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Survey of Treated Water Supply System for the 184-inch Area and Vicinity

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SURVEY OF TREATED WATER SUPPLY SYSTEM FOR THE 184" AREA AND VICINITY

Carl T. Grauer

February 23, 1949

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Purpose of Survey

These data were collected for the purpose of consolidating information relating to the treated water supply as used for electrical cooling purposes.

Included are expense items, data on contamination and electrical requirements, and recommendations for use as a guide in future operations.

Necessity for Water Treatment

It is well known that the East Bay Municipal Utility District has available in the bay region an abundant supply of good mountain water. This is taken from their Pardee Dam on the Mokelumne River in the foothills of the Sierras.

The water served to the residential and industrial consumers is of high quality as shown in Footnote I.

Footnote I

The following table is found in a pamphlet entitled "Mokelumne Water," issued by the East Bay Municipal Utility District. It is included here for those readers who may be interested in the chemical analysis of this water, as received from the Utility Districts' mains:

Common Name	Chemical Formula	Parts Per Million	Grains Per Gallon
Table Salt (Sodium Chloride)	$NaCl$	6.4	0.37
Lime	$CaCO_3$	14.5	0.85
Alumina	Al_2O_3	0.5	Trace
Magnesite	$MgCO_3$	3.0	0.18
Salt Cake	Na_2SO_4	2.1	0.12
Silica	SiO_2	14.9	0.87
Temporary Hardness		18.0	1.05
Permanent Hardness		0.0	0.00
Total Soap Hardness		18.0	1.05

Chemicals used in treatment are Aluminum Sulphate and Chlorine Gas. Milk of Lime is added to the filtered water, in order to make it distinctly alkaline and to reduce corrosion.

These qualities are sufficient for the average industrial plant. However, where plant operation requires the use of water to cool electrical equipment at high voltages, very low conductivities are necessary in order to reduce leakage currents to ground, and attendant electrolysis problems.

During the rainy months the conductivity of this water varies from approximately 54 to 68 micromhos per cm. At the height of the dry season, when a portion of the water is supplied from local storage reservoirs, this conductivity may rise to 200 micromhos or more.

For this reason it became necessary to install equipment capable of reducing these conductivities to safe values. An "Illco-Way Unit," as manufactured by the Illinois Water Treatment Company, Rockford, Illinois, was installed and placed in operation July 26, 1943. This equipment reduces the conductivity of the treated water to values between 2.5 and 10 micromhos, thereby reducing the electrolysis and high voltage leakage problems to a minimum.

For a brief description of the Illco process see Footnote II.

The capacity of this Illco unit is approximately 600 gallons per hour. Caustic Soda and Sulphuric Acid are used for the "Anionic" and "Cationic" tanks respectively. The quantities required are listed under the heading of Chemicals.

Footnote II

In operation water to be treated passes through two beds of special resins, the first of which removes, by base exchange, the positive ions such as calcium, magnesium, sodium, iron, etc., and substituting hydrogen.

The hydrogen combines with the negative sulphate, chloride, nitrate, etc., ions to form the equivalent acids. The carbonates form carbonic acid which passes on through as CO_2 and water, and the CO_2 can be largely dispelled by aeration.

This acidic water passes to a second tank where the negative ions (chlorides, sulphates, nitrates, etc.) are removed by adsorption, giving a final effluent which compares favorably with single-distilled water.

In practice, a small amount of water is taken from the city water main and passed through the Illco plant. Emerging as very low conductivity water it then flows into the closed-circuit cooling system where it is pumped around to the various electrical units requiring low conductivity water.

The heat removed from these electrical units is carried by the water to the cooling towers where the water temperature is reduced at the cost of a small quantity of water lost by spray and evaporation.

It is this small quantity of "make-up" water which is treated by the Illco plant and taken from the city main. Treating a small amount of make-up water gives longer useful runs of the chemicals. If system water is also run through the Illco plant the quantity required prevents low conductivity output, and it becomes necessary to dump out the system water and regenerate. Sudden rises in system conductivity make this necessary also.

