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Water Softening for the Home

LINDON J. MURPHY

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THE convenience of soft water and the economic loss chargeable to a hard water supply is rapidly becoming understood thruout Iowa. The increasing number of requests for information and advice relative to the most advantageous method of treatment and suitable equipment, show an awakening appreciation of the desirableness and economy of softened water.

It is the aim of this bulletin to take up in detail and attempt to answer the problems confronting the average Iowa family when considering the installation of a domestic water softener.

While it is not possible to give credit to all who have contributed to the information which is set forth on the following pages, much credit is due to the many authorities whose studies and writings make up the public storehouse of knowledge on water softening. To Dr. O. R. Sweeney, Head of the Chemical Engineering Department of Iowa State College, is due especial credit for his helpful suggestions and critical examination of the material.

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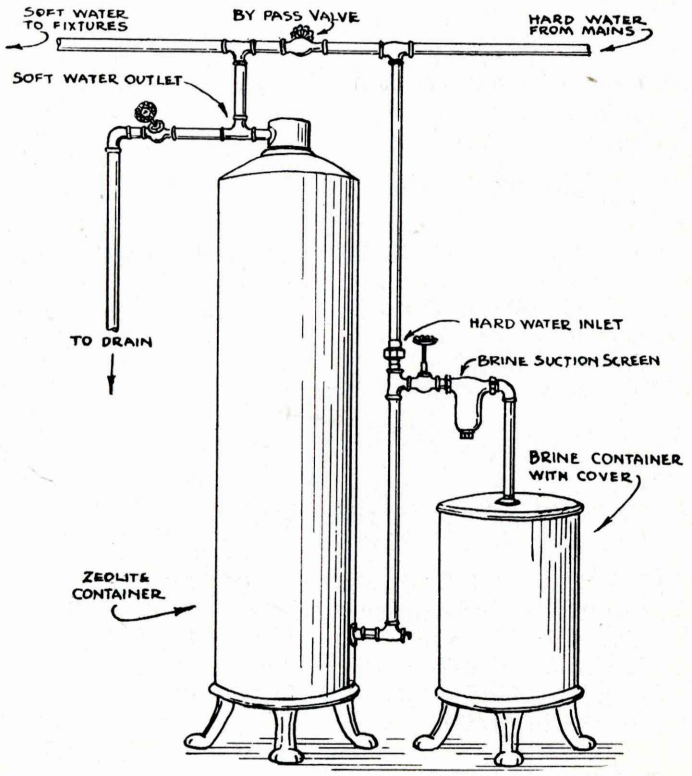

Typical Domestic Zeolite Water Softener.

Water Softening for the Home

LINDON J. MURPHY

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Soft water as well as pure water is coming to be demanded by Iowa families. No longer is the household content to use water which stains and stiffens fabrics, corrodes and encrusts heating and plumbing fixtures, and which forms a disagreeable curd on sinks, wash basins and cooking utensils.

Even a decade or so ago the average home was without the plumbing fixtures now so common. Water heating devices were found only in the most expensive residences. The widespread use of these conveniences in recent years, and the difficulties encountered in maintaining them when hard water is used, are probably the dominant reasons for the increasing demand for a soft water supply. The adoption of finer fabrics for wearing apparel and for home use, which are seriously harmed when laundered in hard water, is another important reason for water softening.

What is Hard Water?

It may be well at the start to understand just what is meant by hard water. When water has the property of requiring a large amount of soap to produce a lather it is considered hard. The term hardness is therefore relative, there being no distinct line of demarcation between a hard and a soft water. What is considered a hard water in one locality might be deemed soft in other localities. It is known that hardness in water is due to certain mineral salts in solution. Compounds of calcium (lime), magnesium (magnesia) and iron are the principal constituents causing hardness.

Water softening is understood to mean that process which removes or changes to unobjectionable compounds the salts of calcium and magnesium, and may or may not materially affect the iron content.

Evidences of Hardness

We are all familiar with the evidences of hard water. We have all noticed the large amount of soap required to soften hard water before a cleansing lather can be secured. We know, too, the greasy scum which deposits in basins, wash bowls, and bath tubs following the use of soap in hard water. This scum or curd tends to clog the pores of the skin and makes proper cleaning difficult.

