Chapter 2

WATER CONSERVATION AT UC BERKELEY: CIRCULATION IN THE WATER DISTILLATION SYSTEM

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Introduction

UC Berkeley, a major water consumer in the East Bay Municipal Utilities District (EBMUD), currently purchases an average of 750 million gallons of water a year. A water conservation program on campus has never been seriously considered as a potential means of saving money and water. This is primarily due to the more costly electric and gas rates. However, investigations into water usage on campus identified the steam-heat water distillation system employed by campus buildings as an inefficient utilizer of water. The purpose of this report is the development of conservation measures aimed at reducing water usage on campus, specifically, methods that will reduce water waste in the steam-heat distillation systems.

During the drought of 1976-77 it was shown that water conservation can be accomplished if areas of water waste are identified and corrected. A successful short-term water conservation program was initiated in response to an EBMUD request for voluntary reduction in water consumption (McCrea, 1983, pers. comm.). UC Berkeley implemented measures that consisted of locating and repairing leaky faucets, reducing toilet and urinal water usage, and reducing landscape irrigation (Bowers, 1983, pers. comm.). These measures resulted in a decrease in water consumption from over 750 million gallons in 1976 to 474 million gallons in 1977 (Figure 1). The years following the drought have seen an increase in water consumption to rates close to those before 1976.

Quality of Distilled Water

Campus buildings with laboratory facilities require large amounts of distilled water to conduct experiments. The mineral quality of distilled water is 0.1-1.0 milligrams per liter (mg/l) total dissolved solids (TDS) (Thomas, 1982, pers. comm.). Water of this quality is a requisite for laboratory use because of its low concentration of calcium, magnesium, sodium, chloride, sulfate and other dissolved solids. This low concentration of TDS reduces the probability of interference with sensitive experiments that may result in inaccurate experimental observations.

Presently, the university receives quality water from EBMUD's Orinda filter plant with an average TDS concentration of 54 mg/l (EBMUD, 1982). To reduce this concentration to acceptable laboratory levels, water distillation systems with distillation rates of 10 to 100 gallons per hour (gph) are employed by individual campus buildings. In the distillation process considerable amounts of water are used to cool and condense the steam-heat distillate. The ratio of distilled water produced to water required for cooling is approximately 1 to 9 (Fuller, 1983, pers. comm.). Nine gallons of water enter the system, condense one gallon of distilled water and then exit via direct drainage to the sewer. Developing a method to circulate this cooling water and thereby reducing the amount of water required, could achieve a substantial dollar and water savings.

Water Purification Systems

There are several water purification systems that do not require cooling water nor use any excess amounts of water. Reverse osmosis and ion exchange are two of these systems. In osmosis, two solutions of different concentrations are separated from each other by a permeable membrane. Water molecules flow from a less concentrated solution, through the membrane, into a more concentrated solution, until both concentrations are equal. In reverse osmosis, pressure is applied to achieve the reverse of the above process. Pressure greater than the osmotic pressure of the concentrated solution forces water molecules to flow out of the more concentrated solution through the membrane, resulting in purified water (Gehma and Bregman, 1976).

During the 1976-77 drought some campus buildings changed water purification systems from steam-heat distillation to reverse osmosis (Wenner, 1983, pers. comm.). The idea was that since all the water entering the system is purified, water waste is reduced. However, the use of reverse osmosis was halted after it was realized that maintaining such a system would be expensive (Wenner, 1983, pers. comm.). Contamination of the membrane, and in turn of the purified water, by bacteria led to constant replacement of the membrane filters, each of which cost $1800 in 1976.

The principle behind the ion exchange purification system is the replacement of one ion by another, theoretically resulting in the removal of all metallic ions in water. Three ion exchange processes exist, sodium cycle, split-stream, and demineralization. In the sodium cycle, hard water (water high in calcium and magnesium) passes through a bed of cation exchangers that remove calcium and magnesium. In split-stream softening, water is passed through both a salt-regenerated exchanger and a resinous (synthetic organic polymer) exchanger which has been regenerated with mineral acid. The net result of this process is the complete removal of iron, manganese, aluminum and bicarbonate alkalinity. Demineralization is the removal of all cations and anions by passing water through both a cation and anion exchanger (Gehm and Bregman, 1976). The demineralization process involves a two step chemical reaction (Figure 2). Water first flows through a cation exchanger containing a strong acid resin bed releasing hydrogen ions. It then enters an anion exchanger containing a weak base resin that neutralizes the flow with hydroxide ions. In Figure 2, R represents an organic compound and both RSO_3H and $2R_4NOH$ are symbols for the complex cation and anion exchange resins.

