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Cooling Tower Waste Reduction

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ABSTRACT

At Lawrence Livermore National Laboratory (LLNL), the two main cooling tower systems (central and northwest) were upgraded during the summer of 1997 to reduce the generation of hazardous waste. In 1996, these two tower systems generated approximately 135,400 lbs (61,400 kg) of hazardous sludge, which is more than 90 percent of the hazardous waste for the site annually. At both, the wet decks (cascade reservoirs) were covered to block sunlight. Covering the cascade reservoirs reduced the amount of chemical conditioners (e.g., algaecide and biocide), required and in turn the amount of waste generated was reduced. Additionally, at the northwest cooling tower system, a sand filtration system was installed to allow cyclical filtering and backflushing, and new pumps, piping, and spray nozzles were installed to increase agitation. The appurtenance upgrade increased the efficiency of the cooling towers. The sand filtration system at the northwest cooling tower system enables operators to continuously maintain the cooling tower water quality without taking the towers out of service.

Operational costs (including waste handling and disposal) and maintenance activities are compared for the cooling towers before and after upgrades. Additionally, the effectiveness of the sand filter system in conjunction with the wet deck covers (northwest cooling tower system), versus the cascade reservoir covers alone (south cooling tower south) is discussed. The overall expected return on investment is calculated to be in excess of 250 percent. This upgrade has been incorporated into the 1998 DOE complex-wide water conservation project being led by Sandia National Laboratory/Albuquerque.

Keywords
DOE, Lawrence Livermore National Laboratory, cooling tower, waste reduction, sand filtration

Introduction

Lawrence Livermore National Laboratory (LLNL) is a U.S. Department of Energy (DOE) research facility located in Livermore, CA. It is jointly operated by the University of California (UC) and DOE. LLNL serves as a national resource of scientific, technical, and engineering capability. Laboratory activities are focused on national security, energy, the environment, biomedicine, economic competitiveness, and science and mathematics education. Many of the scientific research and experiments at LLNL utilize cooling water from a site-wide closed-loop cooling water system. Six sets of cooling towers at the Livermore site are used to remove heat from the closed-loop low-conductivity water (LCW) system through the use of heat exchangers at the cooling tower stations. These cooling towers are located adjacent to Buildings 133, 251, 291, 325, 412, and 511. In 1995, a cooling tower maintenance pollution prevention opportunity assessment (PPOA) was prepared at LLNL (Armatis et al., 1995). The PPOA's recommendation was to reduce cooling tower sludge via catch basin agitation and effluent filtration, and to cover the wet decks (cascade reservoirs). In 1996 at LLNL, the two main tower systems, which are located adjacent to Buildings 291 and 325, generated approximately 135,400 lbs (61,400 kg) of hazardous sludge, which is more than 90 percent of the hazardous waste for the site annually. Using return on investment (ROI) calculations, researchers determined that it would be cost-effective to focus only on reducing the sludge at the two main cooling tower systems located at the Livermore site. The four smaller building-specific cooling towers at the Livermore site were not included in this project.

Location of LLNL

LLNL is located in the Livermore Valley, which is approximately 40 miles (64 km) southeast of San Francisco. LLNL is comprised of two sites: the Livermore site (main site), which occupies an area of 1.27 square miles (3.28 km^2) on the eastern edge of Livermore; and Site 300, which occupies an area of 11.7 square miles (30.3 km^2) located 12 miles (20 km) to the east in the Altamont Hills near Tracy, CA.