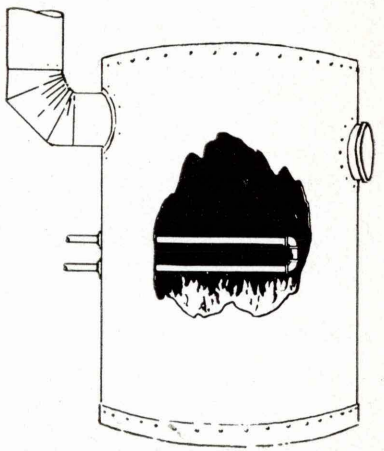
The effects of hard water are also very evident upon laundry work. The various soap compounds used (frequently stearates of lime and magnesia) deposit a sludge in the pores of the cloth, giving the clothes a dirty appearance, as well as having a tendency to stiffen and rot them. Many strong soaps and cleaning compounds contain substances which soften hard water, but which may also ruin all but the toughest fabrics.

The scale formed in tea kettles and cooking utensils is a familiar evidence of the effect of heating hard water. The deposit in heating coils, boilers and plumbing fixtures is a much more costly effect altho not so commonly observed.

That hard water is expensive to use is seldon realized by the average householder. The cost is largely indirect and is often attributed to other accounts.

In addition to the cost of extra soap used to soften hard water before the cleaning action of soap is realized, hard water should be charged with the expense of repairing plumbing fixtures filled by scale, with the loss of heat and the increased fuel used in boilers (more fuel is required when scale is present, the loss of heat increasing with the thickness of scale), and the lessened life of heating units.

Hard water is also expensive when a rain water cistern and separate piping system must be installed to provide a water soft enough to be acceptable for household use.



With hard water the intense heat of a furnace causes calcium and magnesium salts to deposit; heating coils become filled and must be replaced.

How is Hardness Caused?

Large volumes of water are constantly being evaporated from the surface of the earth by the sun. This water is returned again in the form of rain or snow. That part of the rain or snow which is not evaporated again, percolates thru the soil and is largely taken up by plant roots, or flows overground to the nearest watercourse.

In its passage thru the air as rain or snow, water picks up certain chemical constituents which are present in the air. Nitrogen, oxygen and carbonic acid are among those acquired. The total amount of chemical constituents thus absorbed is, however, relatively small as compared to that which is acquired in the passage thru soil and rock strata. Rain-water is therefore considered soft water.

Water absorbs additional carbonic acid and traces of other acids from decaying vegetable matter and from the excretions of plant roots as it percolates thru the soil. The acidity thus acquired greatly increases its power to dissolve mineral substances. Much of the dissolved oxygen which had been taken up in passing thru the air is in turn lost in passing thru the soil. Because of this fact many substances such as iron compounds, which would otherwise be oxidized and rendered insoluble, are dissolved.

After passage thru the soil and subsoil water comes in contact with varying rock strata. Among these are included limestone (calcium carbonate), dolomite (calcium and magnesium carbonate) sandstone and shales, beds of chlorides of sodium (common salt), calcium and magnesium, and beds of calcium sulfate (gypsum). Thru the carbonic acid in the water, the lime and magnesium carbonates of the limestone and dolomite are partially dissolved in the form of bicarbonates.

Calcium carbonate is found in greater abundance in the earth's surface than magnesium carbonate, and ground water usually contains considerably more calcium than magnesium.

The chlorides and sulfates of calcium and magnesium are readily soluble in water, and where these are found in quantity in the country rock, ground water is certain to contain large amounts of them, and to be so hard that it can scarcely be used for domestic purposes.

Temporary and Permanent Hardness

Hardness caused by the bicarbonates is called temporary as these constituents will precipitate or settle out on boiling or when the water is treated with hydrated lime. The hardness caused by sulfates and chlorides is called permanent because these compounds will not settle out upon boiling in an open vessel or by the addition of hydrated lime.

