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Failure of Cooling Tower LOB-CT-1

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scientific laboratory
of the University of California
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MASTER

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by

W. S. Midkiff

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MASTER

FAILURE OF COOLING TOWER LOB-CT-1

by

W. S. Midkiff

ABSTRACT

Following the loss of cooling tower LOB-CT-1, an investigation was conducted to determine the cause and to develop precautions to prevent future cooling tower losses. This cooling tower, located in the office-building basement of the Clinton P. Anderson Los Alamos Meson Physics Facility (LAMPF), was shut down on October 29, 1973. Excessive use of chelate chemical was judged to be the major factor involved in the high corrosion rates observed. A number of precautions are listed which should prevent further 'surprise' corrosion problems. The precautions include precalculation of chemical additions, visual inspection, corrosion coupons, corrosion meters, and chemical analyses of operating conditions.

On October 29, 1973, the cooling tower LOB-CT-1, located in the basement of the office building of the Clinton P. Anderson Los Alamos Meson Physics Facility (LAMPF), was judged inoperative and shut down. An investigation to determine the cause and to develop precautions to prevent subsequent cooling tower losses was initiated. Various stages of the investigation were conducted between December 12, 1973 and December 21, 1973.

Apparently, the LOB-CT-1 was being treated during September, October, and November, 1971, with 20 to 100 mg/l (by weight)* concentrations of Phoenix 255. Phoenix 255 contains the chelates EDTA, NTA, DTPA, and HEEDTA plus a ferrous and a nonferrous corrosion inhibitor and a dispersant. An alternate chemical, Phoenix 209, contains the same chelates but different corrosion inhibitors. Approximately 50% of Phoenix 255 and 209 is responsive to the chelate test. A strike during this period resulted in improper operation of the cooling tower and silica scale was allowed to accumulate. The system was cleaned with ammonium bifluoride in early November.

*"by weight" as opposed to response to chelate test.

Following the bifluoride treatment, the system was apparently operated satisfactorily until early August, 1972. Approximately 50 mg/l (by weight) Phoenix 209 was maintained from November 15, 1971 until August 3, 1972. Test coupons indicated a maximum corrosion rate of 0.704 mils per year (mpy) for steel and 0.172 mpy for copper.

Five to six weeks of operation without treatment followed.

On September 13, 1972, treatment with Phoenix 255 began. Average concentrations of chemical varied from 10 to 50 mg/l (by weight). This treatment was followed until the system was shut down for the winter on November 1, 1972. Test coupons indicated corrosion rates of 0.66 mpy for steel and 3.90 mpy for copper.

Upon start-up in May, Phoenix Cu, a cleaning chemical similar to Phoenix 255 but with less inhibitor, was utilized. This chemical remained in the system from May 1, 1973 until June 11, 1973. Average concentrations of chemical varied from 100 to 300 mg/l (by weight). Test coupons for the month of May indicated a corrosion rate of 66.57 mpy for steel and 1.66 mpy for copper. In mid-June, the treatment chemical was changed to Phoenix

255. Average concentrations varied from 200 to 300 mg/l (by weight). Corrosion was still present. Test coupons for June and July indicated corrosion rates of 20.2 and 32.8 mpy for steel and 1.34 and 1.27 mpy for copper, respectively.

By this time, the stock feed solution of chemical was being maintained at approximately 10 times the concentration necessary for proper treatment. Although the average concentrations calculated to be in the system do not appear to be highly corrosive, the author feels that concentrations fluctuated so much that highly corrosive conditions were intermittently present. The problem of fluctuating concentrations was accentuated during the period from August 8 - August 22, 1973, during which time in excess of 100 lb of Phoenix 255 was put directly into the basin. This had the effect of localized pH values of 4 to 5 which are highly corrosive to steel as well as the cleaning effect of the chelate which constantly keeps the bare metal exposed. Test coupons for August and September have not yet been returned by Phoenix.

On December 12, 1973, six weeks after it was reported inoperative, the cooling tower was disassembled and inspected with the following results:

(1) The inlet end of the header had been corroded completely through causing an opening of 180° connecting the first two sprayers. Corrosion was from the inside out (Figs. 1 and 2).

(2) The steel nipple connecting to the header was badly corroded from the inside (Fig. 3).

(3) Corrosion appeared to be proportional to velocity. The inlet half of the header showed more extensive corrosion than the dead end (Fig. 4).

(4) Outer panels were excellent where protective paint remained. Where it was gone (due to bifluoride treatment?) an oxide surface remained. Corrosion pits and "washes" appeared where splash or spray had been greatest (Fig. 5).

(5) Blower ducts had protective paint remaining in the less exposed areas. The tops and parts of sides exhibited an oxide surface with intermittent pits and "washes" of corrosion (Figs. 6 and 7).

(6) The fill had been reduced to "lace" by corrosion. Holes riddled the baffles from top to bottom. Corrosion was more extensive at the tops of the baffles where their surfaces were exposed to spray and splash. As the draining water formed a film over the lower portions of the baffles, corrosion rates were apparently reduced (Figs. 8 and 9).

