stops when pressure in the press reaches 100 psi, yielding a cake with approximately 45% to 55% residual

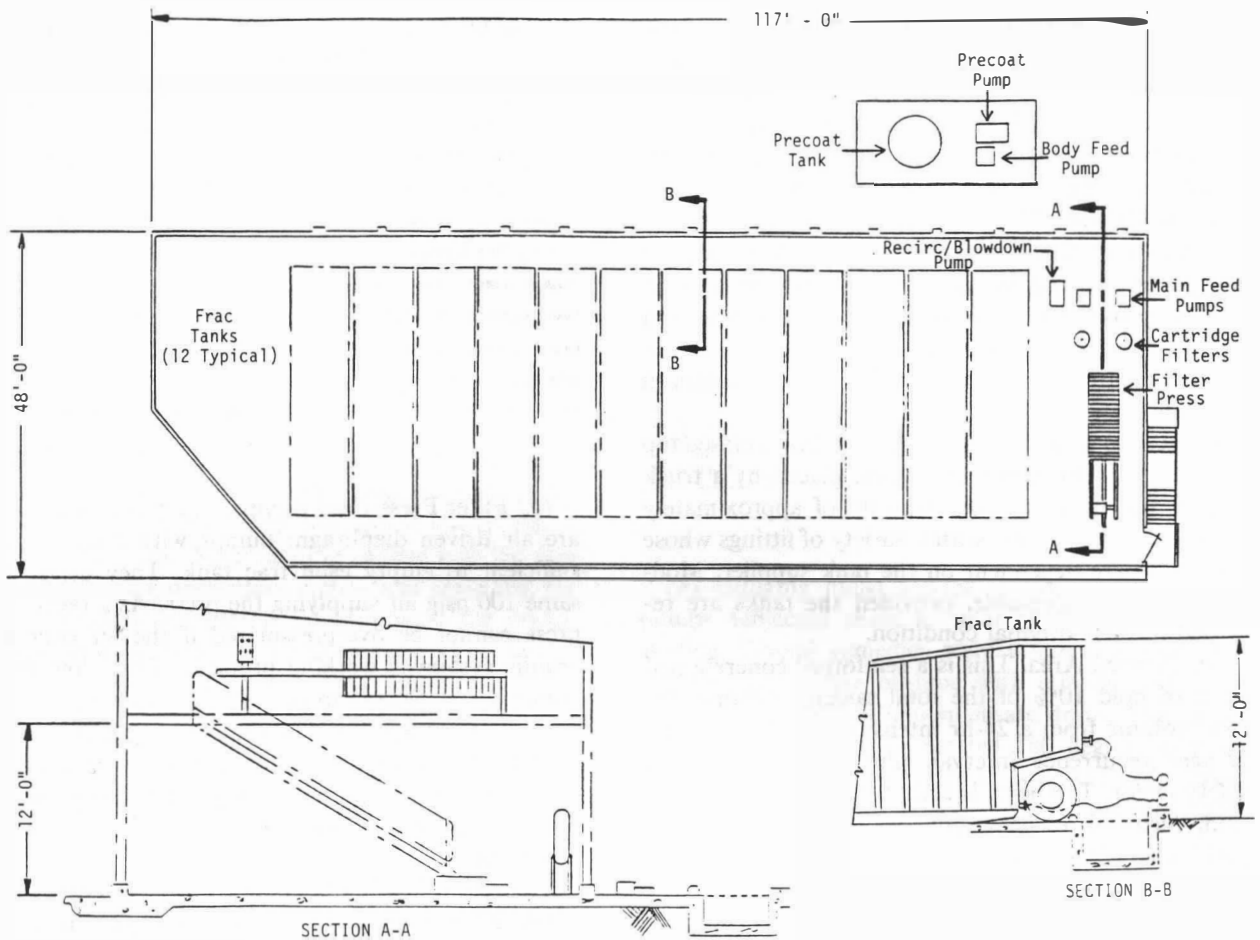


FIG. 2 SYSTEM LAYOUT

moisture. The filter press cake can, if necessary, be dried further by simply applying service air to the press inlet. The other types of devices considered included a vacuum filter, belt filter, centrifuge, and a gravity type separator (clarifier).