WHAT IS WATER SOFTENING

Any method which removes calcium and magnesium salts from solution is called water softening. For centuries soap has been the one softening agent used extensively. In recent years science has evolved more effective and satisfactory methods, and lately it has brought the cost of their use within the scope of the average water user. In fact, comparative figures show that for a number of homes water can be

softened in modern water softening plants at less cost than it can be secured either by the use of soap or thru a cistern. For practical purposes the softening of water is accomplished by either one of two methods; by precipitation, most generally called the Lime-Soda process, or by the exchange process most commonly known as the Zeolite method.

Precipitation Method

The salts of lime and magnesia in solution in water can be separated by chemically precipitating them as insoluble compounds. The salts forming so-called "temporary hardness" are in reality bicarbonates of calcium and magnesium, the carbonic acid present in the water being loosely bound to the carbonates. This carbonic acid is easily removed by caustic lime (calcium hydrate). The use of lime for removing the free and half-bound carbonic acid, thereby converting the bicarbonates into carbonates, is the basis for one of the oldest and most efficient methods of water softening. The lime added is itself precipitated as carbonate of calcium and the magnesium is precipitated as the hydrate.

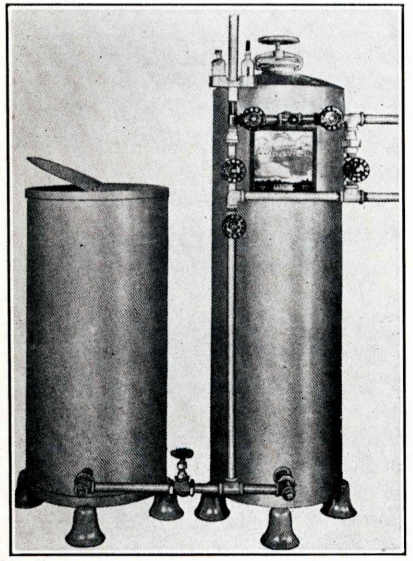
Permanent hardness may be removed by another reagent, soda ash (sodium carbonate). The reactions involving the sulfates, chlorides and nitrates causing permanent hardness all consist of an exchange of acids, whereby the insoluble carbonates of these bases are precipitated and a corresponding amount of the soluble sulphates, chlorides and nitrates remain in solution. The soluble salts are not reduced by this process, but the less objectionable salts of sodium are substituted for those of calcium and magnesium.

Other mineral impurities such as the sulphates of iron, aluminum, and manganese, as well as free acid, may be neutralized with sodium carbonate. Hydroxides of these bases are formed which, because of their insolubility, may be easily removed by filtration. Oxidation of the hydroxides of iron and manganese is usually necessary to secure complete precipitation.

When the precipitation type of water softener is used, large settling tanks are required as all of the water and chemicals must react at least four hours to complete the chemical action and settlement. A filter is required in addition to remove the last trace of the precipitated salt before the water is ready to use. While the precipitation type of water softener is divided into two classes, the continuous and the intermittent, the action in both is substantially the same.

Zeolite Method

Another method of water softening which is particularly adapted to residential use is that known as the Zeolite or exchange method. It involves the use of natural or artificial zeolites. Zeolite is the geological name of a class of insoluble hydrated silicate of aluminum, or iron and aluminum, combined with an alkali or an alkaline metal or both. Zeolites are widely distributed in nature, the most of that which is being used commercially comes from the large deposits in New Jersey and Maryland or from the Ardmarite deposits in South Dakota. After it has been prepared for water softening purposes it has the appearance of sand of a brown or greenish brown color.



Typical "Brine-Tank" Type Zeolite Water Softener

The term Zeolite has come to include a number of artificially prepared compounds having the properties of the original green-sand. These artificial Zeolites are made from a combination of sodium, aluminum and silica. As prepared for water softening purposes they have the appearance of coarse commercial salt except that after use the crystals usually have a yellow or brownish color.

The property which this mineral possesses for exchanging its base for another base has led to its employment in the field of water softening. As hard water is passed thru a bed of Zeolite the calcium and magnesium from the water are exchanged for the sodium in the Zeolite. The softened water contains sodium salts in amounts and combinations equivalent to the hardening salts replaced.