Water Cost

The Radiation Laboratory pays a relatively low rate for water supplied by the East Bay Municipal Utility District, and this is the principal factor in obtaining low operating cost of cooling water, as used in the 184" area.

This rate for untreated water is 15 cents per hundred cubic feet, which is equivalent to $1.50 for 7500 gallons. Since October of 1944, the Utility District has made an additional charge of $27.50 per month for storage standby service for water which is withdrawn from the high storage tank of 40,000 gallons capacity. This is the high tank on the hill N.E. of the 184" area and is fed from a separately metered 6" line which delivers water at 130 P.S.I. pressure from the Grizzly Peak line.

It is understood that after an additional number of consumers are connected to this 6" line, the service charge of $27.50 per month will be reduced, eliminated or refunded. Water from this tank, being at a higher elevation and consequently at higher pressure, is used for fire hydrants to maintain pressures and to supply the Chemistry Building [redacted].

The two tanks at a lower elevation (of 40,000 gallons capacity each) are supplied from a 4" separately metered line which crosses Strawberry Canyon. Prior to October, 1944, all of the 184" area water was billed from meter readings on this line. The following is a resume of charges made for water, as used in the 184" area, before and after the installation of the new 6" high pressure tank line.

Month	Total Cu.Ft.	Billed Price	Standby Cu.Ft.	Billed Price	Standby Charge	Total Standby	Total Bill	Cost of 184" Cooling Water
July	151,400	$227.10	00	------	------	------	$227.10	------
August	173,000	259.50	00	------	------	------	259.50	------
September	129,700	194.55	00	------	------	------	194.55	------
October	98,300	147.45	51,800	$77.70	$27.50	$105.20	252.65	$78.67
November	68,600	102.90	1,000*	1.50	27.50	29.00	131.90	67.77
December	73,100	109.65	60,000	90.00	27.50	117.50	227.15	77.50

*Item questionable by Accounting Department. Amount of water not properly indicated at that time.

Chemicals Used in Water Treatment

The materials used in the "Illco" unit for reduction of water conductivity consist of the two principal items:

(a) Trona Caustic Soda (flake), purchased in 100 lb. sacks @ 3 3/4 cents per lb. from the Pacific Silicate Company, 215 Market Street, San Francisco.

(b) 66 Baume Sulphuric Acid, purchased in 54 gallon drums (750 lbs. per drum) @ 1 1/2 cents per lb. from the Marshall Dill Company, 24 Bluxome Street, San Francisco.

The normal regeneration charge required for this "Illco" unit, consists of the following:

84 lbs. of Soda @ $ .0375 per lb. ------	$3.14
136 lbs. of Acid @ $ .015 per lb. ------	$2.04
Total for materials ------	$5.18

Where the city water only is used in the Illco unit for reduction of conductivity, then to be added to the system water in quantity just sufficient to make up for that lost in spray nozzles and cooling towers, a somewhat smaller amount of regeneration chemical is used:

64 lbs. of Soda @ $ .0375	per lb.	------	$2.42
84 lbs. of Acid @ $ .015	per lb.	------	$1.26
	Total for materials	------	$3.68

Runs No. 168, 169 and 170, as shown in Table I, were made in this manner. Costs of operation have been summarized in Table II.

Labor Expense

It has been reliably estimated by the Water Technicians' Group that an average of eight man-hours are required for operation and supervision of the Illco plant for each regeneration period. To cover the cost of time so used by the Water Technicians' Group an item of $10.00 has been added on to the cost of chemicals as shown in Table I under the column headed "Cost of Regeneration."

Contamination

The Esterline-Angus Water Conductivity Recorder frequently shows sudden increases in conductivity. At such times the Water Technicians' Group makes every effort to determine the causes of such increases. Several items of interest are noted here:

1. G.E. Glyptal No. 1201

   This thick reddish colored synthetic compound is occasionally used by the various tank crews to plug up leaks in the water lines of their operating units. When this is done small quantities of the Glyptal are forced into the treated water system used for tank cooling.