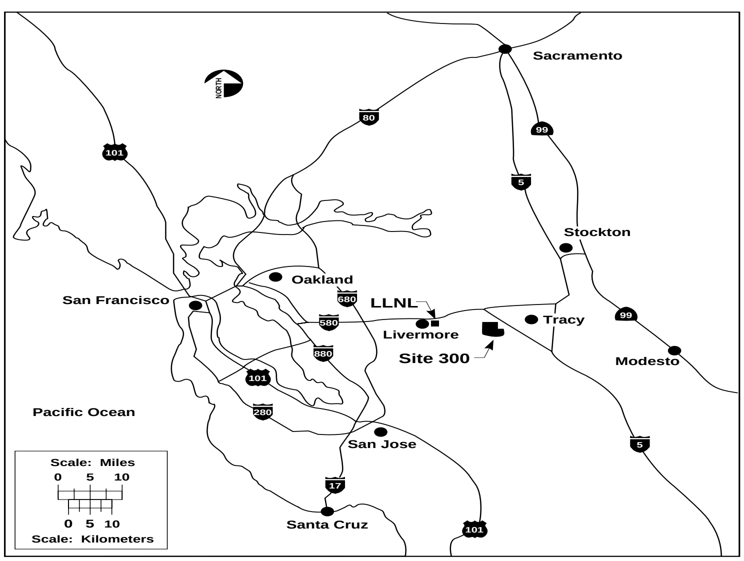

Figure 1. Locations of LLNL Livermore and Site 300

General Climatic Conditions of the Livermore Valley

Typically mild rainy winters and warm dry summers characterize the Livermore Valley. Mean annual rainfall is 14.5 in (36.8 cm), with the predominant rainfall occurring from November through April. In 1996, the mean annual temperature was 15C°; and temperatures ranged from -5C° early winter mornings to 40C° during some summer afternoons (LLNL 1996).

Over the past 10 years, the weather of the Livermore Valley has varied greatly from the norm; it has been very dry followed by very wet. In 1987, and lasting six years, California was hit with its worst drought in recorded history. There was a severe under-supply of water for the entire state. This winter (1997-98), rain in the Livermore Valley and the State was increased greatly due to the effects of El Niño. Thus far, 30.8 in (78.2 cm) of precipitation have fallen this water year (July 1997 through May 12, 1998).

Laboratory site water distribution system

The majority (95%) of the influent water to LLNL is supplied by the County of San Francisco's Hetch Hetchy Reservoir, which collects and stores Sierra snow melt. The remaining influent water is groundwater provided by Zone 7 Water Agency, a water purveyor. The characteristics of both of these influent water sources follow in Table 1.

Table 1

LLNL Cooling Tower System Influent Water Sources' Characteristics		
	Hetch Hetchy	Zone 7
pH	8.7	8.7
Alkalinity	13	62
Hardness	12	76
Calcium	9.4	17
Magnesium	3.5	8
Silica	6	11.8
Chloride	10	47
Sodium	9	46

Once on-site, the influent water has a variety of uses. Major uses at the Livermore site are noted below.

- Boiler make-up water.
- Deionized water.
- Domestic water use.
- Fire suppression water.
- Landscaping/irrigation water.
- Low conductivity water (LCW).

At the Livermore site, the two main cooling tower systems are located in the northwestern (adjacent to Building 291) and southern (adjacent to Building 325) quadrants. See enclosed Figure 2 for a photograph of the northwest cooling tower system.

On a year-round basis, LLNL uses cooling towers that operate by pumping influent water from catch basins. The water is pumped through heat exchangers and then to distribution boxes atop the cooling tower. Wet decks (distribution boxes) separate the water into small streams that down flow through the cooling tower chevrons. Large fans on top of the cooling tower pull air through the down flow of water. As the water streams or particles flow down through the chevrons, heat exchange occurs via evaporation.

Northwest Station

The northwest cooling tower system consists of three 11-megawatt Marley® crossflow towers. This system is situated just west of Building 291. It has a 9,000-ton (9.9 million kg) capacity and requires 35.7 million gallons (135 million liters) of makeup water per year.

Central Station

The central cooling tower system consists of two 8-megawatt Marley® crossflow towers and a seven 8-megawatt Ceramic® counterflow towers. The first system has a 4,000-ton (4.41 million kg) capacity and the second has a 14, 000-ton (15.4 million kg) capacity. In total, the central station requires 33.1 million gallons (125 million liters) of makeup water per year.

Cooling Tower Water Treatment/Chemical Usage

Table 2

LLNL Cooling Tower Chemical Use		
Annual chemical use[a]	NW Station	Central Station
Sodium hypochloride (12.5%)	705 gal (2,670 liter)	780 gal (2,950 liter)
Corrosion inhibitor	170 gal (643 liter)	197 gal (746 liter)
Biocide	110 gal (416 liter)	182 gal (689 liter)

[a] As product received from the manufacturer.

Cooling Tower Sludge Wastes

The algae, along with chemical precipitates and dust, compromise the sludge that accumulates in the catch basins of the cooling towers. Typically sludge was removed on an annual basis, at some time during the winter months when demand on the cooling towers is lowest. In past practice, Plant Engineering staff typically donned Level B personnel protective equipment (PPE), including bottled air, and physically entered the catch basin to scrape the sludge down to the pumping area. A pump truck would remove it off-site for appropriate disposal. This was very uncomfortable work: staff could not stand up straight (due to the low vertical clearance); the basins were wet and cold; and there was a high potential for off-gassing from the sludge.