CATION EXCHANGE REACTION

$$CaSO_4 + 2RSO_3H = (RSO_3)_2Ca + H_2SO_4$$

ANION EXCHANGE REACTION

$$H_2SO_4 + 2R_4NOH = (R_4N)_2SO_4 + \underline{2H_2O}$$

FIGURE 2: A representation of the chemistry involved in an ion exchanger.

Using calcium sulfate as the example, this process also removes sulfates, chlorides, nitrates, magnesium and other metallic ions. The anion exchanger removes ionized acids such as sulfuric, hydrochloric, and nitric acid produced in the cation exchange reaction, with purified water as the end product (Gehm and Bergman, 1976). To maintain a greater efficiency of purification, the exchange resins are housed in one tank. This mixed bed tank reduces the leakage of hard water into the effluent.

Stanley Hall, which houses the Department of Molecular Biology presently employs a mixed bed ion exchanger. Four tanks connected in series operate 24 hours a day, 320 days a year, producing 200 gph of demineralized water. In 1971 the ion exchange system replaced two 20 gph stills. The decision to replace the stills was based on their failure to satisfy the volume of water required by the laboratories in the building. The ion exchange system is favorably evaluated by the building operations manager, who cites minimum maintenance, a high purification rate, no waste water produced, and an energy requirement similar to the previous distillation system (Crowe, 1983, pers. comm.).

Steam-Distillation Systems on Campus

Two types of steam distillation systems are found on campus. Small laboratories have electrically operated stills with rates of 1 to 5 gph. Larger laboratories are supplied by steam-operated stills producing distilled water at a rate of 10 to 100 gph. The focus of this report is on the 24 larger stills listed in the Appendix. This list indicates the still rate, storage tank capacity, location on campus and whether or not a cooling tower is located in the same building. The total still rate for these stills is 555 gph. These stills operate 24 hours per day for 320 days a year. With a ratio of cooling water wasted to distillate produced of 9 to 1, the amount of water wasted per year totals 38.4 million gallons or 51,285 hundred cubic feet (CcF).

Present EBMUD water rates are \$.50/Ccf (EBMUD, 1979). At this rate the cost of water wasted is \$25,642 a year. However, EBMUD has indicated its water rates will increase 10-15% in the fall of 1983 (McCrea, 1983, pers. comm.). At a 15% increase, which is likely to be the case, the total cost of wasted cooling water would increase to \$29,489.

In 1981 the quantity of cooling water lost in the once-through distillation system represented 5.6% of the total water purchased and 24% of the water consumed by buildings with distillation systems (Department of Facilities Management, 1981). Large quantities, roughly 85%, of the distilled water produced is used for glassware rinsing and dish washing (Crowe, 1983, pers. comm.).

Model for Water Conserving Distillation

The development of a conservation measure aimed at reducing the cooling water loss is warranted when consideration is given to the quantity of water wasted yearly and the expected increase in water rates. This section focuses on the development of a circulation system that would capture the cooling water upon its exit from the still, cool the water and return it to the still where it can be reused (Figure 3). The water distillation system in Latimer Hall served as the basis for this plan.

Laboratories in Latimer Hall are supplied with distilled water from a 30 gph still located on the ninth floor. 2,772 Ccf of cooling water are lost annually from this still, which operates 24 hours a day. The basis for the proposed circulation model is the use of the cooling tower located approximately 100 feet from the still. This cooling tower is primarily used to cool the air conditioning units in the building. With the installation of a pipe system from the still to the tower and back to the still, a circulating water system could be developed resulting in essentially zero water loss. Located six feet above the still, the cooling tower has sufficient head distance to require a pump to transport cooling water from the still to the tower. This pump would have to overcome gravity and the water pressure in the tower to achieve the first portion of the plan. Gravity and water pressure in the tower would be sufficient to return the water to the still for the completion of the cycle (Figure 3).

A circulation system like the one outlined above is not without problems. Scaling, corrosion, and biological growth can reduce the water movement through the pipes, causing an increase in pump energy to maintain the water supply. In a circulating system, water must be treated to keep it reasonably noncorrosive and non-scale-forming, as well as free from slime and algae growth (AWWA, 1971). Each time cooling water circulates through a cooling tower it undergoes chemical and temperature changes. Alkalinity, dissolved solid concentration, pH and other changes are brought about by evaoporation and exposure to air. Water lost through evaporation is pure H_2O, but the dissolved solids that it contained remain in the circulating water. This process gradually increases the dissolved solids, leading to scale formation as a result of increase in hardness, silica content, and alkalinity (Sussman, 1969).