   A test made on this material showed that the addition of 1% (by volume) of Glyptal increased the conductivity of 18.8 micromho water by 4.75%.

2. Dry Ice (CO_2)

   Pieces of dry ice, which may fall into the water system at various open points in the vicinity of the 184" platform, will increase the conductivity of the water.

A test showed that adding 3% (by volume) of dry ice to 6.0 micromho water will increase its conductivity 700%. This rules out the change in conductivity due to temperature because the dry ice will tend to lower the temperature of the water, whereas an increase of water temperature of 1° Fahrenheit will increase the conductivity approximately 1%.

3. Liquid Air

On several occasions it had been observed that when there was an overflow of liquid air due to tank trap filling, this heavy vapor rapidly settled under the platform in the area of the open sump tank. Coincidental high conductivities indicated that the absorption by the turbulent water in this tank of the liquid air falling in a fog from the platform above, might be responsible for this effect. Several tests were made, however, which did not support this theory.

4. Helium, Freon, etc.

Various gases, refrigerants, etc., are used by the tank and reassembly groups to test for leaks. When used in this manner in the reassembly shop before a plate is placed in service, there is little possibility of such lightweight gases or low boiling point refrigerants of remaining in the water lines subsequently to be discharged into the water system. Furthermore, their direct effect upon water conductivity is doubtful.

Corrosive gases and liquids could conceivably corrode the inside of water lines, the following water supply washing these products of corrosion into the system, thus raising the conductivity. So far as is known, however, no such corrosive gases or liquids are used for this purpose.

A further investigation into the causes of sudden and sustained rises in conductivity will be necessary, based more on a nuisance standpoint rather than on cost of operation of the Illco plant. See Footnote III.

Electrical

Treated water is passed through porcelain insulating coils as manufactured by the Lapp Insulator Company. These coils have a double water channel through which water flows to and from the electrical equipment which requires cooling.

From an electrical viewpoint, these twin channels can be regarded as two high resistance conductors in parallel when filled with water. Their joint resistance can be easily measured or calculated. The high voltage drop across the coil forces a current through the twin water streams and this current must be kept to a low value to prevent unnecessary waste of power. Electrolytic action on the metal fittings on the positive end of the coil is reduced at low leakage current.

These values are tabulated in Table III which shows the resistance and losses for various water conductivities and voltages for the two types of coils currently in use.

These coils carry the water to and from the anode jackets of the high voltage vacuum tubes, and since these tubes are at high voltage above ground (water system, of course, being solidly grounded) there is a high voltage stress across each

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Footnote III

In order to prevent the growth of algae and slime formations in the basins and cooling towers a silver anode is suspended in the open sump tank and a small current discharged from its surface. This very effectively kills off marine life. It has not yet been determined what the maximum discharge rate should be to prevent any rise in conductivity, but this effect to date has been negligible.

porcelain coil.

Various rates of water flow are required for the several types of tubes in use. The following data are based on tests made with a No. 562 Diode Vacuum Tube (G.E.) on November 7, 1943, the results of which are recorded elsewhere.

TABLE IV

Tube Type	Mfgr's Recomm. G.P.M.	Anode Area Sq.In.	For 10°C Rise K.W. Diss.	For 10°C Rise Reg'd. G.P.M.	For 5°C Rise K.W. Diss.	For 5°C Rise Reg'd. G.P.M.	Recom'ded. Normal G.P.M.
562 Diode	8-15	98	31.8	12	15.9	12	12
562 Diode	8-15	98	26.5	10	13.25	10	12
562 Diode	8-15	98	21.2	8	10.60	8	12
893 Regulator	8-15	98	31.8	12	15.9	12	12
214 Rectifier	?	40	3.22	3	1.61	3	3
214 Rectifier	?	40	1.61	1.5	0.80	1.5	3
222 Rectifier	1-Min.	47	3.78	3	1.89	3	3
222 Rectifier	1-Min.	47	1.89	1.5	0.95	1.5	3

At each end of each water channel in the Lapp coils there is a small electrolysis anode placed there for the purpose of establishing the last point of metallic contact with the water at the high voltage end of the coil.

