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THE PROBABLE SERVICE LIFE OF THE STEAM DISTRIBUTION SYSTEMS AT THE ARMY CENTRAL HEATING PLANTS, HAGERSVILLE, ONTARIO

by

J. P. LIVELY

MINERAL PROCESSING DIVISION

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THE PROBABLE SERVICE LIFE OF THE STEAM DISTRIBUTION SYSTEMS AT THE ARMY CENTRAL HEATING PLANTS, HAGERSVILLE, ONTARIO

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J. P. Lively*

SUMMARY OF RESULTS

Examination of corrosion testers and sections of pipe removed from the systems showed appreciable attack at only one of the areas studied, the corrosion rate here being 125 milligrams per square decimeter per day with pitting attack.

Carryover from the boilers is occurring, resulting in a wide range of condensate pH. Copper pick-up is appreciable in some areas and considerable iron oxide (rust) was found in the condensate.

It is concluded from this study that with normal maintenance, and satisfactory boiler plant operation including adequate chemical treatment the probable service life of the systems is at least ten years.

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* Senior Scientific Officer, Industrial Waters Section, Mineral Processing Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

INTRODUCTION

By letter dated January 19, 1962 (reference DND file HQ 5255-H5/2 TD 2008(D Wks)) the Department of National Defence (Army) requested that an examination be made to determine the probable service life of the steam distribution systems at the central heating plants at Hagersville, Ontario.

Some delay was caused because corrosion testers to ascertain the present rate of attack, if any, in these systems were not available. Subsequently, testers were fabricated and purchased locally and visits were made to London and Hagersville during the period February 27th to March 2nd, 1962.

The writer discussed the problem with Major D.C. McMillan, Officer Commanding, No. 1 Works Company, R.C.E. at London, Ontario since the Hagersville plants are under the control of this Works Company. Permission was obtained for the installation by the Hagersville plant personnel of corrosion testers and information was requested on replacement and maintenance costs at the Hagersville plants over the past 5 years. Subsequently (June 6/1962) information on some of these costs for the period 1958 to 1961 inclusive was received.

Ten condensate return-line corrosion testers were installed in the Hagersville systems during the period March 2nd to 8th, 1962 at locations chosen at the time of the visit in late February. These testers were removed from test on April 13, 1962 after only 36 to 42 days exposure. The short test period was necessary because with the approach of warmer weather the steam loads in the plants were decreasing to the point where condensate flows would not be adequate to give representative corrosion rates: also, a report on the system was urgently required. Such short tests do represent, however, more adverse conditions since stifling of corrosion by build-up of corrosion products does not usually become important in such a short time and, consequently the corrosion rate would be high.

Samples of the condensate, received weekly from the systems at each corrosion tester location, were checked mainly for copper and iron pick-up and pH. Boiler water samples as well as samples from the main steam headers were also analysed to check boiler water treatment control and for possible carry-over of boiler water.

Pipe sections removed when the corrosion testers were installed and later from the main return lines, were examined for corrosive attack. Maximum thinning of the pipe was used to calculate the probable service life of these condensate return lines.

METHODS, APPARATUS AND PROCEDURE

Chemical and physical tests of boiler water and condensate samples are those currently used in the Industrial Waters Section's laboratory.

Mines Branch Report IR 59-97 describes the preparation, installation, evaluation, and limitations of the corrosion testers used to determine the corrosion rates; it also summarizes the classification of corrosion rates used in this study.

Measurements of maximum thinning or deepest pitting of tester rings and removed pipe sections were made with a micrometer. On some sections of pipe measurements were made first, after scraping and brush cleaning and, again after cleaning with inhibited hydrochloric acid. No significant difference was found when either method was used. On some larger pipe such as the 3 inch main return lines the pipe was cut into halves to facilitate measurement and examination.

RESULTS AND DISCUSSION

Table 1 combines the results obtained with the corrosion testers and the chemical analyses of the condensate collected at each tester location. Table 2 reports the examination of pipe sections removed from the systems during the period of this study. Table 3 summarizes the data obtained from No. 1 Works Company, R.C.E. on the approximate cost of maintenance and replacements at these plants from 1958 to 1961 inclusive. Table 4 tabulates the chemical analyses of boiler water and steam header samples collected at the heating plants during the test period.

Only the one corrosion tester No. 33, (Table 1) located in the condensate return line at No. 4 hangar showed a corrosion rate greater than 100 milligrams per square decimeter per day; such a corrosion rate is classed as one that "must be considered or could be serious". The corrosion rates at all other locations studied (Table 1) are well below 100 milligrams per square decimeter per day. It is also noted (Table 1) that the condensate samples collected at tester No. 33 location have a higher pH than condensate at other locations. This is no doubt due to carryover because some hydroxide alkalinity is present; therefore, concentration cells may be the cause of the pitting attack at this location. The pipe section removed from the return-pump discharge line in hangar No. 4 (Table 2) when tester No. 33 was installed was, however, in good condition showing only general corrosion but a section of 3 inch main return line (Table 2) between hangars 3 and 4 was pitted and in poor condition.

