TABLE I—CONDENSERS OF THE TALLEYRAND GENERATING STATION

Unit No.	Date started	Make	Surface area, sq ft	Area, sq ft per kw	Pump capacity gpm 1 pump	2 pumps	Number of tubes	Tube length, ft	Water velocity in tubes, fpm 1 pump Inlet pass	Outlet pass	2 pumps Inlet pass	Outlet pass
1	3-21	Wheeler	22,500	2.25	12,200	19,170	4156	20¼	2.67	3.20	4.20	5.03
4	6-18	Wheeler	11,000	2.75	12,200	......	2385	18¼	4.67	5.56	....	....
5	9-24	Wheeler	22,500	1.80	15,000	23,550	4156	20¼	3.28	3.94	5.17	6.20
6	1-29	Wheeler	39,500	1.58	28,000	44,000	6874	22¼	3.89	4.20	6.10	6.60
7	3-39	Westinghouse	46,000	1.23	33,000	51,000	7950	22¼	4.29	4.32	6.43	6.47

All tubes are 1-in. diameter, No. 18 BWG

isms and industrial waste deposits are our problem. Microscopic examination of river water and slime shows the mixture containing fungi, an abundance of Crenothrix forms, dead mollusks, bacteria, bacterial zoogloea, filamentous algae, diatoms and Protozoa. A culture examination reveals large liquid bacteria colonies composed of small coccoid capsulated, gas-producing forms.

Checking Operation. Changing conditions led to early efforts to evaluate over-all heat transfer coefficients that we could apply to practical operation. In 1931 the first bogeys were established for expected operating vacuums for given loads, circulating-water quantities and temperatures, from the condenser contract guarantees. These then gave a basis for evaluating loss from condenser fouling, Fig. 1.

In 1936 we developed the cleanliness factor derived from the over-all heat-transfer coefficient. In making the formula an adequate working tool, effect of water-velocity changes through the tubes and of temperature were studied. Actual experimental data taken in 1937 on each condenser established the necessary correction factors.

Construction of unit No. 7 took most of 1938 and 39. In July 1940 the relation between heat transfer and water velocity was established. Cleanliness factor became a performance guide and practical working tool. By June 1941 all computations were standardized. The 100% cleanliness factor corresponds now to a corrected heat-transfer coefficient of 360 Btu per sq ft per hr per deg F. Much work can be eliminated in adopting this method if clean new tubes can be used to establish the bogey value of the coefficient.

Cleaning Methods. Cleanliness was not a serious problem immediately following installation of No. 6 unit. Pollution was relatively small and electric load was one-fourth what it is today. When condensers did foul with slime, moss and mussels it was no particular trouble or expense to shut down the unit for cleaning. Steam costs were about 15c per 1000 lb with fuel oil at 68c per bbl. Loss in vacuum was about $3.50 per day for each 1/10th inch excess backpressure on No. 6.

Rubber plugs, blown through with compressed air, scraped off slime from tube interiors. Condenser cleaning cost about $60 per unit; a rough method prorating condenser cost over the number of service days was used to judge when to clean.

Throughout 1932-4 the increasingly ineffective cleaning by rubber plugs was carried on. Men worked hours in a disease-laden atmosphere shooting the plugs through tubes. Fig. 3 shows this method left appreciable amounts of fouling in tubes. Dissatisfaction led to searching for more effective methods.

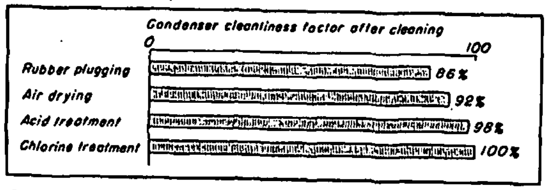
Observation of condensers, opened to atmosphere two to three weeks, showed mud and slime curling and cracking off the surface as they dried. When placed back in service the water washed out the dried scale and the vacuum was improved.

To speed nature's cleaning method, experimentation with air drying was started on No. 1 in July 1934. Two electric heaters of 3 kw each were placed at the discharge of a small 500-cfm ventilating blower. It took 147 hr to complete the job. Air leaving the condenser barely reached 100 F. Wet and dry bulb reading of inlet and outlet air showed 2520 lb moisture had been removed.

As in all development work, valuable and useful information was gained from otherwise unsuccessful experiments. Improvement in equipment and method was rapid. Air drying was standardized in 1935 with three simple rules (1) a fast method of heating must be available (2) free water left in the tubes because of poor drainage must be blown out with compressed air (3) air supply must be adequate.

Live steam was injected into the steam side of the condenser with a limiting temperature of 145 F set on the exhaust casing. Tubes in No. 5 and 6 have to be blown out, while No. 7 drains well. Four 1500-cfm fans were used. Total time out for the unit was reduced to 12 hr; Fig. 2 shows typical air-drying data for a drying-out period.

