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SCALE FORMATION
IN
WATER HEATERS
AND
METHODS OF PREVENTION

By
J. M. KRAPPE
Associate in Gas Engineering

PURDUE UNIVERSITY
Lafayette, Indiana
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1. Bulletin No. 38. Development of a Direct-Contact Water Heater, by L. A. Scipio. (Vol. XV, No. 5, September, 1931.)

2. Bulletin No. 41. Welding with Manufactured, Natural, and Mixed Gas, by H. H. Lurie. (Vol. XVI, No. 4, July, 1932.)

3. Bulletin No. 48. Investigation of the Use of Gaseous Fuels in Warm-Air Furnaces, by R. B. Leckie. (Vol. XVIII, No. 6, November, 1934.)

4. Bulletin No. 58. Automatic Gas-Fired Storage-Type Water Heaters, by J. M. Krappe. (Vol. XXI, No. 5, September, 1937.) *Out of print.*

5. Bulletin No. 64. Improved Hot-Water Supply Piping, by J. M. Krappe. (Vol. XXIII, No. 1, January, 1938.)

6. Bulletin No. 74. Scale Formation in Water Heaters and Methods of Prevention, by J. M. Krappe. (Vol. XXIV, No. 3a, June, 1940.)

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PURDUE UNIVERSITY
CHEMICAL ENGINEERING DIVISION
ENGINEERING EXPERIMENT STATION

Dean A. A. Potter, Director
Engineering Experiment Station

Dear Sir:

The enclosed report entitled "Scale Formation in Water Heaters and Methods of Prevention" may be considered as an extension of the research on the application of gas fuel to water heating. In view of the wider use of high water temperatures especially for service in commercial kitchens, it is felt that this work will be particularly timely and useful. Furthermore, the increased use of the hot water spray for rinsing dishes in the home will result in demand for higher water temperatures.

The material submitted is a summary of results of accelerated scale formation tests performed on gas-fired water heaters at various times during the last two years. It also includes a summary of field experiences with hard-water scale formation and suggested designs for feeders to supply scale inhibiting material.

It is estimated that nearly half the population of the United States is served with water having an amount of carbonate hardness significant from the viewpoint of scale formation. The amount varies widely from city to city, but the highest weighted averages by states are found in Indiana, Illinois, Iowa, North Dakota, South Dakota, Nebraska, Kansas, New Mexico, and Arizona.

Very truly yours,

J. L. Bray,
Head, School of Chemical and
Metallurgical Engineering

March, 1940.

SCALE FORMATION IN WATER HEATERS AND METHODS OF PREVENTION

INTRODUCTION

Until this research was undertaken some individual observations had been made which showed that scale formation where hard water is served is affected by the temperatures maintained by the heater. However, no laboratory verification of these observations had been obtained, nor was it known whether temperature was a major factor in the formation of scale deposit in a water heater. Furthermore, it is difficult to compare experiences from various territories, since such other variables as the comparative hardness of the water, the type of hardness, the quantities of water used, and the design of the heater were known to have an influence.

Some field experiences have shown in a rough way that high tank temperatures resulted in rapid scale formation. For example, in a physician's office where water temperatures of 180 degrees F. or over were required, it was found that the tank required cleaning quite frequently, whereas the identical type of heater installed in a home required very little service as long as the temperature was maintained below 140 degrees F. Other instances of increased scale formation at high temperatures are a matter of common observation. It is well known that furnace coils and uncontrolled water heaters using the crude fuels give considerable difficulty. For example, in some territories it is necessary to replace or clean furnace coils once or twice a year. It is assumed that the rapid formation of a hard scale in this case is largely due to the uncontrolled water temperature. When the house-heating furnace is operating at maximum capacity, it is quite possible for it to deliver water at temperatures as high as 200 degrees F.

With domestic gas-fired water heaters of the automatic type instances of difficulty with scale formation were not as numerous. In many cases it was reported that domestic gas water heaters equipped with temperature controls showed no difficulty from scale formation after periods of as long as eight years, when the thermostat maintained water temperatures at 140 degrees F. or lower.

It has also been observed that small passages or relatively small water tubing in the heat zone have a tendency to become clogged. Hence, the side-arm type heaters and instantaneous heaters using relatively small diameter coils are often considered to be offenders from this viewpoint.

From these experiences the various types of water heaters may be classified in the following order with respect to their tendency to give service difficulty from scale formation.

