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W. R. Conley

EXPERIENCE WITH ANTHRACITE - SAND FILTERS

by

W. R. Conley

Paper for presentation at
AWWA Conference in Detroit, Michigan

November 11, 1960

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EXPERIENCE WITH ANTHRACITE - SAND FILTERS

INTRODUCTION

The General Electric Company operates eight large filter plants for the Atomic Energy Commission at the Hanford works in the state of Washington. Because of the importance of water to the process, research and development on water treatment has been an important part of the overall Hanford research and development program. The research and development on water treatment has resulted in important capital and operating savings and in the production of better quality water. It is the purpose of this paper to present some of the information developed by the programs.

SUMMARY

Results of laboratory, pilot plant, and full scale plant tests with a variety of filter types over a period of 16 years show that filters made of anthracite and sand together are superior to filters made of either material alone.

The results of laboratory tests on filters have been published.⁽¹⁾

The plants have used six main filter types. The comparative value of these filters is determined by their ability to produce high quality water at high filtration rates and with long filter runs. On this basis of judgement, filters made of 6 inches of 0.43 mm effective size sand and 24 inches of 0.9 mm effective size anthracite are superior to any of the other filter types used.

Optimum performance with all of the filter types is obtained when the coagulant feed is just enough to cause the suspended matter in the raw water to grow large enough to be retained by the filters. Excess coagulant feed promotes floc breakthrough. The effect is serious when the water is cold and the filter flow rates are high. The breakthrough is controlled by reducing coagulant feed and adding a few parts per billion of polyacrylamide or polysaccharide to the filter influent.

Very little attention is given to floc size or quality but the filtrate from each filter is monitored for turbidity routinely. If higher than planned turbidity readings are obtained, the chemical feeds are changed.

The chemical treatment methods and superior filters have led to better water at lower capital and operating costs. Increases in water flow have been attained at nominal cost which would have cost over \$20 million in capital investment if conventional methods had been used. Operational

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costs have been reduced significantly. Savings in chemical costs alone have been over \$250,000 a year since 1957. Filtered water quality has been so good that special highly sensitive methods had to be developed to measure the turbidity.

The large capital savings were made possible by increasing the flow through all of the plant components. Consequently, flocculation and settling times are short, and filtration rates are high. One plant filter has operated successfully on a long time test at 8 gpm per sq. ft., with very short flocculation and settling times. Most of the plants are capable of operating at 6-7 gpm per sq. ft.

The limitation to still greater flow rates is air binding of the filter media. The air binding causes short runs at high filtration rates during a few weeks each year.

There has been no difficulty in keeping the filters clean. The percentage of backwash water used is usually below 2% of gross output and is often below 1%.

HISTORY OF HANFORD FILTERS

Filters made of anthracite and sand have been used throughout the country for many years before they were used at Hanford. The original Hanford filters consisted of 10 inches of 0.45 mm sand and 20 inches of 0.7 mm anthracite. It took many years of effort to obtain filters that performed better than the original type.

During the first Hanford expansion, additional filter plants were built. A plant study was made to see if there would be an advantage in using filters made entirely of sand instead of the sand and anthracite combination. The results of a test on one plant size filter showed that the sand filter gave runs which were only half as long as the combination filters gave. Additional plant tests were run using various depths of anthracite and sand. The tests showed that water quality was improved by increasing the depth of sand and decreasing the depth of anthracite. Data from these tests were used to design the filters for three new plants. These filters had 20 inches of 0.45 mm sand and 10 inches of 0.7 mm anthracite. The filters were very successful but no attempt was made to operate at high filtration rates. Performance characteristics of these filters are shown in Table I.

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TABLE I

EFFECT OF MEDIA DEPTH ON PERFORMANCE

<u>Filter Type No.</u>	<u>Sand Inches</u>	<u>Anthracite Inches</u>	<u>Rank Good Quality</u>	<u>Low Head Loss</u>
1	30	--	1	9
2	20	10	2	8
3	15	15	3	7
4	10	20	4	6

Effective size of sand was 0.45 and uniformity coefficient was 1.5. The effective size of anthracite was 0.7 and the uniformity coefficient was 2.0.

At this point a long term investigation was begun to evaluate filters and chemical treatment methods with the goal of increasing the water output of the plants. These tests led to the adoption of the alum-activated silica process as used by Mr. Baylis at Chicago. The results were successful although treatment costs were higher than desired and control of the process was difficult.