Some condensate pH values at tester locations are high due to the carryover of boiler water into the system (see Table 4- steam header samples); others are low due to carbon dioxide forming carbonic acid in the condensate (Table 1). High copper was found only in samples collected at unit heaters, (Table 1) indicating some dissolution of the metal at these locations. The total iron content varied from 0.1 to 110 parts per million as Fe. This iron was mainly rust some of which could have been loosened from the piping at the time of corrosion tester installation.

The probable service life calculated in Table 2 is generally greater than 10 years. In all cases the thickness of standard wall or schedule 40 steel pipe was used as the original thickness of the pipe in the calculation of probable service life. However, it is emphasized that only a limited number of random pipe sections were examined and that corrosion rates were determined at only a limited number of locations. A commitment to complete this report for August, 1962 and the urgency of other matters prevented a more thorough investigation at these plants.

Maintenance costs, relatively low in 1958, 1959 and 1961, were much higher in 1960 (Table 3) due mainly to replacement of unit heaters and repairs to heat exchangers. However, it is noted that labour costs are roughly the same each year ($1,000 to $1,200), apparently the work on heat exchangers and unit heaters in 1961 having been contracted.

TABLE I

Corrosion Tester Results							Chemical Analyses of Condensate (In parts per million)										
Tester number	Tester location	Tester distance from C.H.P. (yds)	Corrosion rate $mg/dm^2/day$	Average penetration metal (inch)	Maximum penetration metal (inch)	Form of corrosion	Date sampled	Location sampled	pH	Phenolphthalein alk. ($CaCO_3$)	Methyl orange alk. ($CaCO_3$)	Sodium (Na)	Total hardness ($CaCO_3$)	Copper (Cu)	Dissolved iron (Fe)	Total iron (Fe)	Specific conductance micromhos (18°C)
5	bldg. No. 8 return pump discharge No. 1 plant	100	6	<0.001	<0.001	–	27-3-62	at tester	7.9	0	4	0.2	0.4	0.00	0.01	0.10	3.7
							3-4-62	" "	7.1	0	2	0.0	0.6	0.00	0.04	0.23	2.4
							10-4-62	" "	7.6	0	3	0.1	0.3	0.00	<0.01	0.19	4.3
8	bldg. No. 9 return pump discharge No. 1 plant	100	12	<0.001	<0.001	–	20-3-62	at tester	6.2	0	4	0.1	0.8	0.12	0.03	0.28	3.6
							27-3-62	" "	7.4	0	3	0.0	1.2	0.06	0.00	0.20	2.2
							3-4-62	" "	6.6	0	2	0.0	0.3	0.08	0.08	1.3	2.6
							10-4-62	" "	7.5	0	3	0.0	0.8	0.00	0.02	0.15	4.4
47	bldg. No. 6 drip line from unit heater No. 1 plant	150	15	<0.001	<0.001	–	20-3-62	at tester	8.2	0	12	4.1	1.4			2.4	21.8
							27-3-62	" "	7.4	0	7	0.5	2.0	1.7	0.06	0.95	11.2
							3-4-62	" "	6.3	0	5	0.6	1.4	0.24	0.18	1.7	10.8
							10-4-62	" "	7.4	0	6	0.5	2.2	0.22	0.11	2.4	9.7
49	bldg. No. 4 return pump discharge No. 1 plant	650	6	<0.001	<0.001	–	20-3-62	at tester bldgs. 4 & 41	6.3	0	4	0.0	1.2	0.02	0.02	0.24	5.3
							27-3-62		7.3	0	4	0.0	0.3	0.00	<0.01	0.85	2.9
							3-4-62		7.2	0	3	0.0	0.4	0.00	0.03	0.12	2.2
							10-4-62		8.1	0	4	0.0	0.4	0.00	0.02	0.15	4.9
32	hangar No. 2 drip line from unit heater No. 2 plant	350	29	<0.001	0.002	–	20-3-62	at tester	6.0	0	12	1.3	4.5	4.2	0.09	110	
							27-3-62	" "	7.5	0	8	0.9	3.2	0.7	–	65	17.3
							3-4-62	" "	7.3	0	6	0.5	4.0	–	–	58	12.7
							10-4-62	" "	6.3	0	4	0.3	3.2	–	–	51	11.3
33	hangar No. 4* return pump discharge No. 2 plant	50	125	0.003	0.008	pitting	27-3-62	at tester	7.3	0	7	3.9	1.8	<0.01	0.10	0.90	22.8
							3-4-62	" "	10.6	70	110	135	–	<0.01	–	3.1	–
							10-4-62	" "	11.3	180	245	340	–	–	–	9.0	–
38	hangar No. 1 steam drip line No. 2 plant	400	7	<0.001	0.001	–	27-3-62	at tester	7.4	0	4	0.0	1.2	0.05	0.11	1.8	4.0
							3-4-62	" "	7.3	0	5	0.6	2.4	0.00	0.14	1.5	7.8
							10-4-62	" "	7.5	0	2	0.0	1.2	<0.01	0.04	0.3	3.0
39	hangar No. 3 return line before tank No. 2 plant	50	38	0.003	0.004	channeling	27-3-62	at tester	6.8	0	4	0.0	0.8	0.01	0.00	2.3	3.7
							3-4-62	" "	7.8	0	3	0.0	0.8	0.00	0.03	16.6	3.5
							10-4-62	" "	6.3	0	2	0.0	1.0	0.02	0.02	4.1	3.4
45	hangar No. 1 return pump discharge No. 2 plant	450	13	<0.001	0.001	–	27-3-62	at tester	7.1	0	3	0.0	0.6	0.06	<0.01	5.0	3.0
							3-4-62	" "	7.8	0	4	0.3	2.4	0.08	0.02	0.12	5.0
							10-4-62	" "	8.3	0	2	0.0	0.8	0.02	0.01	0.81	5.6
50	hangar No. 5 return pump discharge No. 2 plant	100	40	0.001	0.002	pitting	20-3-62	at tester	6.1	0	4	0.0	1.2	0.03	0.05	0.26	3.1
							27-3-62	" "	6.2	0	3	0.0	0.8	0.02	0.08	0.17	3.4
							3-4-62	" "	7.3	0	4	0.0	1.4	0.02	0.08	0.47	4.5
							10-4-62	" "	6.0	0	3	0.1	0.6	0.00	0.02	0.21	3.8