Air drying was superior to the rubber-plug method because it removed more deposit, was equally fast, caused less sickness and reduced the heavy labor involved. It still had the disadvantage of reducing machine availability; but the chief handicap was the same as all mechanical methods, it



3 Chlorination of condensers cleans tubes entirely after completion of each treatment. Regardless of cleaning method fouling increases progressively with use

TABLE II—ST. JOHNS RIVER WATER ANALYSIS VARIATION FOR THREE DIFFERENT YEARS

Water constituent	November 1929	July 24, 1940 Sample 1	July 24, 1940 Sample 2	December 1946
Total solids	1079.4	5590.0	7867.0	2672.7
Suspended solids	......	......	......	10.3
Total hardness as $CaCO_3$	284.0	1028.0	1302.0	444.6
Calcium as $CaCO_3$	111.0	247.0	282.0	164.2
Magnesium as $CaCO_3$	178.0	781.0	1020.0	280.4
Phenolphthalein alkalinity as $CaCO_3$	0.0	64.0	12.0	0.0
Methyl orange alkalinity as $CaCO_3$	59.0	144.0	71.0	53.0
Free carbon dioxide as $CaCO_3$	7.0	......	......	0.0
Chlorides as NaCl	942.0	3866.0	5113.0	2154.6
Sulphates as Na_2SO_4	181.0	761.0	942.0	287.3
Silica as SiO_2	14.0	......	......	8.6
Alumina as Al_2O_3	R_2O_3-3.4	0.0	0.0	Trace
Iron as Fe		0.2	0.2	1.0
Phosphate as PO_4	......	......	......	0.0
Hydrogen ion (pH)	6.8	7.1	7.3	7.3
Chlorine demand taken in 1933 = 3 ppm	......	......	......	......
Chlorine demand taken in 1947 = 11 ppm	......	......	......	......

TABLE III—ECONOMICS OF CONDENSER CHLORINATION TALLEYRAND GENERATING STATION

	No chlorine used for year ending July 8, 1946	Intermittent chlorination, year ending July 8, 1947
No. 7 condenser costs		
Excess steam cost due to fouling	$16,157.76	$2,517.74
Chlorine cost	0	2,197.64
Condenser loss due to fouling	$16,157.76	$4,715.38
Summary of savings:		
No. 7 condenser, steam saving		$11,442.38
No. 6 condenser, steam saving (estimated at 50% No. 7)		5,721.16
Cleaning labor		no credit
Sickness and accident		no credit
Better operating conditions		no credit
High machine availability		no credit
Total saving		$17,163.54

corrected the effect of slime formation but did not eliminate its cause.

Increased Fouling. During 1939 a paper mill was placed in operation adjacent to the station. The air-drying method was becoming less effective. Tube interiors of No. 7 condenser had a coating of greyish-green deposit, somewhat flaky in appearance. Analysis indicated tube corrosion with formation of water-insoluble carbonates of copper and zinc; 73.8% of the material was basic copper carbonate. Removing the coating, we discovered a large part of the tube surface was pitted, although the pits were not deep. Paper-mill waste water discharged to the river is highly alkaline, sample 2 in Table II.

A different cleaning method was tried, circulating a 1% hydrochloric acid solution through the water side of the condenser. Preliminary experiments showed no appreciable metal loss from copper alloy tubes or cast-iron water boxes in contact with this strength acid solution for periods of 1 hr. Results were excellent, as in Fig. 3.

This cleaning method requires blocking off the condenser discharge opening. It also proved expensive, needing 34 carboys of acid at $5 each, which made it undesirable for normal practice.

Since hydrochloric acid proved so effective in removing copper carbonate, chlorination was considered. Chlorine in water forms hypochlorus acid, which kills slime-producing organisms and also reacts with the inorganic material. Realizing that chlorine applications differ with plant characteristics, we put an experimental pilot plant in operation June 1941. Results exceeded expectations; a net saving of $2026 was made the first operating year compared to the previous year. These savings were based on a chlorine cost of 9¢ per lb. Fig. 1 shows the improvement for the trial period, June 1941 to June 1943.

Experimentation proving successful purchase of a commercial installation was approved, but war shortages delayed it till after the war. During 1944-5 all plant equipment was on the line most of the time. The pilot-plant chlorinator, capable of handling only 4 lb per min of chlorine, failed to keep up with the job of supplying chlorine demands of 10 to 15 ppm, especially in the face of increased circulating-water utilization.

War took its toll of skilled operators, imposing greater burdens on those left. The pilot plant was a war casualty. Cleanliness factor fell to an average of 38% the first six months of 1946, Fig. 1. Steadily increasing oil costs helped raise the condenser excess operating cost to $1450 a month.

Installation of two Wallace and Tiernan 6000-lb-per-day chlorinators was completed June 1946, and believed to be the largest setup of its kind in Florida. Housed in a separate building outside the plant, a 6-in. rubber-lined header carries the chlorine solution into the plant. Four- and 5-in. branch headers, with water-operated shutoff valves controlled electrically from the chlorine house, carry the solution to the point of application. Condensers No. 5, 6 and 7 can be treated simultaneously or separately. Every effort was made to install a flexible system of sufficient capacity to insure adequate chlorination, whatever future demands might be. Two treatments are being made each day to each unit in service.

Recently, failure of several sections of rubber-lined header because of poor fabrication led us to air-dry No. 5 unit. A return to this method hospitalized two of eight workmen, and two others suffered disturbing illness. Stream pollution is continually increasing.

It is not often that equipment purchased satisfies every consideration the way the chlorinating equipment does at Talleyrand. As an investment the installation will pay for itself in two years. Table III shows the saving. From an operation standpoint, chlorine supply is ample when and where needed. Because of the local corrosive water supply, maintenance was the least satisfactory factor, requiring 300 man-hours the first year.

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