The test program also resulted in development of a filter that was capable of higher flow rates than the types then in use. The new filter consisted of 3 inches of 0.45 mm sand and 27 inches of 0.7 mm anthracite. This design was used in the construction of the filters for two new plants. These plants operated very successfully at high rates. Because of the success of the plants, it was decided to convert some of the older filters to the new type. However, this was done by removing all of the anthracite and all but 3 inches of the sand from the old filters and adding 27 inches of new anthracite. These filters did not produce good quality water unless additional alum and activated silica were used. The poor performance was found to have been caused by the method of sand removal. The top sand had been removed which contained a relatively large amount of fine material. The remaining sand had an effective size of about 0.59 mm. The performance of these filters was brought up to standard by the addition of sand of the proper size, (0.45 mm). Performance characteristics of two types of filters with different sand size are shown in Table II.

TABLE II

EFFECT OF SAND SIZE ON PERFORMANCE

<u>Filter Type No.</u>	<u>Sand e.s. mm</u>	<u>Rank Good Quality</u>	<u>Low Head Loss</u>
5	.45	5	4
6	.59	7	3

Depth of sand was 3 inches, depth of anthracite was 27 inches.

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During 1956 and 1957, a new chemical process was adopted to replace the alum-activated silica process. The new process consists of coagulation with alum followed by addition of a few parts per billion of a polyacrylamide to the water as it enters the filters. At about the same time, a number of the filters were changed to give a media consisting of 6 inches of 0.43 mm sand and 24 inches of 0.9 mm anthracite. The anthracite size in the filters was changed by adding coarse material and skimming off the fine materials from the surface of the filter beds. The results have been excellent. The converted filters have a practical capability of 6-8 gpm per sq. ft. depending on the flocculation and settling time and the size of the filter effluent piping. One filter was made of 1.3 mm anthracite and 0.43 mm sand. This filter was not as good as expected either in head loss or water quality. The sand and anthracite mixed together to such an extent that there was no distinct sand layer. In spite of the rather complete mixing, the filter ranked no. 1 in head loss and was acceptable in water quality. Performance data for filters made of different size anthracite are shown in Table III.

TABLE III

EFFECT OF ANTHRACITE SIZE ON PERFORMANCE

Filter Type No.	Anthracite		Rank	
	e.s. mm	u.c.	Good Quality	Low Head Loss
7	.7	2.0	4	5
8	.9	1.5	4	2
9	1.3	1.8	6	1

Depth of sand was 6 inches, depth of anthracite was 24 inches. Size of sand was 0.43 mm.

It will be noted from the tables that none of the filters are ideal. An ideal filter would rank first in both water quality and head loss. In the tables the filter that produced the best water had the worst head loss characteristics. The filter with the best head loss produced next to the worst water quality. However, the difference in water quality produced by all the filters shown in Table I except the one with 0.59 mm sand is so small that it is undetectable by the usual analytical methods. Only the light scattering microphotometer method used at Hanford is sensitive enough to show a difference in water quality among the other filters. All of the filters produced water containing less than 0.01 ppm turbidity on the Hanford scale. The Hanford scale is relative.⁽²⁾ An arbitrary calibration method was adopted in order to get the instruments into early use in the plants. The technical problems associated with absolute calibration still have not been solved. However, the absolute turbidity values are thought

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to be considerably higher than the reported relative values. The arbitrary calibration has been so useful and the plant operators have become so accustomed to the scale that it has not been changed since the initial calibration.

A value of 0.01 ppm on the Hanford scale cannot be detected by any other known instrument and cannot be detected by the naked eye when looking at a submerged clearwell light.

It will be noted from the tables that anthracite depth and size have a major effect on filter head loss. The length of filter run from the worst to best filter differs by a factor of over 3. The filter performance index of the best filter ranges from 600 to 2200 gallons per sq. ft., per ft. head loss.

ALUM FEED AND FILTER PERFORMANCE

A coarse grained filter media with a relatively high alum feed will produce a filtrate as clear as that produced by a fine grained media at a relatively low alum feed, until the filter breaks through. Unfortunately, high alum feed contributes to early filter breakthrough. The practical effect is that relatively high alum feeds cannot be tolerated if long filter runs and high filter rates are necessary. A filter must be selected which will make it possible to get good water at relatively low alum feed rates.

EFFECT OF FILTER CONDITIONERS ON FILTER PERFORMANCE

Breakthrough can be controlled if enough polyacrylamide or other filter conditioner, or activated silica is fed. These materials control breakthrough but increase filter head loss. For this reason a filter must be selected which will not require an excessive amount of these chemicals to control breakthrough.

