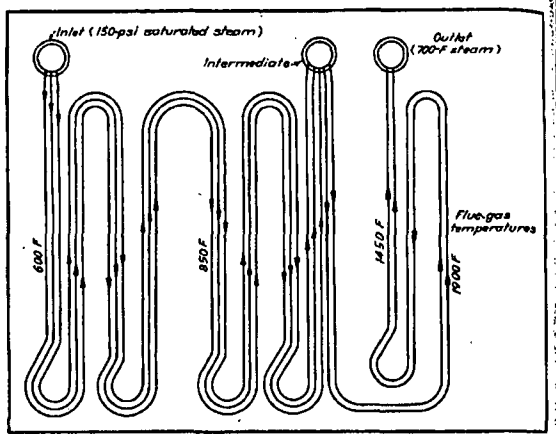
than average when the tubes were new, and is probably the result of removing some of the mill scale during cleaning operations.

The hydrogen-zeolite water softener at the plant of Southern California Gas Co requires approximately 6½ lb of 93% H_2SO_4 per thousand gal of water treated. At a cost of 1½¢ per lb of H_2SO_4 this represents a chemical cost of 10¢ per thousand gal, or a total acid cost of 80¢ for one cleaning. Considering equipment cost, depreciation, taxes, operation, etc, hydrogen-zeolite treated water costs 20¢ per thousand gal. On the basis of 8000 gal of water used, cleaning costs $1.60, plus the labor of piping to and from the superheater.

Use on Boilers. The method proved so successful that the company decided to try the same procedure on several B&W 70,000-lb-per-hr 150-psi integral-type saturated-temperature boilers.

No. 1 boiler in No. 2 plant was opened after 10 months' service, during which time it had not been supplied continuously with properly softened water. Scale in the tubes appeared to be a mixture of hard sulphate and soft carbonate, and was about ⅛ in. thick.

Hydrogen-zeolite treated water was introduced through the mud-drum blowoff line and was discharged from the top of the steam drum without removing internal fittings, as on p 99. Water flow was continued for 12 hr at 22 gpm, or until the pH of the discharge was about 4.4. After cleaning, the boiler was drained and rinsed with water from the sodium-zeolite softener, which has an alkalinity of 193 ppm, Table I. Other units in the plant have been cleaned the same way, and the method is now standardized as the most practical, economical way to clean the boilers and accessories in this plant.



CLEANING HAIRPIN-TYPE SUPERHEATERS with distilled water is both slow and costly by the usual practice. Effluent from ion exchanger does a good job

External Cleaning. Hydrogen-zeolite water is also useful for externally cleaning boiler headers where mineral solids accumulate at handholes. These solids, of the same constituency as those in the concentrated boiler water, are chiefly sodium salts deposited where leaks occur through gasketed handhole openings. The deposits, containing considerable alkali, are quickly removed with hydrogen-zeolite water. After cleaning, the boiler header is rinsed externally with city water from a pressure hose.

Following the successful experience of Southern California Gas, the City of Los Angeles used the same method for washing out their 500,000-lb-per-hr 1200-psi boiler at Harbor Steam Plant. This unit, regularly fed with condensate from surface condensers and evaporator makeup, was filled with water from a hydrogen-zeolite softener and allowed to stand overnight. It was then drained and rinsed with city water. The dilute acid treatment dissolved some solids while the remainder were disintegrated and easily removed by rinsing with water under pressure from a hose.

Southern California Gas Co has washed a total of 9 boilers with hydrogen-zeolite softened water. Of these, 7 were cleaned with cold water and 2 were treated with partly heated water. For heating, a small pilot fire was applied, sufficient to form a slight steam pressure. Heating caused a more rapid reaction and should be especially helpful when boilers are badly scaled. No detrimental effect was noticeable on the boiler metal regardless of whether cleaning solution was at room temperature or heated slightly.

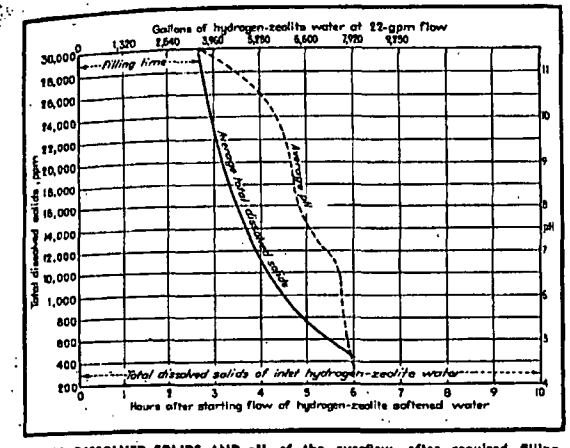
TABLE I—EFFLUENT FROM SODIUM AND HYDROGEN SOFTENERS

Constituents	Raw water	Effluent water—NaZ	Effluent water—HZ	Mixture—31% HZ 69% NaZ
Total Hardness	260	3	3	3
Calcium	163	2	2	2
Magnesium	98	1	1	1
Sodium	98	355	17	182
Hydrogen	0	0	145	0
Total Cations	358	358	165	185
Bicarbonate	169	169	0	20
Carbonate	24	24	0	0
Chloride	47	47	47	47
Sulphate	118	118	118	118
Total Anions	358	358	165	185
Carbon dioxide	0	0	160	143
pH	8.4	10	3.8	5.5