### MATERIAL AND EQUIPMENT REQUIREMENTS

(a) Piping. All process piping is Schedule 40 carbon steel with low point drains. Corrosion is a minimal concern since inhibited acids are used and acid residue is flushed with rinse water. All piping is air purged at 100 psig after flushing to remove residual water.

(b) Transfer Pumps. These pumps are API 610 grade with carbon/tungsten carbide mechanical seals. Their extremely intermittent use (hours/year) and po-

tentially wide pH swings required this rugged pump selection. Design flow was chosen equal to the average drain rate. The pump materials were selected for use with water (due to the flushing) while the seal materials were specified for a pH range of 1-12 and a solids laden liquid. Impeller clearances were selected for passing the largest particle size expected from an air pre-heater wash which represents the "worst case" abrasive service. The seal and casing were hydrotested to a pressure of one and a half times the pressure that would occur from the static head of the boiler filled to the center line of the steam drum. The seal has a cyclone flushing arrangement to prevent solids from contacting seal faces.

Pump motors were supplied with vacuum impregnated windings. Depending on motor size, this added feature is inexpensive insurance for long life in a humid and chemical environment. If intermittent use is ex-

pected, oil mist lubricators should be used. All pumps should have recirculation lines for low flow protection.

(c) Surge Tanks. These are horizontal 1100 gal tanks that provide a stable operating environment for the pumps by minimizing suction pressure swings that would otherwise act to shorten pump life, and more importantly, seal life. The tanks are coal tar epoxyed internally and zinc rich primed externally. A cleaning sparger is installed in each tank. Atmospheric vent lines are provided with air-vent-check valves to prevent liquid release.

Level controls are side mounted to prevent collection of solids.

(d) Rental Tanks. These are atmospheric, closed top "frac" tanks. They are pulled and placed by a truck tractor and have a usable capacity of approximately 20,000 gal. They arrive with a variety of fittings whose placement are dependent on the tank supplier. Modifications are acceptable, provided the tanks are returned in their original condition.

(e) Bermed Area. This is a reinforced concrete pad sized to hold 10% of the total tankage volume, the total volume from a 24-hr intensity rainstorm with a 25-year recurrence interval, plus a 10% freeboard safety factor. The berm is coated with a durable, non-skid, chemical resistant epoxy grout. The berm is approximately 50 ft × 120 ft × 1½ ft high and is sufficient to fit 12 rental tanks, the filter press structure, and supporting process equipment (see Fig. 2).

(f) Filter Press. The filtering device chosen was a filter press. Specifically, a 44-chamber plate and frame press (expandable to 64 plates) was selected based upon results of bench scale tests using representative waste water samples. The bench scale tests determined cycle time, precoat requirements, polymer recommendation, polymer concentration, and expected filter cake percent moisture. These tests were performed by filter equipment suppliers on 5–10 gal samples and was useful in establishing contractual requirements. Table 3 compares some of the bench scale model test results and actual process results.

The filter medium is random weave on one side and calendered on the other. It yields a high purity filtrate and facilitates cake discharge.

Depending on the percent solids content in the tank being processed, cycle time (time to reach rated pressure on the press) can range from 2½ hr to 4½ hr to process 25,000 gal. The volume of cake per cycle is approximately 20 ft<sup>3</sup> (including precoat).

The press is open and closed with an air-over hydraulic system using 100 psig air. An air operated swing drip tray with a drain to the frac tanks prevents plate seepage from entering the drop box.

TABLE 3 COMPARISON OF SCALE MODEL vs ACTUAL RESULTS

	Bench Scale Tests	Process Results
Cycle Time (Hours)	5-8	3-4
Precoat Time (Minutes)	20	5-10
Precoat Pump Rate (gpm)	700	100
Precoat Batch Size (Gallons)	7,000	1,500
Body Aid (D.E.) Usage (lb./hr.)	195	0
Polymer Dosage (mg/L)	10	1
Cake Discharge Time (Minutes)	40	15
Cake Thickness (Inches)	1	1
Cake Moisture (Percent)	45-55	45-55

(g) Filter Press Feed Pumps. The main feed pumps are air driven diaphragm pumps with a suction lift sufficient to empty each frac tank. They utilize the same 100 psig air supplying the press. As a result, the press cannot be overpressurized if the air over hydraulic system is working properly. These low shear pumps were selected to prevent floc break-up.