1. Furnace coils.
2. Water heaters not equipped with temperature controls.
3. Manual side-arm-type water heaters.
4. Automatic side-arm-type water heaters.
5. Instantaneous- or continuous-flow-type without thermostat.
6. Instantaneous- or continuous-flow-type with thermostat.
7. Automatic water heaters with internally heated tanks.
8. Automatic water heaters with externally heated tanks.

Scope of Investigation. The test work performed covers a study of scale formation at the controlled temperatures which are used in the operation of automatic gas-fired water heaters in homes and commercial institutions. Considerable work has been done on the scaling phenomena at the boiling temperature of water and above. These studies, however, have been made in reference to scaling in steam boilers, where the reduction of the heat transfer through the heating surfaces, the burning out of boiler tubes, and the reduction of efficiency due to scale formation were important factors. It was felt that the information obtained at these high temperatures and under the conditions existing in a steam boiler, especially where water was being condensed and fed back to the boiler, would not have much significance at the relatively low temperatures used for water heating.

The principal purpose of the work was to determine the effect of temperature on scale formation when the heater was operating below the boiling point of water. In connection with this study it was realized that the nature of the surface, whether rough or smooth, and water velocities over such surfaces might have an effect on the results obtained. It was also desirable to determine whether the scale deposit formed had an appreciable effect on the thermal efficiency of the water heaters.

Recently a great deal of emphasis has been placed on the use of water temperatures between 160 and 180 degrees F. for sterilization purposes in commercial kitchens and restaurants. An added advantage of high temperature lies in the fact that the dishes when sprayed do not require any toweling but will dry from the heat stored in them. Under these service conditions it was expected that scale formation in commercial heaters would be much more severe than for domestic heater installations. Accordingly a test was performed upon a continuous-flow-type gas-water heater which is designed to supply large quantities of high-temperature water.

ACKNOWLEDGMENTS

This project may be considered as a part of an investigation on the application of city gas to water heating and the study of the operation of automatic-type gas-water heaters. The research in gas engineering is performed on a co-operative basis, being sponsored by the Indiana Gas Association and carried out at the Engineering Experiment Station of Purdue University.

Acknowledgment is due to instructors in the Chemistry Department of Purdue University who furnished the analyses of the water supply and of the scales formed at various temperatures.

Acknowledgment is also given to Calgon, Inc., of Pittsburgh, Pennsylvania, for technical information on the use of the metaphosphates as inhibitors of hard-water scale formations.

The following manufacturers co-operated by loaning automatic gas-water heaters:

The Burkay Company, Toledo, Ohio.

The General Water Heater Corporation, Los Angeles, California.

The Ruud Manufacturing Company, Pittsburgh, Pennsylvania.

TEST METHOD

In order to obtain information on the effect of temperature alone, it was considered desirable to select a given type of heater and test at three different outlet temperatures under laboratory control. For the purpose of obtaining the information in the shortest possible time, the heater was operated continuously day and night at the manufacturer's rated capacity. Since the heater was operated at its maximum capacity, this test might be called an accelerated scale-formation test. All water heaters are equipped with a drain valve at the bottom of the tank for the purpose of removing any sediment which may collect. During these tests, this drain valve was not opened to flush the heater at any time. The total amount of scale which accumulated was determined by weighing the tank before the test began and weighing it again after completion of the test. In the case of the continuous-flow-type heater, the weight of the individual sections of the heater was obtained before and after scale removal.

The thermal efficiency of the heater was measured at the beginning of the test and again at intervals during its operation. The efficiencies thus obtained are the efficiencies of the heater when operating at full capacity. The rate of water flow was accurately controlled by the use of needle valves or "V" slot-type control valves placed in either the hot or cold water lines. A combination pressure regulator and reducer was used to overcome wide fluctuations in the water-supply pressure. A water meter of the rotary disk type commonly used by consumers was installed in the cold-water inlet pipe to the heater. The gas consumption was measured only during the determinations of the thermal efficiency. A laboratory meter of the "wet" type was used for this work. During the efficiency test, weighing tanks were used to measure the water heated during a test run. Water temperatures were measured by means of a mercury thermometer installed in a thermometer well at the outlet of the heater.

After each scale formation test was completed, observations were made of the amount, nature, and severity of the scale deposits and also of the points in the heater which were most severely scaled.

DOMESTIC HEATER TESTS—EFFECT OF TEMPERATURE

The results of these tests were comparative for the different temperatures and gave a definite indication that the rate of scale formation increased quite rapidly with the temperature maintained. A very rapid increase in the rate of scale formation as shown graphically on Figure 1 was obtained between 140 and 180 degrees F. In fact, the rate of scale formation at the higher temperature was seven times as great as that at normal domestic service temperatures.