Where the high voltage end of the coil is of positive polarity, the anodes are eaten away by electrolytic action and must be periodically replaced. They are all approximately 3 1/2" lengths of No. 6 B & S gauge copper wire, having an exposure area of 1.53 square inches, and weighing very nearly 12 grams.

These anodes are eaten away at the rate of 0.23% per day per milliampere discharge. Therefore, at constant operation and discharge of one milliampere, half of the original weight (or 6 grams of copper) would be lost in 7.25 months.

From a maintainance viewpoint, it would, therefore, be in order to inspect and replace all Lapp coil anodes every six months. See Footnote IV.

Footnote IV

A test made on a 4" piece of No. 6 copper wire, soldered into a Lapp coil anode holder so that its exposure length was 3 1/2", showed the following weight loss at 25 ma. discharge rate:

Original Weight ------ 11.4336 grams (fitting not included)
Final Weight ------ 10.8354 grams
Weight Loss ------ 0.5982 grams in 22 hours or 5.70% weight loss per day per 25 milliamperes.

High conductivity water would allow greater discharge currents with reduced anode life, and since the cost of treated water is low in comparison with the cost of skilled maintainance labor and Lapp coil fittings, continuous use of low conductivity water becomes essential.

Temperature

Some thought has been given to regulating the water supply to the various electrical units based on temperature rise rather than on flow in G.P.M.

From a strictly economical viewpoint this method has merit because just a sufficient amount of water would be supplied each tube to hold it at a safe operating temperature. This method, however, has two definite disadvantages so far as the Radiation Laboratory is concerned:

(a) It would be necessary to obtain and then mount a number of indicating thermometers directly on the high voltage sockets of the various tubes, for that is the only point where temperature indications mean anything at all. The dials of these thermometers would all have to be readable at points remote from enclosed high voltage areas, and this would require extensive changes in the present installation setup.

(b) The water requirements would vary with temperature rises of the tubes, which in turn would depend upon the electrical loads placed upon the various units. Since these loads are subject to wide and continuous changes, the Water Technicians' Group would be required to spend a large portion of their time, in cooperation with the Electronics' Maintainance Personnel, altering and maintaining suitable water flow rates. Since failure of just one 893 tube, due to insufficient water flow, entails an expense of approximately $550 for the tube alone, this amount is sufficient to more than pay the entire water bill of the project for two months.

By setting the flow rates in G.P.M. high enough, as shown in Table IV and Table V, changes in operating loads can be safely ignored within reasonable limits without the risk of burning out expensive tubes and interrupting tank experiments.

Recommendations

In view of all of the foregoing data, the following recommendations are made:

1. Maintain water conductivities of 15 or under.
2. Maintain a low discharge rate (approximately 25 ma. on the silver anode equipment, until further checks are made).
3. Replace all electrolysis anodes every six months.
4. Maintain the rates of flow for the various tanks as shown in Tables IV and V.

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TABLE II

AVERAGE COST PER DAY FOR WATER, CHEMICALS AND LABOR

TO OBTAIN CONDUCTIVITIES WITHIN CERTAIN LIMITS

CONDUCTIVITIES GIVEN IN MICROMHOS PER CENTIMETER

For Conductivity Under 10		
Run No.	Avg. Cond.	Cost Per Day
144	7.5	$8.85
145	6.9	7.45
147	7.8	7.10
155	7.7	7.22
162	7.5	5.87
164	7.6	5.82
Totals	45.0	$42.31
Avg.	7.5	$7.05