These sodium salts remain in solution when the water is heated, aerated or treated with lime. Inasmuch as there is no sludge or precipitate formed in this process, there is no disagreeable curd in washing, nor deposit in boilers and heating coils.

Zeolite treatment likewise removes one of the most commonly recognized disadvantages of hard water. The reaction between the calcium and magnesium salts of hard water with soap (which is usually sodium oleate) has long been a source of trouble to the housewife. The soap precipitate has tended to stick to fabrics in laundering, making them stiff and harsh, as well as causing spots and stains. Thus by taking these calcium and magnesium salts out of the water, sufficient soap is often saved to alone pay for the water softener. The other benefits of soft water are thus clear gain. A Zeolite softener is able to continue this exchange up to the capacity of the particular sodium compound which it contains.

However, when the supply of sodium in the Zeolite is lowered so

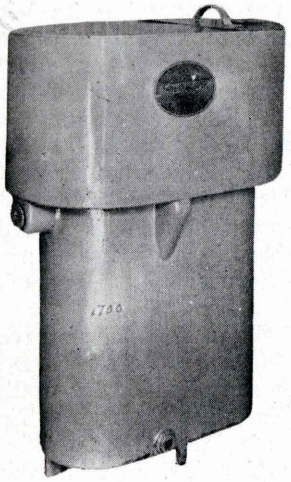
that the exchange of sodium for the calcium and magnesium has reached its limit, another remarkable property of the Zeolite is utilized for restoring it to its original condition. By introducing a strong solution of sodium chloride (common salt) the first exchange is reversed. The sodium of the salt substitutes itself for the absorbed calcium and magnesium. After washing out the excess of salt solution, together with the solution of calcium and magnesium chlorides, the Zeolite is again in condition to soften water. The process can be repeated indefinitely as there is no loss of the exchange properties. This method of softening water is very useful for smaller installations as no careful adjustment of chemicals is required. It is extensively used in homes, laundries and institutions.

COMPARATIVE MERITS OF SOFTENING PROCESSES

Softening Properties

While both the Lime-Soda and Zeolite water softeners have distinct advantages and limitations, for domestic use the merits of the Zeolite process far outweigh its limitations. To illustrate this fact several points of comparison may be considered.

In the matter of hardness both processes give very satisfactory reduction for domestic use. In fact the Zeolite method used for the great majority of domestic plants gives water that is practically free from calcium and magnesium compounds over the greater portion of its normal operating period. While this hardness may run as high as 1.4 grains per gallon, for all practical purposes Zeolite softeners may be considered to yield water of zero hardness. On the other hand Lime-Soda softeners usually leave the water with a residual hardness of 11 grains per gallon and never reduce the hardness below about four grains.



Automatic Electrically Operated Zeolite Water Softener.

Zeolite softening does not, however, reduce organic matter, silica or alumina, nor does it remove carbon dioxide. If the raw water contains an appreciable quantity of iron, it must be pre-treated for iron-removal before entering the Zeolite softener.* Or if the water is turbid it must be filtered before passing to the Zeolite, in order to prevent coating the active material.

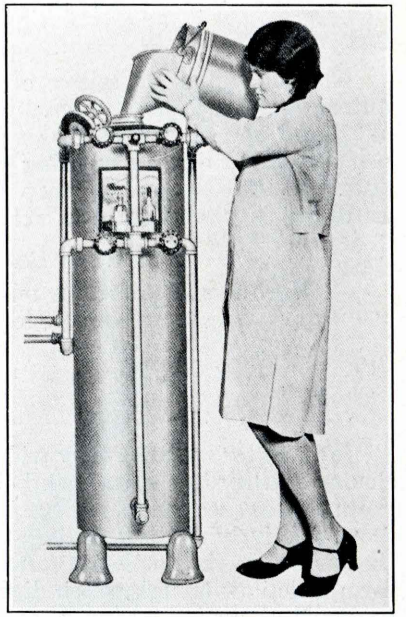
*There are several notable exceptions to this rule in that at least two of the newer softeners of this type have been prepared so that they do effect a very appreciable reduction in the iron content.