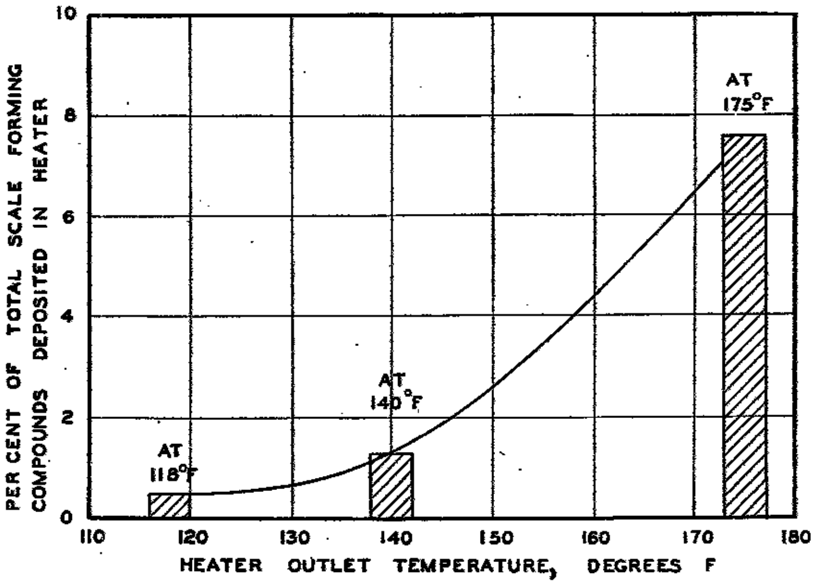

Fig. 1. Domestic Heater Tests. Effect of Temperature on Scale Formation.

The gas-fired heater is a quick-recovery type having a 20-gallon storage tank. The galvanized iron tank contains an internal flue and is equipped with a cast iron circulator. Water enters the circulator from the bottom of the tank, as shown in Figure 2, and is discharged to the top of the storage tank by means of a long copper tube. The total heating surface consists of the circulator, the bottom of the tank, and the internal flue built into the storage tank. The heater is equipped with a thermostat capable of being adjusted to maintain the water supply at any temperature from 110° to 180° F.

The deposit in the circulator at the left of Figure 3 was obtained after five years of domestic service with the water temperature maintained at 140 degrees F. The scale deposit on the right was formed after two years of domestic service with the outlet temperature at 175 degrees F.

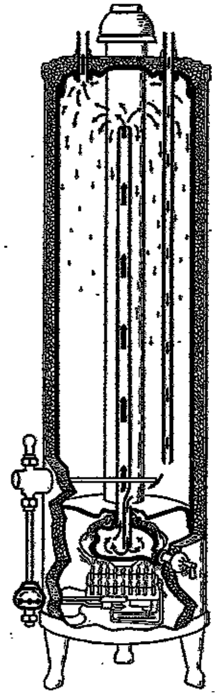

Fig. 2. Interior View of Domestic Gas-Fired Water Heater Equipped with Circulator.

It was surprising to note that the thermal efficiency of the heater did not decrease appreciably from the beginning to the end of each test. Apparently these under-fired storage-type heaters have an ample amount of heating surface; and even though the lower surfaces may contain scale deposits, there is sufficient heating area remaining to give efficient heat transfer.

From the test results the time that this heater may be in service before the scale deposit interferes with the operation of the heater may be estimated as follows:

With the thermostat set for an outlet temperature of 120°—12 years.

With the thermostat set for an outlet temperature of 140°—7 years.

With the thermostat set for an outlet temperature of 180°—2 years.

These statements are based on the accelerated scaling tests using a water supply having a hardness of 20 grains equivalent calcium carbonate per U. S. gallon. They are also based on the average usage of 50 gallons of 140° F. water per day or its thermal equivalent for other temperatures.

An accelerated scale-formation test on a storage-type heater equipped with a Monel metal tank was also performed to determine whether the scale deposit would adhere to the relatively smooth surface of this material. This test was performed at a normal service temperature of 140° F. The results demonstrated that scale deposit formed at the same rate that it would in the storage heater equipped with a galvanized iron tank. The scale form was of the usual variety adhering tightly to the bottom of the under-fired tank. The weight of scale formed and other pertinent information on the domestic heater test is given in Table 1.

