UPGRADES AND OPERATING EXPERIENCE WITH A BORON RECYCLE SYSTEM

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ABSTRACT

This paper discusses Pacific Gas and Electric Company's operating experience with a boron recycle system at the Diablo Canyon Power Plant. This system processes approximately 2 million gallons of radioactive liquid a year via ion exchange, filtration and evaporation. This use of the system obviates the treatment and discharge of a large quantity of water by the liquid radwaste system, thus reducing radioactive discharges to the environment. The system recovers reactor coolant for reuse as makeup water. Sixty percent of the makeup water at Diablo Canyon is produced from the reverse osmosis of sea water. Since makeup water is derived from sea water, there is a cost incentive for the recovery of reactor coolant. The system is also capable of recovering boric acid. This can reduce the annual procurement cost of boric acid and eliminates boric acid radwaste solidification.

The various modifications made to this system will be described. These modifications include: conversion of the evaporators from batch operation to continuous operation, bypass of the monitor tanks, conversion from 12 wt% to 4 wt% boric acid concentrates, and upgrades to the instruments, venting, and over-pressure protection for the boric acid evaporators. These and other modifications have played a critical role in enabling the much maligned practice of evaporation to become a reliable component in this treatment system.

Operational strategies regarding resin selection, boric acid selection and silica control are addressed.

INTRODUCTION

Diablo Canyon Power Plant (DCPP) is located on the Pacific coast in Avila Beach, California. Pacific Gas and Electric Company (PG&E) owns and operates the two Westinghouse 1100 MWe PWR units. The commercial operation dates for Units 1 and 2 were May, 1985 and March, 1986, respectively.

The boron recycle system (BRS) was initially designed and supplied by Westinghouse Corporation. This system collects reactor coolant discharged from the primary system, purifies it, and converts it to a concentrated boric acid solution and reactor makeup quality water. The system typically recovers and recycles over 2 million gallons of liquid annually. As shown in Fig. 1, discharged reactor coolant is collected in Liquid Holdup Tanks (LHUTs). The liquid from these tanks is pumped through one of two trains of two demineralizers and then through a resin trap filter to the evaporator package. The evaporator distillate is then pumped through one of two demineralizers and a resin trap filter to the primary water storage tank. There is one of these systems for each unit. The concentrated boric acid solution is pumped through a filter to the concentrates holding tanks. It is then sent to the Boric Acid Storage Tanks (BASTS) for reuse in the plant.

The use of this system provides four major benefits:

1. reduced processing load on the liquid radwaste system,
2. elimination of boric acid radwaste solidification,
3. reduced purchase of boric acid,
4. reduced makeup water requirements.

The treatment of 2 million gallons a year from the LHUTs by the BRS is a major benefit for the liquid radwaste system. By not burdening the liquid radwaste system with an additional 2 million gallons, additional time and flexibility is obtained for processing inputs to the liquid radwaste system. This is extremely important during upset conditions. This also reduces the discharge of treated tritiated water.

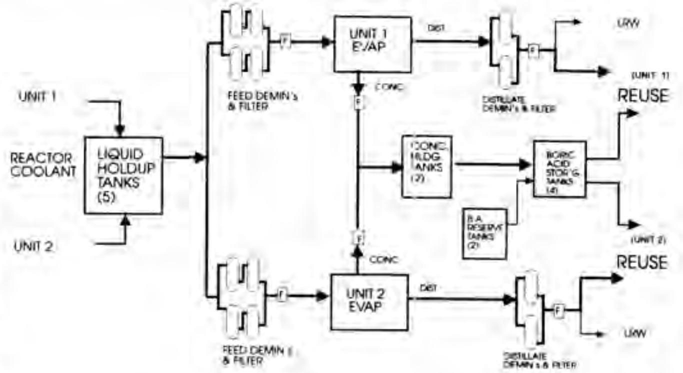

Fig. 1. DCPP boron recycle system.

At DCPP, boric acid costs without recycle would be approximately $100,000 per year. With recycling, this cost is avoided. Recycling reactor coolant is important because 60% of the plant's makeup water is produced from the reverse osmosis of sea water. The cost of this makeup water source is about $8 per 1,000 gallons.