Relative Costs

Among the other factors worthy of consideration is that of comparative costs between the Lime-Soda and the Zeolite processes. This cost includes the expense of the original installation, of treatment regenerating salt or chemicals for softening, and of maintenance. On all of these items, because of the necessary size of mixing, coagulating and settling tanks, the continual cost of chemicals, and the maintenance parts more likely to become clogged or out of order, the cost of Lime-Soda softening for the small residential installation is considerably higher.

Attention Required

A factor of overwhelming significance in a comparison of the processes as adapted to residential use is that of the attention, physical or mental, required to keep the apparatus functioning as it should. The labor and attention needed by the Zeolite softener is slight, consisting principally in recharging the bed upon exhaustion. On the other hand treatment with lime and soda involves mixing and proportioning of chemicals at frequent intervals—a complicated, messy, and inconvenient process for the average householder. In fact for the small quantities of water used in a home it is almost impossible to properly measure and mix the minute quantities of each chemical needed. And the frequent attention necessary makes this method not only inconvenient, but impractical for household use.



Regeneration of the simple "Salt-in-the-Head" Type Zeolite Water Softener.

Engineering Considerations

The Zeolite softener also has distinct advantages on the strictly engineering considerations in domestic softeners. It has less size and can be built with much smaller capacities than are practicable with the Lime-Soda softener. In addition, practically all Zeolite softeners are operated under pressure, so that the original head of water in the system is maintained, less the loss of head thru the Zeolite. In this way re-pumping the softened water is generally avoided. In the Lime-Soda system any large in-

itial pressure is lost, as this type of softener works under a gravity head.

It is evident, then, that from the standpoint of total cost, satisfactory operation, efficiency, care and attention, and suitability for domestic use, the Zeolite water softener is much superior to the other types.

THE COST OF WATER SOFTENING

The expenses involved in the use of hard water for a domestic water supply are so varied and some are so obscure that it is exceedingly difficult to intelligently even approximate them. By way of illustration, the loss of satisfactory service from clothes washed in hard water might be cited, also the loss of heat from countless household water heaters, which have heating coils incrusted with mineral deposits. We are able to ascertain some of the costs, however, with reasonable accuracy.

Cost of Soap

The first apparent source of expense is that of the extra soap required to soften hard water. It has been estimated by Prof. G. C. Whipple* and others that the average family uses at least one gallon per person per day for washing purposes in the kitchen, bathroom and laundry. The amount of soap required to soften water of differing hardness is shown in the following table:

AMOUNT OF SOAP TO SOFTEN WATER

Hardness in parts per million as calcium carbonate	Soap in Pounds per 1,000 gallons
100	22.2
150	32.2
175	37.1
200	41.7

Iowa water supplies vary widely in hardness, according to the particular locality in the state and the acquifer supplying the water. In the northeast section of the state water of excellent quality is secured from relatively shallow wells. Water bearing stratas which come to the surface in the northeast corner of Iowa, Wisconsin and Minnesota, form a shallow trough which dips to the southwest, being encountered by wells at an increasingly greater depth as the acquifer is traced south and west. The water which is moderately soft in northeast Iowa absorbs minerals from the rock as it travels south and west, so that in wells which penetrate the deeper rock strata in southern and western Iowa we find water which is excessively hard. Even shallow wells into the loess and drift of southwest Iowa encounter water containing an appreciable amount of mineral matter.

*Whipple's formula for calculating soap is 2+ (0.2 × hardness) = pounds of soap per 1,000 gallons.

Hence because of the varying hardness found in different waters of the state it is impossible to select a situation which will be typical of any considerable portion of Iowa. Several eminent authorities recommend that water be softened when it contains over 150 ppm. of hardness. Many domestic supplies in central and southwest Iowa contain from 300 to 500 ppm. hardness. Some greatly exceed this amount.

For the purpose of illustration a domestic supply of 300 ppm. may be used. At one gallon per person per day, a family of five would use over 1,800 gallons of softened water per year.