CONTINUOUS-FLOW-TYPE HEATER

Accelerated scale-formation tests were performed upon a continuous-flow-type gas water heater which is designed to supply large quantities of high-temperature water in commercial kitchens and restaurants. The capacity of this heater was found to be 2.6 gallons per minute when raising the water from an inlet temperature of 60° to an outlet temperature of 180° F. The water passes through a continuous copper coil from the inlet to the outlet of the heater, as shown in Figure 4. In this design the water velocity would naturally be

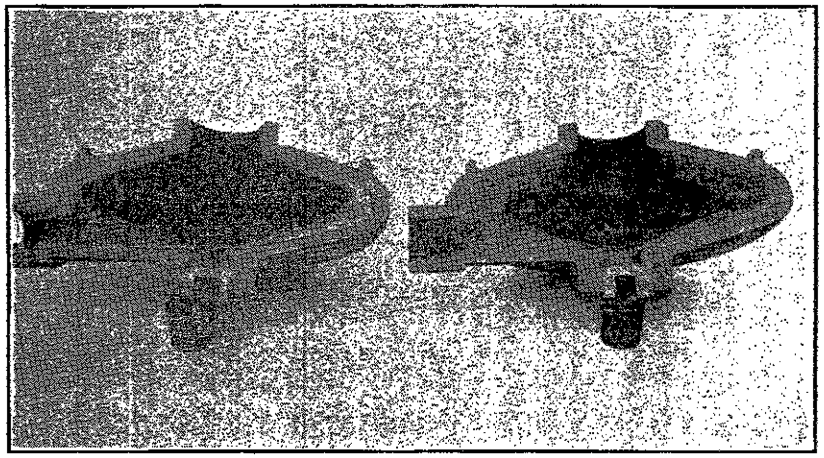

Fig. 3. Hard-Water Scale Deposits in the Circulator.

TABLE 1

RESULTS OF ACCELERATED SCALING TESTS ON GAS-FIRED STORAGE-TYPE WATER HEATERS

Type of Heater	Water Temperature at Tank Outlet, Degrees F.	Thermal Efficiency		Hot Water Supplied During Test, Gallons	Weight of Scale Deposits in Heater, Pounds	Weight of Scale-Forming Compounds Contained in Water Supplied to Heater, Pounds	Scale-Forming Compounds Deposited in Heater, Percentage of Total in Water Supply	Remarks
		Beginning of Test, Percentage	End of Test, Percentage					
Automatic Storage with Internal Flue and Circulator	118° F.	——	75%	185,000	1.75 lbs.	386 lbs.	0.5%	Heater operating normally at end of test.
"	140° F.	74%	73%	88,500	3.3 lbs.	253 lbs.	1.3%	Heater operating normally at end of test.
"	175° F.	71%	72%	24,500	5.3 lbs.	69.9 lbs.	7.6%	Copper tubes at circulator practically closed with scale deposits. Steam formed in circulator.
Automatic Storage with External Flue Monel Metal Tank	140° F.	73%	——	43,500	1.5 lbs.	124 lbs.	1.2%	Heater operating normally at end of test

quite high, and it was assumed that the high velocity combined with a smooth interior surface of the copper coil might reduce scale formation to a negligible quantity. However, the result of the tests indicates that scale formation definitely took place in a relatively short time. A total of 62,000 gallons of 180-degree F. water were supplied from the heater before the scale formation interfered with its operation. Assuming a restaurant using an average of 300 gallons a day, this would represent a service time of seven months. Under laboratory conditions a total water pressure of 80 pounds was available, and the heater was operated until scale restrictions prevented obtaining the manufacturer's rated hot water output.

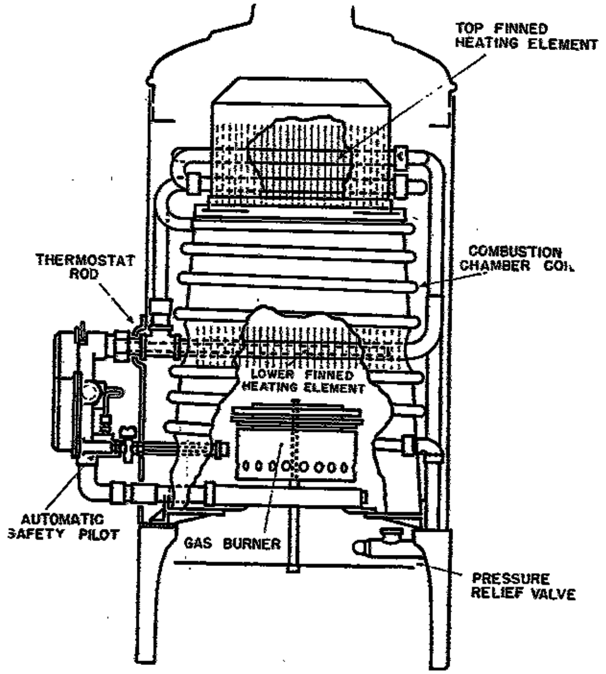

Fig. 4. Continuous-Flow-Type Gas-Water Heater.