* Handles all the returns from hangars 4, 5, 6 & 7

TABLE 2

Observations and Micrometer Measurements of Pipe Specimens

Bldg. #	Plant No.	Location	Tester No.	Installed	Pipe size (inch)	Initial thickness (inch)	Measured thickness (inch)	Form of corrosion	Oxide coating	Loss in thickness (inch)	Average life expectancy (years)	Condition of pipe
8	1	return pump discharge	5	1958	1 1/4	0.140	0.136	shallow pits	brick red	0.004	>10	good
9	1	" " "	8	1959	1 1/4	0.140	0.120	scattered broad pits	" "	0.020	>10	good
6	1	line from unit heater	47	1942	3/4	0.113	0.12	general	red and black	0.010	>10	very good
4	1	return pump discharge	49	1959	1 1/4	0.140	0.130	general	dark brown	0.010	>10	good
between bldgs. # 8 & 11	1	main return line		1957	2	0.154	0.144	shallow broad pits	red-brown	0.010	>10	very good
at plant	1	main return line		1958	3	0.216	0.205	general	red	0.011	>10	very good
between bldgs. # 31 & 34	1	main return line		1950	1 1/4	0.140	0.125	general	red	0.015	>10	very good
hangar #2	2	discharge from unit heater	32	1942	3/4	0.113	0.100	general	brick red	0.013	>10	good
hangar #4	2	return pump discharge	33	1957	1 1/4	0.140	0.130	general	brown & red	0.010	>10	good
hangar #1	2	steam drip line	38	1942	3/4	0.113	0.100	general	brick red	0.013	>10	good
hangar #3	2	return line	59	1954	1 1/4	0.140	0.130	broad pitting	red & brown	0.010	>10	good
hangar #1	2	return pump discharge	45	1957	1 1/4	0.140	0.135	general	light brown	0.005	>10	good
hangar #5	2	return pump discharge	50	1954	1 1/4	0.140	0.130	shallow pits	brick red	0.010	>10	good
between hangars # 3 & 4	2	main return line		1950	3	0.216	0.078	pitting	red-brown	0.138	>5	poor
hangar #3	2	main return line		1950	3	0.216	0.180	shallow pits	brown	0.036	>5	good