In addition to controlling breakthrough, polyacrylamides or polysaccharides, when fed to the water as it enters the filter, cause a general decrease in filtrate turbidity, when flow rates and alum feeds are high. The polyacrylamides and polysaccharides cause an improvement in water quality and an increase in head loss which would not be considered normal for the filter media size used.

OPERATIONAL CONTROL

Properly made anthracite-sand filters provide a means for increasing water plant capacity without making any other basic plant changes. These filters cannot accomplish their purpose unless alum feed and polyacrylamide feed are controlled accurately and correctly.

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Primary emphasis is placed on systematic sampling of all filters and of the general plant effluents for turbidity with a light scattering microphotometer. (3) The analytical information is used to regulate the chemical feeds. Procedures have been worked out which allow the operators to produce filtered water to any reasonable specification with remarkable consistency.

Floc tests are no longer run for operational control because turbidity measurement of the filter effluent gives more reliable results.

AIR BINDING

The Columbia River water is saturated with air. This air causes short filter runs during a 4 to 8 week period every year. Enough air accumulates in the filter media to reduce runs to about one half of normal. The effect of the air can be reduced by removing from the filters all anthracite which passes a 20 mesh sieve. The air binding can be reduced by increasing the depth of water standing over the anthracite.

ANTHRACITE LOSS

Anthracite loss during backwash has been from 1 inch to 4 inches per year depending on the frequency of backwash. Most of the anthracite is lost during the period when air binding is a problem. It is thought that the air floats the anthracite out of the filters during backwash. The loss is not a serious problem either in terms of money or operating efficiency. The lost material is replaced every year or two. The annual cost of the anthracite is less than 10% of the annual cost of alum.

SAND LOSS

Some sand is lost through the underdrain system of some filters. The underdrain system consists of gravel and a Wheeler bottom. On some of the older filters, sand loss has increased to the point that replacement of the gravel is being considered. Lost sand has been replaced at an annual cost of less than 1% of the annual cost of alum.

MUD BALLS

The filters are equipped with rotary surface wash devices. These devices have been so successful that mud balls have not been found after 16 years of operation.

RELATIVE IMPORTANCE OF PROCESS STEPS

Based on numerous laboratory, pilot plant and full scale plant tests, as well as general operating experience, the process steps in water filtration of Columbia River water are listed in the order of their importance as follows:

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1. Alum Feed Control
2. Polyacrylamide Feed Control
3. Filtration
4. Flocculation
5. Settling

If the first three process steps are adequate, the last two are of minor importance. For this reason, both in plant design and in operation, the major emphasis is placed on the first three steps.

On a pilot plant scale it has been shown that when the first three steps are adequate, the last two steps can be eliminated without any effect except short filter runs. Hanford plant experience has confirmed the pilot plant work in the range of 30 minutes to 120 minutes flocculation and settling time.

GENERAL CONCLUSIONS

1. Filter media having the smallest particles produces the clearest filtrate when other conditions are equal.
2. Filter media having the largest particles in the top layer has the lowest rate of head loss increase.
3. Filters made of the proper sizes and depths of anthracite and sand together are superior to filters made of either material alone.
4. Chemical treatment has a greater effect on water quality and head loss than filter media composition or any other plant variable.

LIMITATION OF OBSERVATIONS

The observations made in this paper apply with certainty only to Columbia River water at Hanford. This raw water contains an average of about 100 ppm total dissolved solids. The organic content is relatively low. Turbidity of the raw water is usually low except during the spring. Extreme values of 1 ppm and 1600 ppm have been observed. Water temperatures are relatively cold, being below 10° C for several months every year.

ACKNOWLEDGEMENT

The good results obtained with the Hanford filter plants reflect the work of many individuals. Research and development work on this problem has been more or less continuous since 1943. At times as many as five engineers

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and chemists have devoted essentially full time to this problem. Over 20 individual engineers and chemists have made important contributions. Particularly noteworthy was the work of R. W. Pitman who made important contributions in developing adequate control methods and who also first discovered the action of polyacrylamides on filter performance.

The work of the operating personnel is equally noteworthy. The skill and effort of over 100 supervisors and operators made it possible to apply quickly the information developed by testing. In many cases, problems not discovered by testing appeared which threatened the success of operations. These problems were solved by the operating personnel. The overall success of the Hanford filter plants is witness to the good management and technical skill of the operating personnel.

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