COST OF SOAP

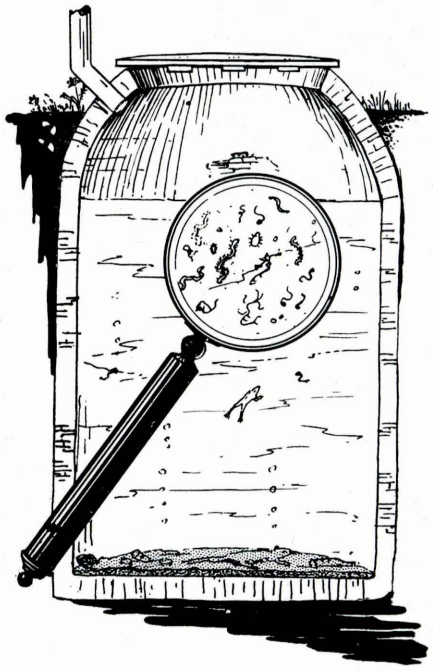
Extra Soap Used by Family:

$2 + (0.2 \times 300) = 62$ pounds of soap per 1000 gal.

$\frac{1800}{1000} \times 62 = 112$ pounds per year.

At 15 cents per pound the cost per year is $16.80.

This is the cost of soap required to soften the water before any of the soap is available for cleansing purposes. This soap goes to help make the objectionable soap curd.



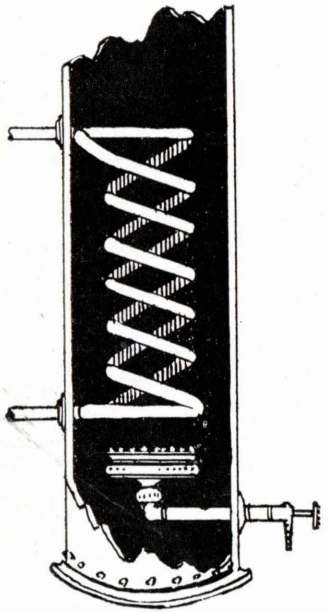
Cost of Cistern

The use of hard water for washing purposes is accompanied by so many disagreeable features that a large proportion of homes in areas afflicted with hard water have installed soft water plumbing and cisterns. Some type of pump is usually installed to force the soft water to the plumbing fixtures. While the use of cistern water costs more than hard water, it is so much more pleasant that we are usually willing to pay the difference. Prof. Foulk of Ohio State University has estimated the cost of cistern water at Columbus, Ohio, as follows:

COST OF CISTERN WATER

Cistern, pump, pressure tank and extra plumbing	$292.00
Interest at 6% and depreciation at 4%	29.20
Saving in soap by use of cistern water	14.88
Annual cost per family for cistern water	14.32

While a cistern supplies water acceptable for certain limited uses, it is being eyed with suspicion by health authorities. In fact, many have come to consider the cistern a veritable germ breeder. A great deal of filth gets into the cistern even tho a filter may be used. They should be cleaned out frequently, but are not. Most folks are too busy to clean their cisterns, and filthy water is the result. Several disease epidemics have been traced to the use of water from contaminated cisterns. It is quite common to find molds, fungi and aquatic growths of various sorts in the cistern, all of which add their quota to the tastes and odors in the water.

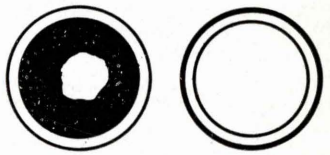


Coils in a hot water heater likewise become clogged with the deposit from hard water and must be replaced.

In addition cistern water is frequently found to be far from soft. The carbonic and vegetable acids absorbed by the water from decaying organic matter in the cistern and from other sources outside are active in dissolving lime and other mineral substances from the concrete walls of a cistern. Hence it is evident that from both a health and a water softening standpoint a cistern is far from satisfactory. The cost figures given in the table above indicate that this method of securing soft water is not as economical as many of us have supposed when all the factors are brought into consideration.

Cost of Repairs to Plumbing

Those who have used hard water in heating plants, hot water heaters, coils and plumbing fixtures are disagreeably familiar with the frequent repairs and replacements made necessary by corrosion and scale. The accurate cost of such maintenance, and the cost of fuel wasted by heaters which have become inefficient thru scale deposits cannot be determined. Investigations do show, however, that repairs made by plumbers amount to about $4.00 to $5.00 a year in a household where hard water is used.