INITIAL OPERATING EXPERIENCE

The initial operating experience with the BRS indicated several deficiencies which are summarized below:

- The Boric Acid Evaporators were originally designed to operate in the batch mode for processing boric acid solution. This severely limited the system through-put for several reasons. Each completed batch had to be held in the evaporator for analysis before it could be pumped to the single concentrates holding tank. There was also a considerable time required for pumpout, refilling, and restarting the evaporator. In some cases it took more than a day to perform all the above operations. The repeated starts and stops was also when problems were most likely to occur.

The through-put of the evaporators was barely adequate to support plant operations. The LHUTs were frequently near their maximum capacity. Their capacity was certainly inadequate to support plant operation in a load-following mode which was being considered at that time.

- The evaporator package is protected from over-pressurization by a large rupture disk located on the condenser. The batch mode of processing resulted in many evaporator startups and shutdowns. Due to the large number of these transients, the evaporator rupture disc burst frequently. Replacing the disc typically resulted in one to two weeks of down time. Opening of the ruptured disc can have dire consequences. Both the control board for the Auxiliary Building equipment and the access control for the Radiologically Controlled Area are located on the same floor as the boric acid evaporators.
- The evaporator level transmitters operated erratically. This was caused by concentrates crystallizing in the sensing lines as well as solids from the evaporator plugging the lines.
- There were frequent failures of the seals in the evaporator concentrates pumps.
- The vent condenser often flooded during system start-up. This backed water into the gaseous radwaste system to which the vent condenser gases discharge.
- In the original design, the distillate from each of the two evaporators was pumped to one of two Monitor Tanks before recycling it. While the distillate was held in these tanks, it became contaminated with dissolved oxygen. Despite all efforts to correct this problem, a significant amount of distillate had to be discharged via the Liquid Radwaste System.
- The boric acid concentrates produced by the BRS and used in the plant systems were in the form of a 12% solution. This required heat tracing to prevent boric acid precipitation. The heat tracing was maintenance intensive and its failure resulted in chronic problems.

SYSTEM MODIFICAITONS AND IMPROVEMENTS

Continuous Discharge of Evaporator Concentrates

A decision was made to modify the evaporators to allow the continuous discharge of the concentrate from the evaporator bottom. This flow is controlled by an online density sensor. As the concentrate is discharged, it is replaced by additional feed. This dilutes the liquid in the evaporator and the discharge is stopped until the concentration rises again. The U-tube type sensor was selected rather than the straight-tube type based upon successful experience with other boric acid evaporators and lower cost. (See Fig. 2.)

A high boric acid concentration trip of 15 wt% was an input set point for the density sensor. If a high boric acid concentration is reached, the liquid feed to the evaporator is stopped, the concentrates in the evaporator are recycled

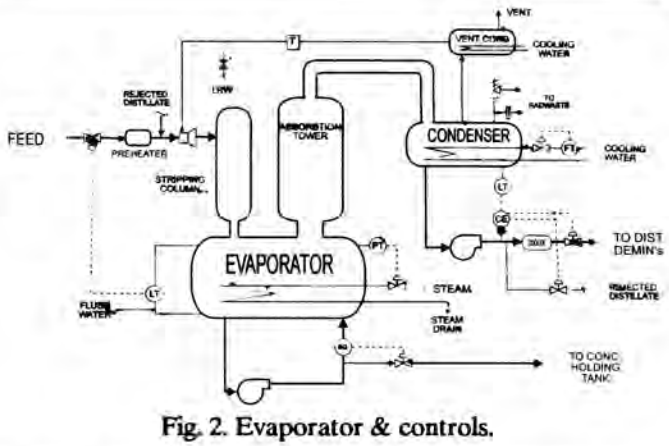

Fig. 2. Evaporator & controls.

within the evaporator package and an alarm alerts the operator of the problem.

A second concentrates holding tank was added to the system by converting the abandoned radwaste concentrator bottoms holding tank for this purpose.