For Conductivity Under 15		
Run No.	Avg. Cond.	Cost Per Day
144	7.5	$8.85
145	6.9	7.45
146	8.1	7.31
147	7.8	7.10
149	8.6	8.57
152	10.1	9.63
153	9.8	8.65
154	9.3	6.48
155	7.7	7.22
157	10.3	5.62
159	10.1	6.44
160	10.1	4.97
162	7.5	5.87
164	7.6	5.82
165	8.5	5.67
166	10.0	5.80
Totals	139.9	$111.45
Avg.	8.7	$6.95

For Conductivity Under 20		
Run No.	Avg. Cond.	Cost Per Day
144	7.5	$8.85
145	6.9	7.45
146	8.1	7.31
147	7.8	7.10
149	8.6	8.57
150	12.2	9.33
152	10.1	9.63
153	9.8	8.65
154	9.3	6.48
155	7.7	7.22
157	10.3	5.62
158	13.0	4.95
159	10.1	6.44
160	10.1	4.97
162	7.5	5.87
163	13.0	6.56
164	7.6	5.82
165	8.5	5.67
166	10.0	5.80
167	15.1	7.25
168	14.3	5.85
169	13.3	3.85
Totals	220.8	$149.24
Avg.	10.0	$6.80

For Conductivity Over 20		
Run No.	Avg. Cond.	Cost Per Day
151	14.0	$7.92
161	15.0	5.70
170	19.7	2.57
Totals	48.7	$16.19
Avg.	16.2	$5.40

Note: Run 148 not included, since its short run of 57.5 hours caused an abnormal cost per day.

[redacted]

TABLE III

LAPP COIL RESISTANCE AND LOSSES AT VARIOUS VOLTAGES AND WATER CONDUCTIVITIES

Water Conductivity in Micromhos	3/4" Lapp Coil (Type 8871)			1" Lapp Coil (Type 10290)		
	Coil Res. in Megonms	M.A. Losses Per Coil		Coil Res. in Megonms	M.A. Losses Per Coil	
		20 KV.	35 KV.		20 KV.	35 KV.
1	142	0.141	0.246	86.8	0.230	0.403
2	71	0.282	0.492	43.4	0.46	0.807
3	47.3	0.423	0.74	28.9	0.69	1.21
4	35.5	0.563	0.98	21.7	0.92	1.61
5	28.4	0.705	1.23	17.4	1.15	2.01
6	23.6	0.846	1.48	14.4	1.38	2.43
7	20.3	0.984	1.72	12.4	1.61	2.82
8	17.8	1.12	1.96	10.8	1.85	3.24
9	15.8	1.26	2.21	9.7	2.06	3.61
10	14.2	1.40	2.46	8.7	2.30	4.02
11	12.9	1.55	2.71	7.9	2.53	4.43
12	11.8	1.69	2.96	7.25	2.76	4.83
13	10.9	1.83	3.21	6.68	3.00	5.24
14	10.15	1.96	3.44	6.20	3.23	5.65
15	9.46	2.11	3.70	5.78	3.46	6.05
16	8.86	2.25	3.93	5.33	3.75	6.57
17	8.35	2.40	4.20	5.11	3.91	6.85
18	7.90	2.53	4.43	4.83	4.14	7.25
19	7.48	2.67	4.70	4.57	4.37	7.65
20	7.10	2.82	4.93	4.34	4.61	8.07
25	5.70	3.50	6.12	3.47	5.76	10.10
30	4.75	4.20	7.37	2.89	6.91	12.10
35	4.06	4.92	8.60	2.48	8.06	14.10
40	3.56	5.60	9.82	2.17	9.20	16.10
45	3.16	6.31	11.00	1.93	10.35	18.15
50	2.84	7.03	12.32	1.74	11.50	20.10
60	2.36	8.45	14.80	1.45	13.80	24.10
75	1.89	10.55	18.50	1.16	17.20	30.20
100	1.42	14.10	24.60	0.87	23.00	40.25
200	0.71	28.2	49.20	0.43	46.50	81.40
250	0.57	35.0	61.40	0.348	57.50	100.50

The Lapp coils referred to are No. 8871 - 3/4" twin-hole size, and No. 10290 - 1" twin-hole size, as listed on page 5 of Lapp Insulator Company's Bulletin No. 137.