(h) Precoat System. The precoat system consists of a 1000 gal precoat tank, one centrifugal precoat pump, one air-driven diaphragm body feed pump, and a mixer. The precoat tank holds a mixture of service water and D.E.

To prevent filter cloth blinding, prior to waste water entering the press a D.E. precoat is applied until the pressure drop through the press is approximately 5 psi. When waste water solids loading is light, D.E. can be body fed to help fill the filter press cavity.

(i) Polymer Injection. Polymer concentration rates are typically on the order of 1 ppm. If a pump with appropriate turndown is not available, then the polymer must be diluted to a concentration appropriate for the pump turndown capability. It is important to note that as the press fills with cake, the pressure drop increases, and the flow rate of the air driven diaphragm pump decreases. To maintain a constant injection ratio, the polymer injection pump flow rate must track main pump flow. This can be performed manually by adjusting the injection pump flow at 10–15 psi increments. In practice, the polymer pump is typically shut down at about 60% of maximum press design pressure.

(j) Blowdown Pump. This centrifugal pump serves two functions. It can be used for recirculation during pH adjustment or for discharging treated water to plant outfall. Discharge to outfall is through dual cartridge (polishing) filters and an integrating flow meter.

(k) Paint. For this chemical environment, a three-coat paint system was selected for all equipment. This consists of a zinc-rich epoxy primer 3–5 mils thick, a

5–8 mil thick epoxy intermediate coat, and 2–3 mils thick polyurethane final coat.

(l) Instruments. All instruments (pressure gauges, switches) should be liquid filled for isolation from the process fluid. This prevents solids from plugging instrument tubing.

(m) Sample Taps. Sample stations should be located both upstream and downstream of the filter press.

The size and rating of major equipment are summarized in Table 4.

## START-UP PROBLEMS AND SOLUTIONS

(a) Initially, the press filtrate was free of visible solid particles but discolored. Testing of the filtrate showed that pH was low indicating that metal ion solubility was still excessive. Recirculating caustic into the frac tanks to further precipitate metals and recycling the water through the filter press eliminated the discoloration and reduced the concentration of metals in solution to acceptable levels. (Heavy solids in the filtrate would have indicated a broken cloth.)

(b) Precipitation of solids in the rented tanks leaves a thick bottom layer of viscous sludge, with supernatant above. As the press feed pumps pull suction from the tank bottom, a “rat hole” develops and the pumps pull only the clear liquid. This causes erratic filter press and feed pump performance. To provide a more uniform solids feed, 100 psi service air was injected through a spare fitting at one end of each tank. This provided adequate mixing. When the tank level dropped below this fitting, a 30-ft air sparger was used. The sparger was constructed from three pipe lengths of 1½, 1, and ¾-in. diameters with ¼-in. staggered holes spaced 6 in. apart.

(c) Near the end of the treatment process, the remaining suspended solids in the frac tanks are not sufficient to fill the entire press volume. This results in poor press performance and a wet cake due to an incomplete cycle. To remedy this, we simply decreased the number of active plates in the press by installing a “blanking plate” made from sheet metal. This plate can be installed between any two press chambers to decrease the useful volume, assuring a complete cycle. Before the press is opened, 100 psig air applied at the press inlet for 10 min will further dry the cake.

(d) As with any tank/pump system, vortexing is a concern. It became necessary to install vortex breakers in the surge tanks. They were fabricated from ¼-in. plates approximately 10 in. high. These crossed plates rested over the tank discharge nozzle and prevented vortex formation.

TABLE 4 EQUIPMENT RATINGS

MAJOR EQUIPMENT RATINGS	
Filter Press:	Forty-four 36-inch Recessed Plates Expandable to 66; Chamber Volume 20 Cubic Feet; Maximum Inlet Pressure 100 psig
Filter Media:	Polypropylene; 12 Ounces Per Square Yard; 40 CFM Per Square Foot
Feed Pumps:	50 gpm, 100 psi, Air-Operated, Diaphragm Pumps
Precoat Pump:	Centrifugal Pump, 100 gpm at 30 Feet
Body Feed Pump:	12 gpm at 30 Feet of Head
Blowdown/Recirculation Pump:	250 gpm, at 50 Feet
Transfer Pumps:	
Boiler Group IV:	400 gpm at 50 Feet
Boiler Groups II and III:	300 gpm at 50 Feet
Boiler Group I:	200 gpm at 30 Feet
Surge Tanks:	1,100 Gallons
Frac Tanks:	20,000 Gallons
Cartridge Filters:	5 Micron Cartridges for a 250 gpm Flow Rate