In the first series of tests, scale formation in the water control valve, which was located in the hot water line, gave difficulty in maintaining a fixed outlet temperature. However, another series in which the control valve was placed in the cold water line was more successful, since it was possible to control the water temperature to between 175 and 185 degrees

F. After the test the various parts of the heater were dismantled and the scale was removed in order to determine its distribution in various parts of the heater. It is interesting to note in connection with this water-temperature phenomenon that no scale was found in the lower finned element which contained the thermostat rod. This was to be expected, since the heater was so designed that the water temperature at this point was not over 110 degrees F. The most concentrated scale deposit was found in the combustion chamber coil, which consisted of a continuous run of copper tube soldered to a conical shaped combustion chamber. It should be noted that this was the final heating zone and that the highest-temperature water existed in this section of the heater. A scale deposit was also found in the top heating element, which is located above the burner and which received heating gases directly from the burner. Again in this case it was noted that the thickest scale deposit was found in that portion of the copper tubing carrying the highest-temperature water. Table 2 shows the distribution of hard water scale deposit in various parts of the heater.

Again it was surprising to find that the thermal efficiency of the heater was not affected as greatly as one might suppose. As shown in Figure 5 there was no appreciable decrease in efficiency when 50,000 gallons of hot water had been supplied by the heater. When 60,000 gallons of water had been passed through the heater, the thermal efficiency had decreased by five per cent.

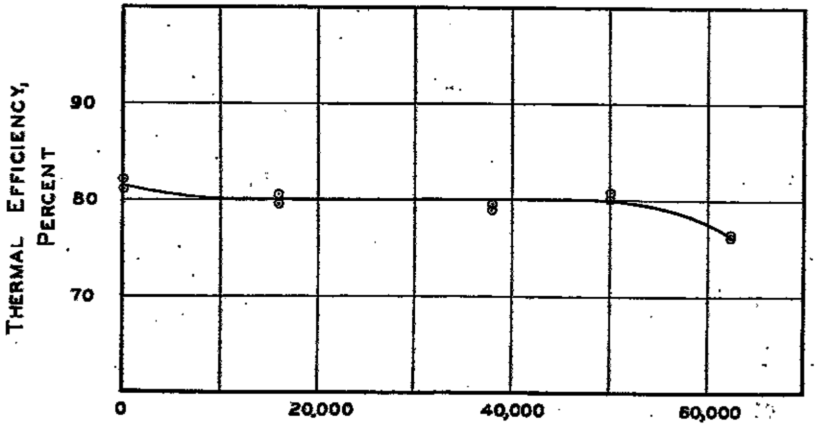

Fig. 5. Continuous-Flow-Type Gas-Water Heater. Thermal Efficiency During Scale Formation Test.

TABLE 2

Weights of Hard-Water Scale Removed from Continuous-Flow-Type Heater

(Total Water Usage 63,500 Gallons at 180 Degrees F.)

Unit	Weight Before Scale Removal, Pounds	Weight After Scale Removal, Pounds	Difference, Pounds	Internal Area of Each Unit, Square Feet	Weight of Scale Pounds Per Square Foot of Internal Area
Combustion Chamber Coil	11.2	8.4	2.8	3.8	0.74
Top Finned Heating Element	20.5	19.5	1.0	1.85	0.54
Lower Finned Element (Thermostat Rod)	5.0	5.0	..	...	None
Tee and Pressure Relief Valve*......	0.62	0.62	..	...	None

* Pressure relief valve located at cold water inlet to heater.

A total of 3.8 pounds of scale adhered to the internal water surfaces of this heater when operating at an average temperature of 180° F. This quantity represents 2.1% of the total scale-forming compounds in the water supplied to the heater during the test period. In addition there was a considerable amount of scale deposit in the outlet water piping from the water heater.

WATER AND SCALE ANALYSES

Untreated water obtained from the Purdue deep wells at West Lafayette, Indiana, was supplied to the gas-fired heaters. The hardness of this water expressed in terms of calcium carbonate is 19 grains per U. S. gallon. As shown in Table 3, the hardness is both of the carbonate (temporary) and non-carbonate (permanent) type. An indication of the proportion of each type of hardness may be obtained from the relative amounts of the bicarbonate and sulphate content in the analysis of the water.