TABLE I

ANALYSIS OF OPERATION DATA COVERING WATER CONDUCTIVITY REDUCTIONS IN THE 184" AREA

Run No.	Total Hours	Conductivity in Micromhos		No. of Gallons of Water Required for the Run				Cost of Water	Cost of Regen.	Total Cost of Run	Cost Per Day	Avg. Cond. of Run
		Low	High	City	System	Regen.	Total					
144	64.5	6.5	8.5	20060	14840	7650	42550	$8.54	$15.18	$23.72	$8.85	7.5
145	83.5	5.2	8.5	19920	23080	10250	53250	10.70	15.18	25.88	7.45	6.9
146	88.0	5.2	11.0	15170	29030	8100	52300	10.50	15.18	25.68	7.31	8.1
147	81.0	6.0	9.5	14040	21060	8700	43800	8.76	15.18	23.94	7.10	7.8
148	57.5	7.1	18.0	27690	2660	13750	44100	8.80	15.18	23.98	10.00	12.6
149	66.0	6.5	10.6	27470	7000	7230	41700	8.35	15.18	23.53	8.57	8.6
150	57.0	8.8	15.5	28110	1110	6540	35760	7.15	15.18	22.33	9.33	12.2
151	73.0	7.0	21.0	31990	6630	5940	44560	8.92	15.18	24.10	7.92	14
152	55.0	6.2	14.0	13780	11740	9250	34770	6.95	15.18	22.13	9.63	10.1
153	67.5	6.5	13.0	21030	16600	7900	45530	9.15	15.18	24.33	8.65	9.8
154	93.0	6.3	12.2	27280	15220	6550	49050	9.90	15.18	25.08	6.48	9.3
155	78.0	6.5	8.8	33750	None	7600	41350	8.27	15.18	23.45	7.22	7.7
156	26.5	6.8	8.5	11500	None	5600	17100	3.42	15.18	18.60	16.83	7.7
156A	37.0	6.5	15.2	14740	520	6360	21620	4.33	15.18	19.51	12.68	10.8
157	114	5.6	15.0	40170	9830	7300	57300	11.50	15.18	26.68	5.62	10.3
158	130.5	6.0	20.0	39120	12130	7270	58520	11.70	15.18	26.88	4.95	13.0
159	92.0	8.0	12.2	27800	10630	9100	47530	9.50	15.18	24.68	6.44	10.1
160	127.5	7.0	13.2	39480	8420	8200	56100	11.20	15.18	26.38	4.97	10.1
161	110	7.0	23.0	33710	12190	8700	54600	10.90	15.18	26.08	5.70	15
162	110	6.4	8.6	34580	15920	8300	58800	11.70	15.18	26.88	5.87	7.5
163	92	8.0	18.0	36420	3580	9900	49900	10.00	15.18	25.18	6.56	13.0
164	107	5.8	9.4	36410	9890	7400	53700	10.70	15.18	25.88	5.82	7.6
165	113	5.0	11.9	33330	14670	9900	57900	11.60	15.18	26.78	5.67	8.5
166	110	5.0	15	36010	13290	7900	57200	11.40	15.18	26.58	5.80	10.0
167	82.5	10.2	20	40500	None	8300	48800	9.80	15.18	24.98	7.25	15.1
168	95	9.0	19.5	39490	1110	6800	47400	9.50	13.68	23.18	5.85	14.3
169	153	9.1	17.5	46700	None	7600	54300	10.90	13.68	24.58	3.85	13.3
170	232	10.4	29.0	50100	None	5900	56000	11.20	13.68	24.88	2.57	19.7

Note: (a) Runs No. 156 and 156A were experimental only.

(b) Cost of regeneration includes a $10.00 charge for labor.