Over-Pressure Protection for the Evaporator

Although running the evaporator in the continuous discharge mode reduced the startup and shutdown pressure transients that could burst the evaporator rupture disk, additional modifications were made. A relief valve, hard piped to the liquid radwaste system would have been the ideal selection. However, it was not practical to install a valve large enough to accommodate all possible over-pressure flows. Therefore, a tee was installed in place of the 15 psig rupture disk. The rupture disk and a smaller relief valve were installed on the tee. This rupture disk can accommodate all possible flows. The relief valve has a 10 psig setpoint to accommodate the low flow transients which are more likely to occur. The discharge of the rupture disks and the relief valve are hard-piped to the Liquid Radwaste System

Evaporator Level Transmitter Modification

The plugging problems with the sensing line on the evaporator level transmitter led us to consider installing different types of instruments. However, it was concluded that it would be less costly and more reliable to just install a flush provision on the line that connects the evaporator to the capillary diaphragm on the level sensor. Periodically flushing this line removed solids and reduced the concentration of boric acid so there was little chance of precipitation.

Replacement of Evaporator Concentrates Pumps

The original concentrates pumps were of canned rotor type and had required considerable maintenance due to casing leakage and blocking of internal passages from boric acid crystallization during initial plant operation. As part of the evaporator upgrade, installation of magnetic coupled pumps was attempted to alleviate maintenance problems. However, testing indicated excessive cavitation due to inadequate NPSH. According to pump data and hydraulic calculations, the NPSH available was marginal at the rated flow; however, in real operation the NPSH was inadequate. The evaporators are mounted on an 18 inch high concrete pedestal with pumps located on the floor beside it. Had this pedestal been about a foot higher, inadequate NPSH would not have been a problem.

Since it was imperative that these pumps be available to process the LHUT inventory, canned rotor type pumps were reinstalled with an improved preventive maintenance program. The pumps are monitored closely for leakages and changed out and repaired off line upon any indication of leakage. Proper operation of the heat tracing and insulation integrity is also monitored to prevent internal boric acid crystallization within the maintenance procedures. However, if the maintenance cost becomes excessive, replacement of these pumps will be reconsidered.

Upgrades to Vent Condenser Drainage

Because the vent condenser is located low on the evaporator package, it does not drain by gravity to the evaporator. *Feed flow to the* evaporator passes through an eductor which drains the condensate out of the vent condenser. Transients during startup caused the drainage to stop or in some cases forced water back into the vent condenser. A valve was added to allow the condensate to drain to the radwaste system during startup. Once steady state conditions are reached, this valve is closed and the distillate flows to the eductor and then to the evaporator.

Bypass of Monitor Tanks

Many attempts were made to locate the source of oxygen intrusion into the monitor tanks to no avail. Nitrogen was added above and below the tank bladder and all welds were tested for leakage. However, oxygen intrusion continued. A design change was issued to bypass these tanks, routing condensate directly to the Primary Water Storage Tanks. A conductivity analyzer and oxygen analyzer were installed in the transfer line. Upon reaching the instrument set point of either detector, a three-way valve is activated which diverts off-spec water to the Monitor Tanks.

Bypassing these tanks also provided extra tank capacity to the plant. One set of monitor tanks was modified to receive on-site wet wash laundry drains in addition to off spec evaporator condensate. The other set of monitor tanks has been utilized in the BRS for additional boric acid concentrates storage, as discussed below.

OPERATING EXPERIENCE WITH UPGRADED EVAPORATORS

The upgrades discussed above were completed by 1990 and the system has performed very well. The evaporators can produce up to 15 gpm of oxygen-free condensate continuously. No relief valves or rupture disks have opened to date. The level detector has not plugged.

In addition to the above upgrades, there was also an effort being made to provide additional capacity to the system by converting the abandoned radwaste concentrator to a boric acid evaporator. Due to the fact that the plant will not load follow and the good operating experience with the two modified evaporators, this effort was abandoned.

The Westinghouse evaporators employ a control system where each of 6 variables is measured by one sensor which controls one valve to maintain the variable at a preset point. (See Fig. 2.)

Although it has been suggested that a more complex and sophisticated system is required, these 6 separate control loops maintain the evaporator in steady operation.