TABLE 3

BALANCED ANALYSIS OF DEEP-WELL WATER, FEBRUARY, 1938

Constituent	Parts per Million
Calcium	91.1
Magnesium	22.5
Sodium	3.5
Potassium	3.9
Bicarbonate Radical	243
Sulphate Radical	68
Nitrate Radical	2.5
Chloride Radical	3.5

Constituent	Equivalent Calcium Carbonate	
	Parts per Million	Grains per U. S. Gallon
Calcium, 91.1/0.4	228	13.3
Magnesium, 22.5/0.24	94	5.5
Total	322	18.8

The hardness of this water may be reported as the amount of calcium carbonate equivalent to the calcium and magnesium found in the analysis.

At temperatures below the boiling point, temporary hardness in the form of calcium bicarbonate is the component of the water supply which gives difficulty from scale formation. Under the action of heat, calcium bicarbonate is broken down into calcium carbonate, which deposits on the heating surface. An analysis of the scale formed (Table 4) showed that it consisted principally of calcium carbonate with small parts of calcium and magnesium sulphate. The analysis of the scale formed compared with that of the water indicated that temporary hardness in the water supply is the source of practically all of the scale when the heater is operating below the boiling point of water.

All scale deposits were of the hard, porous, but tightly-adhering variety. When still wet, the outer layers of the deposit could be scraped off with relative ease, but upon exposure to the air, the whole mass became very hard and more difficult to remove.

TABLE 4

ANALYSES OF SCALES FORMED, OCTOBER, 1938

		Tank Temperature	
		140° F.	175° F.
SiO_2	Silica	2.1%	2.1%
R_2O_3	Aluminum and Iron Oxides	8.2%	8.9%
CaO	Lime	43.0%	42.7%
MgO	Magnesia	5.8%	6.0%
SO_3	Sulphate	4.2%	4.6%
CO_2	Carbonate	35.3%	34.7%
		98.6%	99.0%

While results of complete analyses of this type are generally expected to be low, these results total sufficiently less than 100% to indicate the presence of some undetermined material, probably chloride.

The scales are essentially calcium carbonate with small amounts of calcium sulphate and magnesium carbonate and sulphate.

SCALE PREVENTION

From the above experiments and field experiences it can be seen that excessive scale formation can be avoided by using heaters equipped with water-temperature controls and by setting the control at the lowest possible temperature which will give a satisfactory service. It can readily be seen that water heaters without temperature controls will supply water at unusually high temperatures and will thus increase the rate of scale formation in the heater. However, scale formation can not be prevented entirely by controlling temperature.

The usual type of water softener consisting of a storage tank and a chamber for holding the reacting chemical will successfully prevent scale formation when of adequate capacity and when cared for according to the manufacturer's instructions. This type of water softener is often called the zeolite- or the exchange-type softener since it substitutes sodium ions in place of calcium ions in the water supply. Thus the calcium bicarbonate is converted into sodium bicarbonate by the action of the softener. Sodium bicarbonate is a relatively stable salt and is not broken down by the action of heat.

A new method of preventing scale formation by mixing small proportions of a chemical compound with the water supply shows great promise from the viewpoint of developing a low-cost softener requiring a minimum of attention. It has been shown that the addition of two parts per million of hexametaphosphate to the water supply will prevent precipitation when the water is heated to 176 degrees F. for one hour.* This method of preventing precipitation is called "threshold" rather than softening treatment, since these quantities of the hexametaphosphate do not soften the water but only form enough of a complex ion with calcium to prevent precipitation. Another property of sodium hexametaphosphate is also of value. If scale formation should take place from neglect in replacing the material in the feeder, the scale formed would be slowly dissolved when the solution was replaced.

In order to apply this finding to commercial water heaters, it is necessary to design a feeder in such a manner that quantities of the order of five parts per million will be continuously and effectively fed into the water supply. When considering water usage in commercial kitchens, it can be seen that the storage requirements for the hexametaphosphate solution are at a minimum. Taking a typical example of a restaurant using 9,000 gallons of 180-degree F. water per month, it can be seen that only four-tenths of a pound of sodium hexametaphosphate would be required during a one-month period.

If sodium hexametaphosphate is already used for softening purposes in the commercial kitchen, it would be desirable to feed this chemical into the water supply just ahead of the water heater. The concentrations required for softening the water are 1.5 to 2.5 pounds per hundred gallons of water. This quantity is far in excess of the amount required to prevent scale formation in the heater; hence no scale difficulty should arise. These larger quantities soften the water completely from the viewpoint of soap usage, since no insoluble calcium soap precipitates are formed.