(7) The pipe leading to the centrifugal pump was corroded on the inside.

(8) The ferrous nut and washers holding the pump impeller showed corrosion but the nonferrous pump and impeller showed no damage.

A sample of water was taken from the basin at the time it was disassembled. The water had been standing for

approximately one month and was about double operating concentration. An atomic absorption analysis by Group H-7 revealed the following concentrations:

Calcium	24 mg/l
Magnesium	6.2 mg/l
Copper	0.12 mg/l
Iron	119 mg/l
Zinc	79 mg/l
Alkalinity	250 mg/l
pH	6.8

CONCLUSION

Excessive use of chelate chemical resulted in the high rates of corrosion. Of the four chelates used in Phoenix Cu and Phoenix 255, one or more was always present which to some extent was able to pull iron away from iron oxide. If this protective oxide layer is constantly being pulled from the parent metal, the bare surface is exposed to oxygen for further corrosion. As a result, corrosion rates were highest where the oxygen-water-metal interface was being renewed fastest, in the spray zone.

RECOMMENDATIONS

To prevent further corrosion or scale problems, the following precautions should be practiced.

(1) Operate cooling tower at recommended levels of chemical treatment.

(2) Calculate, by weight, quantities of chemical to be added. Weekly record checks of quantities of chemical added versus quantities of water used should confirm the precalculated concentrations.

(3) Facility should be provided for easy and routine visual inspection of the header-fill area.

(4) Routine (monthly) use of corrosion coupons and rapid analysis will supplement visual inspection. The capability of on-site analysis within two weeks following removal from the system should be investigated.

(5) Electrical measurement of corrosion rates should be investigated. Both resistance and linear polarization probes are commercially available and both allow rate of corrosion to be monitored. Test coupons provide only single point data for a corrosion rate assumed to be linear.

(6) At least weekly chemical analyses of the water system (including treated make-up water) should be made. The operator and supervisor should be aware of changes from the ordinary or other clues suggesting non-standard operation. For example:

(a) Excessive chelate concentrations can give erroneous or even zero response to the chelate test.

Dilutions may be required for accurate analyses.

(b) Excessive chelate can interfere with the hardness test giving low answers or rendering the test completely unresponsive.

(c) Excessive chelate can be responsible for stimulation of bacteria growth and increased chlorine demand.

Adherence to these precautions will remedy the cooling tower problems that have been most severe at LAMPF. The records indicate that LOB-CT-1 has been operated safely with more than one chemical treatment

when recommended concentrations were maintained. Five possible precautions have been outlined to insure safe operations. While satisfactory long-term operation relies ultimately on the suitability of the chemical treatment recommended, at least three Phoenix chemicals have been demonstrated to be adequate at LASL when properly applied. Investigation and surveillance will continue in an effort to improve the selection and application of chemicals.

A detailed history of LOB-CT-1 follows.

HISTORY - LOB-CT-1

	Date	Flow Meter	Chemical	Comments
	9-1-71	635120	255,3#	
	9-8-71	649850	3#	$\frac{12\#}{61,020 \text{ gal}} = 23.6 \text{ mg/l}$
	9-15-71	672110	2#	
	9-22-71	680480	2#	
	9-29-71	688670	2#	
	10-6-71	696140	5#	
	10-14-71	706160	10#	$\frac{25\#}{31,530 \text{ gal}} = 95 \text{ mg/l}$
SiO ₂ deposits	10-20-71	708770	0	
Workers' strike	11-4-71	719150	10#	
	Bifluoride Treatment			
	11-15-71	727670	209, 1 gal	$\frac{3.25 \times 10.9}{61,380 \text{ gal}} = 70 \text{ mg/l}$
	11-17-71	729930	1 gal	
	11-23-71	736820	1 gal	4 conc hardness
No scale	12-27-71	774560	1 qt	pH 8.5-9
	1-13-72	789050	1 qt	$\frac{0.5 \times 10.9}{14,980 \text{ gal}} = 43.5 \text{ mg/l}$
Steel 1.09 Cu 0.027	1-24-72	798200	1 qt	
	2-2-72	804030	1 qt	
	2-14-72	813830	1 qt	$\frac{1 \times 10.9}{29,000} = 45 \text{ mg/l}$
	2-22-72	821290	1 qt	
	2-28-72	826970	1 qt	3½ conc hardness
Steel 1.05 Cu 0.294	3-6-72	833030	2 qt	
	3-15-72	844890	2 qt	$\frac{1.25 \times 10.9}{28,550} = 57 \text{ mg/l}$
	3-21-72	Installed new pump (seal failure)		
	3-24-72	852840	1 qt	
Coupons in excellent condition	4-3-72	861580	1 qt	$\frac{0.75 \times 10.9}{48,240} = 20 \text{ mg/l}$
	4-12-72	874600	1 qt	
Steel 0.555 Cu 0.014	4-26-72	892990	1 qt	3 conc hardness
	5-19-72	909820	2 qt	
	5-23-72	916820	1 qt	$\frac{1.25}{24,360} = 67 \text{ mg/l}$
Steel 0.509 Cu 0.172	5-26-72	922200	1 qt	
	5-30-72	929270	1 qt	
	6-5-72	941180	1 qt	
	6-7-72	944930	1 qt	
	6-12-72	954010	2 qt	
	6-16-72	963020	2 qt	$\frac{4.5 \times 10.9}{80,430} = 73 \text{ mg/l}$
Steel 0.704 Cu 0.111	6-19-72	970820	2 qt	
	6-20-72	974340	2 qt	2½ conc hardness