The BRS has been utilized extensively at the end of the fuel cycle to reduce radwaste generation and simplify operation. The deboration of reactor coolant at the end of a fuel cycle can be accomplished by the BRS, or by direct removal of boric acid using the primary deborating demineralizers. There is an economic and operational tradeoff between evaporation and demineralization to remove boron. When the input boron concentration to the evaporator is low, there is a good chance the recovered boric acid concentrates will be off-spec due to chemical contaminants. This is because at low input concentrations, poor kinetics will cause the chemicals to pass through the evaporator feed ion exchange vessels. By using an optimized resin in the feed beds, the breakpoint has been lowered. At DCPP, the deborating demineralizer is not aligned until the reactor coolant system (RCS) boron concentration is below 20 ppm. This is much lower than the standard breakpoint of 60 ppm. This allows a single 30 ft3 bed of anion resin in the deborating demineralizer to reduce boron concentration to nil at the end of a fuel cycle. This in turn means that only one regeneration of a deborating bed is required at the end of the fuel cycle and that regeneration is not required to be performed during a plant shutdown. This practice reduces the volume of regenerant radwaste and decreases the generation of spent deborating resin.

Conversion to 4 wt% Boric Acid

An NRC information notice suggested that plants operating BRS consider lowering the concentration of the boric acid to avoid loss of system function due to line plugs from boric acid crystallization. In order to convert the BRS to 4 wt% several modifications were required.

The heat tracing that was considered essential for safe conduct of plant operation could now be downgraded to non-safety-related because the minimum temperature to prevent boric acid precipitation is about 65°F for a 4 wt% BA solution. The heat tracing controllers were turned down to their minimum temperature of about 100°F, rather that being replaced with new lower temperature controllers.

The more diluted solution requires us to have additional tanks to store the required quantity of chemical shim. This was achieved by converting the Unit 2 Evaporator Distillate Monitor tanks to Boric Acid Reserve Tanks. These tanks can quickly refill the Boric Acid Storage Tanks, which are required for safe conduct of plant operations in either unit. Although the NRC was concerned primarily with the safety-related portions of the system (the Boric Acid Storage Tanks and associated equipment and instruments), the entire system was converted to the 4 wt% solution. It would not have been practical to operate the evaporators at 12 wt% and then dilute the concentrate to 4 wt% for storage and use. Therefore, conversion of the evaporators to operate at 4 wt% was required. This entailed a modification to the online density controller to reduce its setpoint. The high density alarm setpoint was also reduced to 6 wt% boric acid.

Use of Low Silica Boric Acid

Shortly after initial operation of the BRS, a calculation was performed to determine when recovered boric acid would build up silica beyond the acceptable limit. The calculation predicted that, based upon the amount of silica in the RCS, within two years concentrated batches of boric acid would have an unacceptable content of silica. Although an effort was made to obtain relief on silica limits from Westinghouse and INPO when all other contaminants are in spec, no such relief has been obtained.

In the summer of 1991, a batch of recovered boric acid was rejected for the first time due to silica. The rejected boric acid was diluted and discharged via the liquid radwaste system. Because the feed to the evaporator had been demineralized and filtered, discharge of this liquid had little impact on the activity released from the plant. The feed filter in use currently has a 2 micron rating and the concentrates filter has a 1 micron rating.

The major source of silica was determined to be the boric acid. Specifications were revised and low silica content boric acid was procured.

The backlog of silica content (contained in the Boric Acid Storage Tanks) was purged from the system during the conversion to 4 wt% boric acid. Boric acid concentrates are still being rejected due to silica. It is uncertain whether the silica source continues to be "old boric acid" in the RCS or silica-laden spent fuel pool water. The high density racks in the spent fuel pool leach silica. An effort is underway to keep spent fuel pool water from mixing with RCS during outages. This will prevent silica from migrating into the BRS and contaminating the evaporator bottoms. Feed and bleed continues to be practiced to purge the system of silica. Fine mesh filters (0.3 micron) with a zeta potential have been installed in the distillate and boric acid filters to increase the removal of silica.

A proposal to remove silica by reverse osmosis (RO) from the Concentrates Holding Tanks is under review. This would involve recirculating 4 wt% boric acid at operating temperature through an RO unit. Treating the concentrates has the advantages of a small volume of liquid to process (about 2,000 gallons per batch) and the efficiency obtained by processing concentrated silica. Once the boric acid batches routinely meet the silica spec, the RO unit can be removed from service.

CONCLUSIONS

The initial operating experience indicated that several modificaitons to originally supplied equipment were necessary for the BRS to meet the intended functions of the system. After implementing these changes, the BRS has proved to be an effective means of reducing the liquid radwaste inventory. It provided an alternate and economical source of reactor grade makeup water and reduced the procurement cost for fresh boric acid.