If attempts are made to reduce the feeding rate to such small quantities as five parts per million, a wick-type feeder would be one possible design. The hexametaphosphates will dissolve in water up to seventy per cent by weight. Thus a concentrated solution of sodium hexametaphosphate and crystals could be stored in a small container and fed into the storage tank or hot water line as shown in Figure 6. These concentrated solutions are corrosive to iron and steel; hence the

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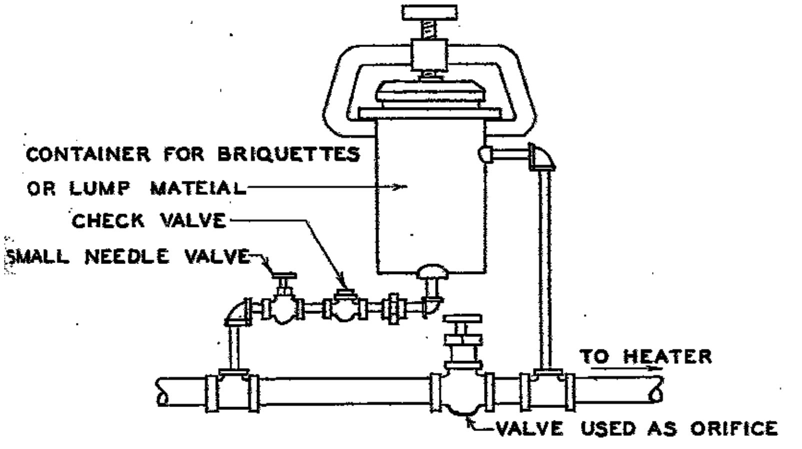
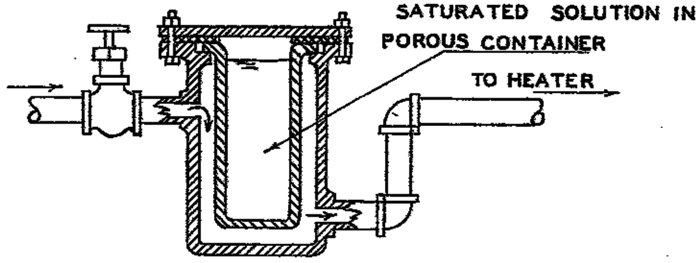
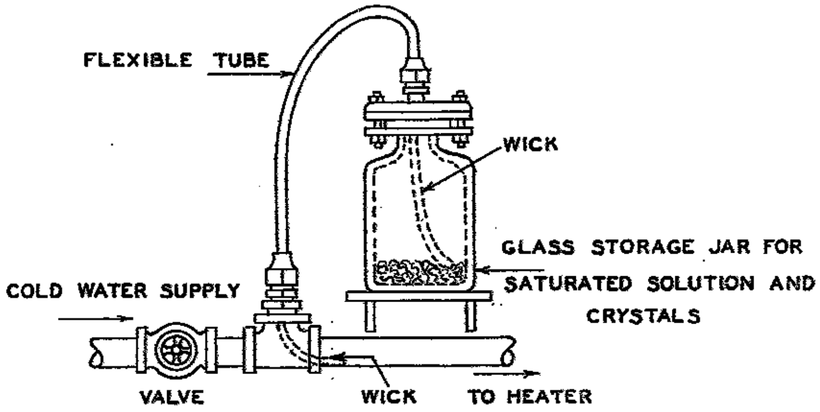
* *Industrial and Engineering Chemistry;* Vol. 31, p. 51, Jan., 1939.



BY-PASS TYPE FEEDER



DIFFUSION FEED METHOD



WICK FEED METHOD

Fig. 6. Feeder Designs for Threshold Treatment to Prevent Scale Formation.

container and fittings should be made of corrosion-resisting materials. The glass container shown in the sketch would be designed to withstand normal water-supply pressures and would have the advantage of giving a visible indication when replacement of the scale-inhibiting material was necessary. The rate of diffusion of the concentrated solution into the water supply could be regulated by varying the length of the wick immersed in the supply pipe.

The principle of osmosis could also be employed in designing a small feeder. As shown in the sketch, a saturated solution would be held in a porous container and the water supply allowed to pass around the outside of this container. The rate of diffusion through the porous membrane would regulate the rate of feed. In this design provision should be made for cleaning the container, since dirt, rust, and organic growths would tend to clog the pores.

The by-pass-type feeder is already in common use where it is necessary to treat boiler feed waters. The type of feeder shown is most suitable for brickette or lump material, which is generally used for boiler feed treatment. Control is obtained by means of a valve placed in the main water supply line and an auxiliary small needle valve in the by-pass line. The main valve serves as an orifice and gives sufficient pressure drop to cause a slow feed of water through the by-pass arrangement.