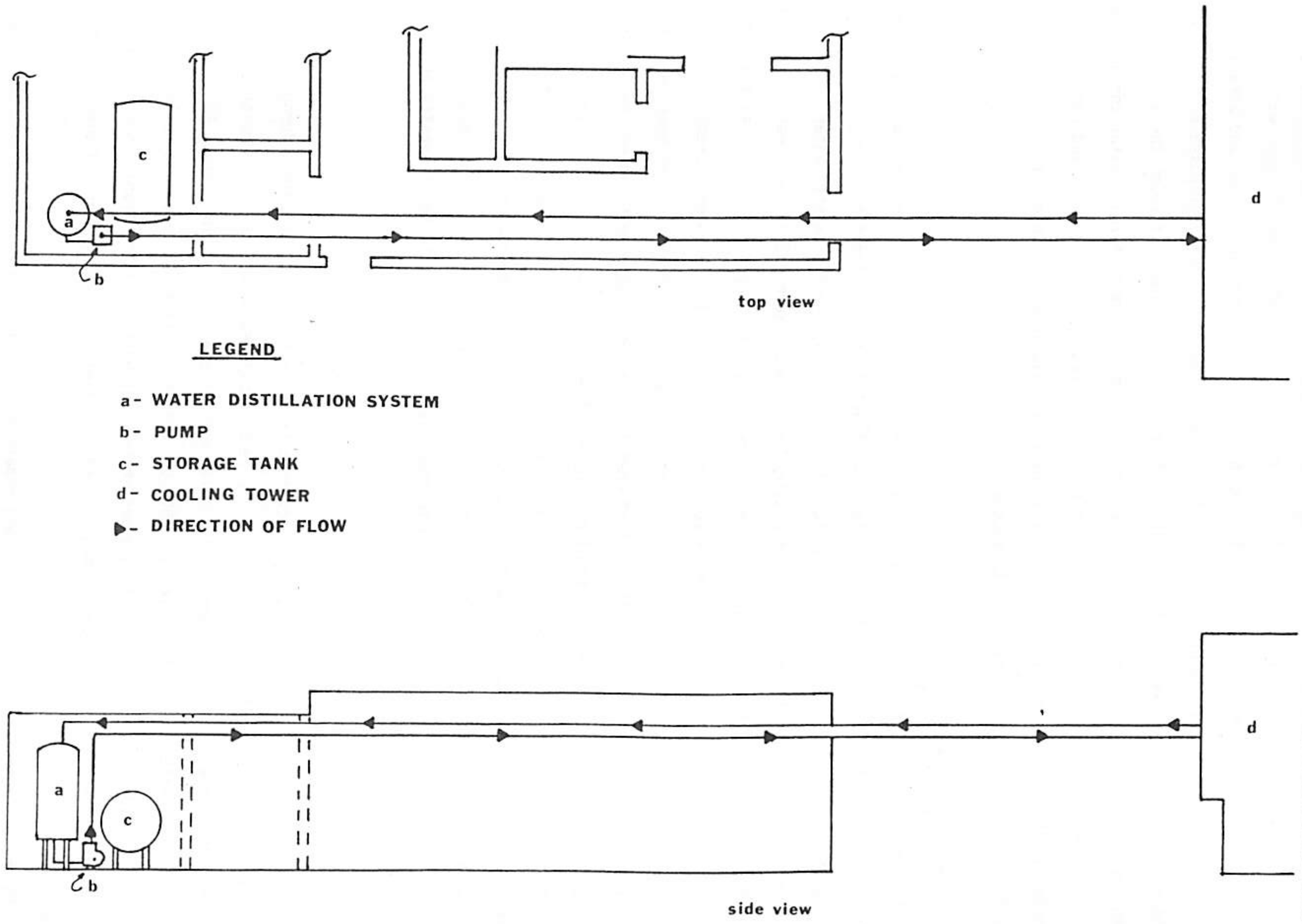

FIGURE 3: WATER CIRCULATION MODEL

scale: $\frac{1}{8}''$ = 1'-0"

Current treatment of cooling tower water at Berkeley consists of adding a biocide to control biological growth, sulfuric acid for alkalinity and scaling control, and a corrosion inhibitor (Donohoe, 1983, pers. comm.). In addition to this treatment, a fixed volume of tower water is periodically released (blowdown) and resupplied with new water (makeup) low in TDS and alkalinity. This prevents the concentration of dissolved solids from increasing. In the proposed system, treating the cooling water would result in maintaining efficient water movement through the pipe system between the tower and still. This would ensure a minimum pump energy in forcing water through the pipes. What needs to be determined is the pump energy required to pump the water and the cost of developing a circulating system. A cost-benefit analysis would answer these questions, as well as determine the feasibility of converting to such a system.

Water Conservation Potential

The total water consumption in the six buildings with distillation systems and cooling towers was 164,232 Ccf in 1981 (DOFM, 1981). The total distillation rate for these buildings is 330 gph (see Appendix), resulting in 22.8 million gallons (30,494 Ccf) per year of wasted water. Circulation of this water in a system similar to the one outlined above would save $15,247 per year at current EBMUD water rates and $17,534 per year under the proposed 15% rate increase scheduled in fall of 1983.