TABLE 3

Four Year Maintenance and Replacement Costs

Year	1958		1959		1960		1961	
	Ft.	Per cent of total cost	Ft.	Per cent of total cost	Ft.	Per cent of total cost	Ft.	Per cent of total cost
Black steel pipe 1/3 inch					44	0.04		
" " " 3/4 "	60	0.73	44	0.3	44	0.05		
" " " 1 "	18	0.26			125	0.23		
" " " 1 1/4 "	64	1.0	126	1.9	88	0.22	22	0.4
" " " 1 1/2 "					44	0.12		
" " " 2			66	1.7				
" " " 2 1/2 "					44	0.24		
" " " 3 "	301	15.4	206	10.	20	0.15	100	5.6
" " " 4 "	82	4.9					110	8.1
Total replaced pipe (ft)	525	22.3	442	13.9	409	1.1	232	14.1
Traps, parts, strainers, etc.		13.9		10.7		3.6		11.8
Valves, parts, etc.		4.5		2.6		1.3		11.1
Miscellaneous fittings, black iron, elbows, bushings, nipples, etc.		3.8		4.6		1.1		4.2
Repairs to condensate pumps						1.9		
Repairs to bucket traps, fittings						1.5		
Repairs to heat exchanger hangar #6 and #7, replace coils, traps.						58.1		
Replacement of 7 unit heater cores, traps in hangars 3,4,5.						20.8		
Welding of return piping				5.2				
Repairs to steam lines						0.2		
Labour		55.6		63.0		10.6		58.7
Total cost (dollars)	$1799(100%)		$1905(100%)		$11,365(100%)		$1703(100%)	
Total cost 4 years (dollars)			$16,772.07					

TABLE 4

Chemical Analyses of Samples from the Central Heating Plants
(In parts per million)

Plant number	Location sampled	Date sampled	pH	Phenolphthalein alk. ($CaCO_3$) "P"	Methyl orange alk. ($CaCO_3$) "M"	2 P - M ($CaCO_3$) "OH"	Phosphate (PO_4)	Sulfite (SO_3)	Specific conductance micromhos (18°C)	Total dissolved solids	Total solids	Suspended solids	Sodium (Na)	Total hardness ($CaCO_3$)	Copper (Cu)	Dissolved iron (Fe)	Total iron (Fe)
1	boiler #2	20-3-62	-	640	755	525	5	6	4355	3969	4469	500	-	-	-	-	17.0
	"	27-3-62	-	715	890	540	5	38	4275	4602	4682	80	-	-	-	-	19.0
	boiler #1	3-4-62	-	640	815	465	15	0	4845	6216	6383	167	-	-	-	-	24.0
	"	10-4-62	-	555	660	450	5-10	10	4410	4576	5716	1140	-	-	-	-	17
	steam header	20-3-62	11.0	65	100	30	5	4	1345	-	-	-	-	-	-	-	29
	" "	27-3-62	9.7	8	24	0	-	-	139	-	-	-	29	6.6	0.04	-	6
		3-4-62	11.1	115	140	90	-	-	1065	-	-	-	280	4.8	-	-	13
	" "	10-4-62	10.2	20	50	0	-	-	436	-	-	-	94	9.3	-	-	17
2	boiler #3	20-3-62	-	300	385	215	5	7	1280	1061	1094	33	-	-	-	-	4.5
	boiler #2	27-3-62	-	460	570	350	5	9	2160	2001	2368	367	-	-	-	-	14
	boiler #1	3-4-62	-	440	625	255	35	0	2475	2308	2601	293	-	-	-	-	23
	boiler #1	10-4-62	-	425	605	245	25	49	2545	2541	2588	47	-	-	-	-	16
	steam header	20-3-62	-	310	420	200	15	6	1495	-	-	-	-	-	-	-	31
	" "	27-3-62	-	400	460	340	-	-	1725	-	-	-	524	-	-	-	26
	" "	3-4-62	-	430	555	305	-	-	2170	-	-	-	750	-	-	-	13
	" "	10-4-62	-	365	495	235	-	-	2120	-	-	-	680	-	-	-	16

CONCLUSIONS

Carryover from the boilers at the Hagersville plants is now resulting in a highly alkaline condensate in certain areas; this may give some protection to the piping but it could also lead to oxygen concentration cells causing the pitting attack noted. Oxygen may enter the systems with the steam if there is insufficient sulfite residual maintained in the boilers and at vents on condensate return tanks; pitting attack can result from this dissolved oxygen.

Copper plating out on the condensate pipes can also lead to pitting attack and channelling may occur due to the acid condensate formed by solution of carbon dioxide.

While some such attack is evidently occurring at certain locations, it is considered that based on the study here reported the Hagersville steam distribution systems in general are in fairly good condition. It is expected that with satisfactory boiler plant operation and adequate treatment to reduce present carryover and to prevent oxygen and acid condensate attack, these systems should give at least 10 years' service with no more than normal maintenance. This life is expected if future attack is assumed to be uniform and continuous. However should the rate be markedly accelerated and severe pitting occur at certain points some failures may occur at an earlier date. One of the points is the 3" main return line between hangars 3 and 4. Under present conditions its life is estimated at only about 5 years and it may fail earlier. However this is about 180 feet of pipe and the cost of its replacement would be relatively small and probably be covered by annual maintenance. It is expected that with more careful control of oxygen content and carryover attack at this point can be decreased.