Metaphosphates having relatively low solubility have been developed for the purpose of facilitating the proportioning of metaphosphates for threshold treatment. One pound of this material placed directly in the water line will dissolve at the rate of one part per million when the flow is one gallon per minute. In other words, if a continuous-flow-type gas water heater having a rating of three gallons per minute is in service and a feed of three parts per million is desired, nine pounds of this material should be placed in the line. A suitable container for this application could be made up from a length of pipe or an ordinary drum trap fitted with appropriate screens of corrosion-resisting material.

METHODS OF SCALE REMOVAL

The most common method of removing scale from water-heater tanks is the mechanical method. The heater is dismantled and the tank removed. The scale is broken up by

striking the outside of the tank with a hammer and at the same time running water continuously over the dislodged material. It is found that the material is soft and breaks up more readily when it is in a wet state. Sometimes the mechanical removal of scale is facilitated by using a torch to heat the scaled portion of the tank and striking the tank with a hammer at the same time.

When the zinc coating is removed by acid, difficulties with rusty water are likely to occur. Furthermore, field experience with the use of acid has shown that scale seems to form more quickly after the first cleaning with muriatic acid. For example, a tank which had been cleaned after a number of years of service required cleaning again in six months. It is possible that the inside surface was left in such a condition that the scale adhered more easily.

The chemical method involves the use of muriatic acid, which is a commercial form of hydrochloric acid. It is the best of the common acids as far as its efficiency in dissolving the scale is concerned. However, acids remove the zinc coating on galvanized iron tanks, and hence tend to reduce the life of the tank. Consequently, the mechanical method of removing scale is the preferred method for galvanized iron tanks. However, when the tanks are constructed of copper-nickel or copper-silicon mixtures, muriatic acid may be used without damaging the tank, provided that it is not allowed to stand in contact with the metal for a longer period than that necessary to remove the scale.

Circulating tank-type heaters or continuous-flow heaters using copper coils can be descaled most conveniently by the following device:

The apparatus consists of a tank or sump, and a circulating pump of acid-resisting material with copper tubing or other acid-resisting piping to make the connections. The purpose of this apparatus is to circulate the acid solution through the heater and back to the sump, both thus discharging dissolved scale and allowing the gases formed to escape. The suction side of the pump should be piped to the side of the tank and protected by a screen to prevent recirculation of the pieces of scale. The suction pipe should be at least three inches above the bottom of the tank so that it will not pick up sediment. The pressure side of the pump should be connected to the cold-water inlet to the heater by means of flexible copper tubing or acid-resisting rubber hose. The heater outlet should be piped to the tank or sump to allow for the discharging of the circulated acid and the gases formed.

For this method the heater need not be dismantled for the descaling operation. The circulating acid reacts with the scale as it passes through the heater, and the gases are discharged over the tank. The process will require from three to eight hours for complete descaling. Indications that the descaling operation is complete will be noted when the circulating acid no longer carries any appreciable amount of gases.

CONCLUSIONS

In conclusion it may be said that all the test work done indicates that water temperature is the principal factor causing scale formation in water heaters. It is apparent that more extensive use of water softeners or other methods of preventing scale formation will be required in commercial installations, especially when high-temperature water is being served.

A very rapid increase in the rate of scale formation is obtained between 140 and 180° F. In fact, the rate of scale formation at the higher temperature is seven times as great as that at normal domestic service temperatures.

The effect of high water velocity is to reduce the rate of scale formation at any given temperature. For comparative purposes the test results on the storage-type heater versus the continuous-flow-type heater may be cited. For the storage type heater, 7.6% of the scale-forming compounds in the water were deposited in the heater; whereas for the continuous-flow-type water heater, only 2.1% of the scale-forming compounds were deposited at approximately the same temperature of 180° F.

Scale deposits caused by a carbonate or "temporary" hardness in the water supply will adhere to interior surfaces such as galvanized iron, copper, and nickel-copper alloy.

Scale deposits formed at 180° F. will rapidly obstruct relatively narrow passages in spite of the fact that the water velocity is high at these points.

At a temperature of 180° F., scale deposits will obstruct outlet pipes from the heater before enough material has formed in the heater to interfere with its operation.

At temperatures below the boiling point of water, temporary hardness in the form of calcium bicarbonate is the component of the water supply which accounts for practically all of the scale formed.

Metaphosphates added to the cold-water supply to the heater show considerable promise as scaling inhibitors when used in an effective feeder.

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