Campus buildings with no cooling towers could be converted to ion exchange systems. The additional water and cost savings from such a conversion would amount to 20,791 Ccf per year and $10,396 respectively. For an estimate as to the cost of changing the remaining nine buildings to ion exchange systems, a commercial water treatment company would have to be consulted. The ion exchange system employed in Stanley Hall was purchased under an agreement that stated payment for the quantity of water purified would suffice, as opposed to the usual payment for the exchange resin beds. This results in a less costly system (Crowe, 1983, pers. comm.). Perhaps the university could pursue a similar agreement with a firm that is willing to negotiate a contract with the university and have them as a customer.

Conclusion

The 1976-77 conservation program, initiated as a response to a larger problem, demonstrates that water conservation on the Berkeley campus can be accomplished successfully. A major reason for such a program is the reduction in the yearly dollar expenditure in water purchases. At current water rates, the campus water expenditure averages $500,000 per year. If a 20% reduction could be accomplished through identifying and correcting areas where water waste is considerable, such as in the distillation systems, the savings could then be used to offset the more substantial electric and gas expenses.

With the assumption that water rates would remain at $.575 for the next ten years, the total savings would amount to $294,890 and 380 million gallons (512,850 Ccf) of water conserved. It can further be assumed that total water consumption on the Berkeley campus will continually increase, especially with the proposed construction of new biological sciences and chemistry buildings. A water conservation program at this time would greatly reduce water costs and waste. The conservation programs discussed in this paper represent a logical and efficient method for accomplishing the goals.

REFERENCES CITED

1. American Water Works Association (AWWA), 1971. Water Quality and Treatment: New York, McGraw-Hill, 510pp.
2. Black, Paul, Esnior Engineer, Dept. of Facilities Management, Energy Conservation Office. Personal communication, February, 1983.
3. Bowers, Jack, Assistant Plumbing Supervisor, Dept. of Facilities Management. Personal communication, January, 1983.
4. Crowe, Don, Building Operations Manager, Dept. of Molecular Biology. Personal communication, April, 1983.
5. Department of Facilities Management, 1981. Annual Waste Water Surveys for EBMUD, 1960-1981. Evaluation of Permit Application under Waste WAter Control Ordinance.
6. Donohoe, Marlin, Stationary Engineer, Management Services Office. Personal communication, January and February, 1983.
7. EBMUD, 1979. Water Rate Structure for Users, Public information handout, 4pp.
8. _____, 1982. Unpublished data. Chemical Analyses of Sources of Supply. Water Quality Laboratory, January-August, 1982.
9. Fuller, John, Stationary Engineer, Steam Plant. Personal communication, January, 1983.
10. Gehm, H.M. and J. Bregman, 1976. Water Resources and Pollution Control: New York, Reinhold, 802pp.
11. McCrea, B., Public Information Officer, EBMUD. Personal communication, February, 1983.
12. Sussman, S., 1969. Reuse of Industrial Cooling Tower Water: Water and Waste Engineering, v. 6, no. 1, pp. A6-A10.
13. Thomas, Jerome, Professor of Sanitary Engineering, UC Berkeley. Personal communication, November, 1982.
14. Wenner, Dave, Stationary Engineer, Steam Plant. Personal communication, January, 1983.

APPENDIX: WATER DISTILLATION SYSTEMS ON CAMPUS

Building	Location Room	Still Rate Gal/Hr	Storage Cap. (Gal)	Cooling Tower
Biochemistry	710	15	100	yes
Biochemistry	710	15	100	
Biochemistry	710	15	20	
Warren	Roof 602	15	150	no
Warren	Roof 602	15	150	
Morgan	420	10	50	no
Morgan	420	10	60	
Mulford	334-A	10	60	no
Oxford Tract	120-M	20	3 tanks @ 350 each (1050 total)	no
Oxford Tract	120-M	30		
Life Sciences Building	Fan Rm 2	100	1200	yes
Life Sciences Building	Fan Rm 1	100	1200	
Hilgard	329	15	3 tanks @ 100 each (300 total)	no
Hilgard	329	15		
Hilgard	314	15	100	
Latimer	906	30	400	yes
Lewis	Attic	15	300	no
Birge	Attic	10	100	yes
Bio-Dynamics	Roof	15	200	yes
Bio-Dynamics	Roof	15	200	
Cowell	Attic	10	100	no
Gilman	Roof	20	50	no
Donner Annex	Attic	15	300	yes
Hildebrand	403-A	25	500	no
TOTAL		555 Gal/Hr		

Source: Black, 1983, personal communication.