On the left a typical section taken from a coil almost completely filled with deposit from hard water. On the right a typical section of a coil where soft water has been used.

Cost of Water Softening Plant

Domestic water softeners are made in several sizes and the cost of course varies with the size. The prices for the small size are very nearly the same for all makes—around $150.00. The softener installed may be estimated at about $200.00. Allowing 10% for interest and depreciation, the cost for the softener may be estimated at $20.00 a year.

The operating cost of a water softener is very low. Most commercial softeners are now guaranteed not to use over ¾ of a pound of salt per 1000 grains of hardness removed from the water. This is equivalent to 13.2 lbs. of salt per 1000 gallons of water used of 300 parts per million hardness.

With a plentiful supply of clean, soft water available the average family will use in the neighborhood of 500 gallons per week. Salt for use in water softeners can be purchased in 100 pound bags and costs about one cent per pound. Thus the cost of salt for softening a week's supply of water will be approximately 6.6 cents—a total of $3.40 per year.

COMPARATIVE COSTS

Cost with Hard Water (300 parts per million)		
Extra soap used	$16.80	
Extra plumbing repairs	4.00	
(Heat loss due to scale, injury to clothing and fabrics, etc., not included)		
Total annual cost per family		$20.80
Cost of Cistern		
Interest and depreciation	$29.20	
Total annual cost per family		$29.20
Cost of Zeolite Domestic Softener		
Interest and depreciation	$20.00	
Salt for regeneration	3.40	
Total annual cost per family		$23.40

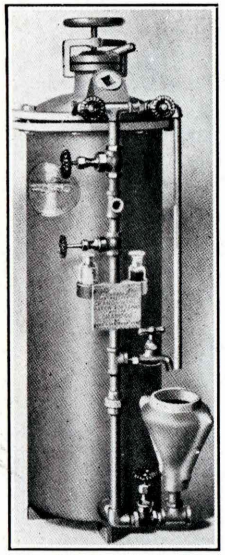
It is evident from a comparison of the tangible costs given above, and these represent only a part of the total cost of hard water, that a domestic water softening plant costs very little, if any, more than the other methods utilized to supply the household in a hard-water area with water which is usably soft. The intangible costs and the factors of convenience and health cannot be weighed, although they are of very real importance and merit study when considering the various possible ways of securing soft water.

SELECTING A HOME WATER SOFTENER

While each commercial softener has certain features which distinguish it from others, the fundamental qualities which mark a good water softener are simple. A few of these guideposts may well be mentioned as an aid to the householder in selecting a home water-softener which is designed to give lasting, satisfactory service at a reasonable cost.

Capacity of the Softener

An obvious requirement is that the softener be of the proper capacity. This very necessary quality is determined largely by the hardness of the water and the amount used by the household. An analysis to determine the hardness can be readily secured. Many of the manufacturers of water-softeners do analytical work for prospective customers without charge. Local plumbers handling water-softeners are usually glad to take samples and send them in for analysis. In a few localities sufficient analyses have been made to give local plumbers reliable data on the hardness of water in shallow wells. Where it is desired, the State Department of Health or the chemistry departments of the state educational institutions can give information as to competent chemists who can make such analyses.



Simple "Salt-Pot" Type Zeolite Softener.

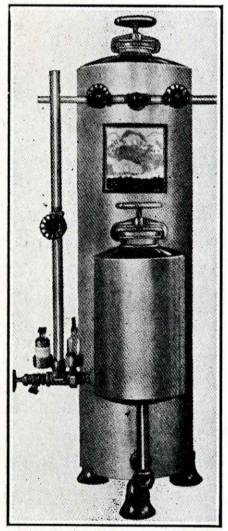
As mentioned before, where a plentiful supply of clean, soft water is available the average family of five persons will use about 500 gallons of water a week. In households where the water is metered the exact amount may be ascertained by multiplying the cubic feet usage per month, as shown by the meter readings, by 7.5 to change it to terms of gallons. Many householders prefer to bypass from the softener certain of the fixtures, such as the lines leading to the toilets and to the lawn, thereby materially reducing the demand on the water softener. As considerable variation will occur from month to month due to seasonal causes some leeway is desirable in the amount set.