TABLE II—EFFLUENT FROM SUPERHEATER TUBE DURING FIRST CLEANING WITH WATER FROM THE HYDROGEN-ZEOLITE SOFTENER

Characteristics	Hours after starting wash 16	24	41	45
Total solids calculated, ppm	17,000	1,870	750	438
Conductivity in micromhos	20,000	2,200	865	525
M O Alkalinity, ppm	1,682	104	104	1
Silica, SiO_2, ppm	40	36	18	21
Phosphate PO_4, ppm	40	13	0	0
pH	10.7	6.3	6.3	4.4

Note: There were interruptions at the start so that it was 16 hr before the boiler was filled to overflowing. Frequent tests were made but only these few recorded.



TOTAL DISSOLVED SOLIDS AND pH of the overflow, after required filling time of 2½ hr, continues to fall at fairly uniform rate until cleaning stops

Test coupons, 1 by 4 in., cut from boiler tubing, were sandblasted to remove rust, scale or other coating that would protect the metal from exposure to acid solution. Half the coupons were stressed by bending one end 90 deg. There was no substantial difference in the rates of corrosion regardless of whether the coupons were stressed or not. All averages of results in Tables III and IV were obtained from 50% stressed and 50% unstressed coupons. The free mineral acidity of the treated water was substantially as reported under *column 3 of Table I*, or about 145 ppm in terms of calcium carbonate. The inhibited acid was a 5% hydrochloric (HCl) solution using 0.2 cc of inhibitor for each 100 cc of acid.

Hydrochloric acid has been more effective (POWER Sept, Oct, 1946) than sulphuric for cleaning boilers because the end product, calcium chloride, is highly soluble, whereas the end product of sulphuric acid with calcium carbonate, calcium sulphate, is relatively insoluble. Formation of calcium sulphate interferes with the penetration of sulphuric acid solution through the scale.

When using a dilute acid, comparable in strength with that from a hydrogen-zeolite softener, hydrochloric or sulphuric acids are equally satisfactory. Sulphates in the raw water and, therefore, in the effluent from a softener are not high enough to produce an insoluble product of calcium sulphate.

Tables III and IV show comparative rates of corrosion of the test coupons when using stationary hydrogen-zeolite treated water as compared with stationary 5% inhibited acid at room temperature. Comparing columns 1 and 2 of Table III shows that the rate of corrosion with hydrogen-zeolite water is only about 50% of that with 5% inhibited acid.

Heating Test Samples. If the hydrogen-zeolite treated water is heated to 200 F, however, its rate of corrosion is then about twice that of 5% inhibited acid at 72 F. Corrosion rate of the inhibited acid at 200 F was only half its rate at 72 F. One explanation for this peculiar behavior is that the higher temperature accelerated the inhibitor's effectiveness. Results here do not agree with practical experience in cleaning boilers with inhibited acid because temperatures of 200 F have been reported to cause substantial corrosion. *Instructions for cleaning boilers with inhibited acid normally call for a maximum temperature of 160 F.*

Because laboratory tests showed a rate of corrosion with hydrogen-zeolite water about four times as great at 200 F as at 72 F and, considering that the boiler deposits reacted readily with cold dilute acid, it was decided to follow a regular procedure of using hydrogen-zeolite water at room temperature for boiler cleaning.

Subjecting a boiler to reaction with hydrogen-zeolite water for a 12-hr period does not imply that the acidity in contact with the metal always has a pH of about 2.5. The dilute acidity is immediately neutralized as it reacts with the calcium or magnesium carbonate so that, for a greater part of the time, water leaving the boiler is definitely on the alkaline side. It has been found practicable to stop cleaning when water leaving the boiler is at about pH 4.4.

(*Continued on page* 140)

TABLE III—RESULTS OF TESTS 1 AND 2

Stationary water, temperature 72 F. Hydrogen-zeolite treated water 0.015% vs inhibited acid.

	Avg loss in 24 hr for 18 tests—Hydrogen-zeolite water	Avg loss in 24 hr for 18 tests—5% inhibited acid
Weight, lb per sq ft per day	0.0034	0.0064
Thickness in inches per day	0.00041	0.00077
% in wall thickness per day	0.016	0.30

TABLE IV—RESULTS OF TESTS 3 AND 4

Stationary water, temperature 200 F. Hydrogen-zeolite treated water 0.015% vs 5% inhibited acid.

	Avg loss in 24 hr for 4 tests—Hydrogen-zeolite water	Avg loss in 24 hr for 4 tests—5% inhibited acid
Weight, lb per sq ft per day	0.0136	0.0029
Thickness in inches per day	0.00164	0.00035
% in wall thickness per day	0.187	0.023