(e) Utilizing moist service air for the diaphragm pumps subjected them to intermittent freezing and stalling. Several remedies were attempted, including installing an in-line oil-lube with ethylene glycol, a filter, and an automatic condensate drain. The center block of the pump was rotated 180 deg. to exhaust vertically down and the exhaust extended 12 in. in an attempt to move the zone of rapid expansion (freezing) away from the pump. The final solution was to install an insulated in-line electric air heater upstream of the pumps.

(f) During boiler drains, the turbulent flow of the waste water caused foaming in the surge tanks. The air vent float check valve on the tanks could not contain the foam. It was decided that standard operating procedures would include injecting an antifoaming agent through the surge tank sparger during the boiler drain.

(g) During several high level excursions, the air-vent-float-check valves on the surge tank allowed 1–3 gal of waste water to pass through before seating. As a temporary fix, the vent was routed to a drum within the spill containment area at the transfer stations. A permanent fix is to install a long vent stack to prevent pass through.

(h) Over-injection of polymer initially created a gelatinous cake and some blinding of the filter media. A mild acid wash was attempted but proved ineffective in removing the polymer. Steam cleaning was required.

(i) Normally, seepage through the filter press plates occurs until the precoat is fully applied. Occasionally seepage will occur at or near press design pressure which indicates hydraulic system oil pressure setpoint drift. Adjustment corrects this problem.

A wrinkled filter cloth can also cause seepage since the cloth acts as a gasket around the plate edges. A

deformed cloth can be painted with latex paint around the edges in contact with the plates to eliminate the deformity and the seepage.

## RESULTS AND RECOMMENDATIONS

Analyses of the chemical drain and of the treated filtrate are shown in Table 1. Prior to discharge, tests for the seven metals listed are required by the Regional Water Quality Control Board per the plant's NPDES permit.

The waste water sample is taken during boiler draining upstream of the surge tanks. The values listed for the waste water are the results of testing per the Operation Plan criteria which pertain to the NPDES discharge permit. The Operation Plan testing criteria are based on RCRA requirements and must be performed by an independent certified lab. Since iron is not a RCRA metal, the iron test data in the waste water sample column was arrived at in the plant's lab.

The filter press filtrate numbers are the results of testing on a composite sample from the tanks used for temporary storage of the treated water. The filtrate is discharged to plant outfall. The filter cake (approximately 10–12 cu yd per cleaning) is hauled away to a Class I waste disposal site.

Table 1 indicates how effective this simple treatment system can be at a time when waste management legislation is becoming increasingly volatile. The processed water is dischargeable, and the small quantity of solid waste to be transported is in a form which is not only safe but relatively inexpensive to handle.

The process can be enhanced if a single tank is dedicated to sludge collection with the supernatant

temporarily stored in the other tanks. Since the press operates more effectively with a uniform solids concentration, a simple clarification tank with a weir plate is being considered for this purpose at future installations.

In addition, enhancing the recirculation capability of the frac tanks would aid in processing. Proper pH adjustment during boiler drains can minimize the need for recirculation at the frac tank area. However, if chemical cleaning is performed by a contractor, pH adjustment accuracy is dictated by their treatment methods.

A portable surge tank/transfer pump skid would eliminate the need for a transfer system for each boiler group. However, this option requires concurrence with the appropriate permitting agency.

## CONCLUSION

The purpose of these discussions has been to illustrate that in this climate of changing regulatory policies, there exist viable (although more expensive) alternatives to this industry's traditional practice of using evaporation ponds. PG&E made a commitment to be removed from the EPA's hazardous waste storage list. Since no permanent storage tanks are employed, this design achieved the goal, and was the lowest cost treatment system of all feasible alternatives.

The regulatory agencies demonstrated a willingness to work together with PG&E on a fast track, successful endeavor. In this case, the close coordination and sharing of information was a critical ingredient to this project's success.