With this total usage per day or per week and the hardness of the water determined by an analysis, the householder is in a position to choose the capacity of water softener needed to meet his particular conditions. Charts furnished by the local plumber or by manufacturers of softeners make this selection a very easy matter.

Size of the Softener

The dimensions of the tank should be such as to give ample room for the required depth of Zeolite with an extra allowance for a layer of gravel underneath (in a down-flow softener) to promote good distribution of wash water, and additional space above the Zeolite to prevent its loss during agitation or washing. This will give a total required depth of four and one-half feet—with some types of softeners it will be considerably more.

Each water softener is designed to operate at a certain maximum rate. If operated at a higher rate the water may not be perfectly softened or with some types of filter the filtering media may be disturbed and washed out. Hence it is apparent that the maximum rate at which water is to be drawn from the softener will influence the size of softener required, and should be considered when selecting the size and type of softener.



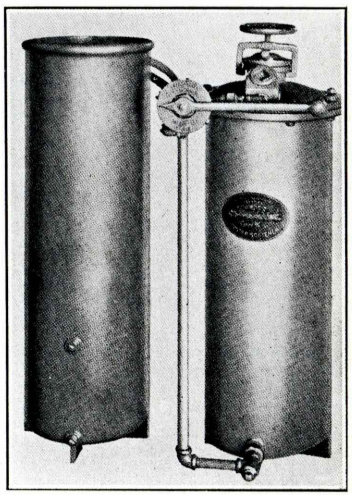
"Salt-Pot" Type Zeolite Water Softener.

Mechanical Details

The whole softener should be of substantial construction, the tank and other parts made of a good grade of steel or other suitable material of adequate thickness. As far as possible all valves and fittings should be easily replaceable and of standard design in order that a low maintenance cost may be assured. All openings, such as the hand hole for introducing salt and the pipe connection holes, should be well reinforced.

Ample inlet and outlet pipes are necessary to allow liberal use of water for agitating the Zeolite bed (in a down-flow filter), thus preventing sections of the bed from becoming hardened and ineffectual.

Every water-softener should be provided with a "salt pot" or container for introducing the regenerating salt into the Zeolite bed. Any container which will introduce the salt in a concentrated (5%) solution will be satisfactory. It should be of sufficient size to hold the amount of salt solution required for each regeneration, and like the softener tank, should be constructed of good steel or other material which will resist the corrosive action of salt. It should be conveniently located for introducing the salt solution. Openings should be of adequate size for inspection and access.



Semi-Automatic "Brine-Tank" Type Zeolite Softener.

Relative Costs

Very little needs to be said about the relative costs of the various commercial softeners on the market. In the main they speak for themselves. The usual range for Zeolite household softeners

without installation is from $100 to $250 depending, upon size, sturdiness, completeness of equipment, etc.

Quality of Water

It is important that the water introduced into a Zeolite softener be clear and free from suspended matter. Dirt particles will clog the bed, obstruct the flow of water and interfere with the softening process. If dirty water must be treated it will be advisable to install a filter preceding the softener.

Some Iowa waters contain an excess of iron in solution, thus requiring aeration or additional chemical treatment before softening. Other waters contain such a preponderance of mineral bicarbonates or free carbon dioxide that Zeolite treatment is not economically feasible Hence in every case where domestic water softening is being considered it is essential that definite information on composition of the water be secured before softening equipment is purchased.

With these qualifying conditions domestic water softening can be commended as being a real boon to the Iowa household. Domestic installations are fast coming into general use and are proving of almost indispensable convenience and economy.

AVAILABLE BULLETINS OF THE ENGINEERING EXTENSION SERVICE

No. 6. Surface Oiling of City Streets.
No. 15. Collection and disposal of City Refuse.
No. 20. Street Name Signs.
No. 28. Butt Treatment of Wooden Poles.
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