	<u>Date</u>	<u>Flow Meter</u>	<u>Chemical</u>	<u>Comments</u>
	6-23-72	982240	2 qt	
	6-26-72	992230	2 qt	
	6-28-72	1000140	2 qt	
	6-29-72	1006500	<u>2 qt</u>	
	7-6-72	1021610	2 qt	
	7-11-72	1030770	2 qt	2 conc hardness
	7-14-72	1038650	2 qt	
	7-17-72	1053810	2 qt	
	7-20-72	1062070	2 qt	$\frac{4.25 \times 10.9}{110,630} = 50 \text{ mg/l}$
	7-21-72		2 qt	
Steel 0.640 Cu 0.144	7-24-72	1076540	2 qt	
	7-26-72	1084300	1 qt	
	7-27-72	1089600	1 qt	
	7-31-72	1114580	<u>1 qt</u>	
	8-3-72	<u>1132240</u>	2 qt	
5-6 weeks, no treatment		1396400		264,160 gal
	9-13-72		255-5#	
	9-20-72		5#	$\frac{10\#}{150,270} = 8.3 \text{ mg/l}$
		1489750	<u>-----</u>	$1\frac{1}{2}$ conc hardness
	10-2-72	<u>1546670</u>	4#	
	10-6-72		5#	
	10-11-72	1610870	10#	
	10-13-72		10#	
	10-16-72	1651544	15#	$\frac{64\#}{145,880} = 52.5 \text{ mg/l}$
	10-18-72		<u>20#</u>	
Steel 0.66 Cu 3.90	10-24-72	<u>1692550</u>	20#	
	10-27-72		20#	
	11-1 to 4-30	turned off for winter		
	5-1-73	1739610	Cu, 8#	
	5-7-73		10#	
	5-11-73		20#	$\frac{133\#}{127,740} = 125 \text{ mg/l}$
	5-14-73	1816770	30#	
Steel 66.57 Cu 1.66	5-18-73		20#	
	5-22-73		20#	
	5-25-73		15#	
	5-29-73		<u>30#</u>	
	6-1-73	<u>1867350</u>	30#	$\frac{90}{40,280} = 270 \text{ mg/l}$
	6-6-73		30#	
	6-11-73		<u>255-30#</u>	
Steel 20.2 Cu 1.34	6-18-73	<u>1907630</u>	Basin, 10#	
	6-20-73		25#	$\frac{60}{37,590} = 192 \text{ mg/l}$
	6-25-73		10#	
	6-29-73		<u>15#</u>	
	7-2-73	<u>1945220</u>	25#	
	7-5-73	injector plugged		$\frac{90}{34,960} = 310 \text{ mg/l}$
	7-9-73		25#	
	7-11-73		30#	
	7-13-73		<u>10#</u>	
	7-16-73	<u>1980180</u>		
	7-18-73		10#	$\frac{215}{76,450} = 338 \text{ mg/l}$
	7-20-73		10#	

	<u>Date</u>	<u>Flow Meter</u>	<u>Chemical</u>	<u>Comments</u>
Steel 32.8 Cu 1.27	7-23-73		10#	
	7-25-73		30#	
	7-27-73		30#	
	7-30-73		Basin 20#	
Steel showing high corrosion rates, copper OK	8-1-73		30#	
	8-3-73		25#	
	8-6-73		25#	
	8-8-73		Basin 25#	
	8-15-73	<u>2056630</u>	Basin 20#	
	8-17-73		255, 20#	in basin
	8-20-73		Basin 20#	
	8-22-73		Basin 20#	
	8-29-73		12#	$\frac{200}{123,180} = 195 \text{ mg/l}$
	8-31-73		12#	
	9-4-73	2129850	15#	
	9-7-73		30#	
	9-10-73		Basin 10#	
	9-12-73		15#	
	9-17-73		15#	
	9-19-73	<u>2179810</u>	10#	
	9-21-73		10#	
	9-24-73		15#	
	9-28-73		10#	+ 6# basin
	10-3-73		20#	
	10-9-73		20#	$\frac{180}{142,780} = 150 \text{ mg/l}$
	10-11-73		20#	
	10-17-73		12#	
	10-19-73		12#	
	10-23-73		20#	
	10-26-73		25#	
	10-29-73	Tower not operating		
	11-2-73		35#

*Fig. 1.
Header.*

*Fig. 2.
Header, close-up.*

*Fig. 3.
Nipple.*

*Fig. 4.
Sprayer port.*

Fig. 5.
Outer panels.

Fig. 6.
Blower duct, left.

Fig. 7.
Blower duct, right.

Fig. 8.
Fill, left.

Fig. 9.
Fill, right.