Sludge Characteristics

Sludge characteristics for the northwest and central cooling towers are given in Tables 3 and 4, following the text. Values for the constituents that meet the State of California or the federal “hazardous” regulatory classification are displayed in boldface type.

Cooling Tower Modification Project

General Description

The cooling tower modification project was originally intended to provide catch basin agitation and filtration, and to add covers for both the northwest and central cooling tower systems. For the northwest station, both portions of the system were provided. Inadequate electrical supply negated the installation of agitation and filtration at the central cooling tower system. There, only covers were installed.

An agitation system was constructed in the catch basin of the northwest cooling tower system. The agitation system is a network of six inch piping: three rows of eight nozzles, spaced sixteen ft (4.88 m) between rows and four feet between nozzles. Each of the three cells at the northwest cooling tower system was fitted with sand filters. Filters have a capacity of 750 gpm (2,840 lpm) each. Each cell has a flow rate of 20 gpm/sqft (814 lpm/m^2) of media surface and the filtering efficiency of 90% for 10-micron particles. The units are sized to filter system volume, once per hour. See Figure 3 for a photograph of the agitation system.

The wet decks of the cooling towers were fit with covers, for a total of five covers. The LLNL fiberglass covers were designed for Zone 4 seismic and 30 psf (150 kg/m) wind loading. The covers essentially blocked all direct sun. The addition of the covers significantly reduces the production of algae, which is directly linked to the production of sludge and gases from the decaying algae. With a reduction in algae, the amount of biocide needed has lessened also. A non-quantifiable additional benefit is that droppings from pigeons that formerly roosted on top of the wet decks is no longer a problem. See Figure 4 for a photograph of the fiberglass covers at the central cooling tower system.

Actual Cost and Schedule

Total installation cost for the project was $284,000 (1997 dollars).

Table 5

Actual Cooling Tower Modification Cost ($K)		
Design		74
Construction - Total		210
fiberglass covers	70	
sand filters, outside piping & appurtenances	162	
distribution piping within the basin	48	
Grand Total		**284**

Actual construction began in April 1997 and was completed in September 1997. The construction schedule was affected by research and experiments at LLNL which restricted any modifications to the cooling towers during certain time periods. Several very windy days also delayed installation of the fiberglass covers, and very hot weather prevented taking any portion of the cooling tower system out of service.

Although the actual construction schedule was extended by two months, the final cost was approximately 9% less than the original estimate of $310,000 (1997 dollars). (Much of the cost differential was due to a lower than expected cost for the purchase of the fiberglass covers.)

Cooling Tower Modification Results

The project resulted in the reduction of sludge from both the central and northwest cooling towers systems. In November 1997, the central cooling tower, which received only the fiberglass covers addition, was cleaned of 33,360 lbs (15,130 kg) of sludge.

In January 1998, accumulated sludge in the northwest cooling tower was removed. it totaled less than one-third of a drum (i.e., less than 165 lbs [74.5 kg]). The northwest cooling tower system's sand filters and catch basin agitation system appear to be a major factor in this significant reduction.

Advantages

- Reduction in the use of chemicals within the cooling tower.
- Heat exchangers and appurtenances are considerably cleaner, which allows for better heat exchange and improved efficiency.
- Increase in worker safety. (Prior to the modifications, on an annual basis workers entered the catch basins, which are classified as "confined space," to remove accumulated sludge.
- Significant cost reduction in sludge handling, transport and disposal.
- Reduction in cooling tower and heat exchanger maintenance.

Disadvantages

- Initial installation cost.
- Small amount of additional equipment that must be maintained.

Conclusion

Older cooling towers can be modified to decrease the need for chemicals, increase heat exchange efficiencies, and reduce waste. This project had a return on investment in excess of 250% and the intangible advantages to its implementation include a better work environment for the personnel who operate and maintain the cooling tower systems.

The installation of the sand filter system in conjunction with the catch basin agitation system appear to have a major effect in the reduction of accumulated sludge in the tower's catch basin.

The wet deck fiberglass covers appear to have reduced algal growth in the cooling tower systems. Presently, we are conducting a pilot study to determine the feasibility of a reduction of biocide. We have reduced the biocide by 50%, which equates to a $400 per week savings in chemicals, without adversely affecting the operation of the cooling towers. These results shall be included in the 1998 DOE complex-wide water conservation project report being led by Sandia National Laboratory/Albuquerque.

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