

HIGH RATE FILTRATION PILOT TESTING FOR IRON REMOVAL

PRESENTATION FOR AWWA MEETING

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ABSTRACT

The Mt. Pleasant Water and Sewer Commission (Mt. Pleasant, South Carolina) since 1974 had been receiving numerous aesthetic quality complaints by customers served by the Snee Farm Water Plant. The plant has two (2) raw water aquifers; one aquifer was found to contain high fluoride concentrations. The second was high in iron and hydrogen sulfide concentrations for which the operators had no means of treating. Evaluation of the alternatives available resulted in a proposal to treat fluoride concentrations by blending the well waters and then treating the combined waters for iron and sulfide removal. The proposal resulted in pilot testing an iron oxidation-filtration treatment system at five times nominal filtration rates. The results were better than 98 percent iron removal and complete sulfide oxidation. Based on pilot test results, the South Carolina Department of Health and Environmental Control provided a variance for operation and construction of the Snee Farm treatment plant at iron removal filtration rates of ten gallons per square foot.

INTRODUCTION

The water plant discussed in this paper is in the Town of Mt. Pleasant, South Carolina, Water Plant Number III, more commonly referred to as the Snee Farm Plant (after the subdivision surrounding it). When first installed in 1972, it was owned by a private development company and was composed of four (4) shallow wells pumping to a 100,000 gallon storage tank and two (2) high service pumps delivering to a closed distribution system, without an elevated storage tank. The high service pumps were variable speed, pressure controlled, with lead and lag modes of control.

In 1974 the subdivision was incorporated into the Town of Mt. Pleasant, the Water and Sewer Commission assumed ownership of a water plant and its distribution system. The Snee Farm distribution system was connected with the Mt. Pleasant water distribution system. The Mt. Pleasant water system then consisted of two (2) other water plants and several elevated storage tanks. At that time, as now, all the distribution systems are connected to one another.

Continued community growth soon outstripped the water system capabilities, and four (4) additional shallow wells and an 1800 foot deep well were installed in 1976. At this time, the Snee Farm Plant was provided with additional capacity but still was without a treatment facility other than chlorination. The quality of water in this system was marginal at best. The shallow wells are high in iron and hydrogen sulfide with turbidity ranging from 1 NTU to as high as 100 NTU's. The blended chlorinated water lacks much in aesthetic value with objectionable taste and odors, and with a visible gray to pale brown tint. The iron/manganese concentrations are high enough to create objectionable deposits on pipes and plumbing. This resulted in a phosphate compound being used to attempt to sequester these contaminants.

After addition of the phosphate, continued customer complaints about discolored water and objectionable tastes and odors were received. Mt. Pleasant paid for numerous loads of laundry that had been "ruined" by the water and was continually fielding customer complaints, namely being blamed for illness, e.g., the canary died, the goldfish died, the house plant died, etc.

Despite the poor quality of the water, the surrounding Snee Farm community continued to grow and the pressure for acceptable water quality multiplied accordingly. A year ago, Mt. Pleasant decided the only solution was to build a water treatment plant that would improve the water quality.

Several alternatives for treatment processes compatible with the existing Snee Farm requirements were analyzed. Cost considerations for treatment and available funding limitations also were reviewed. The result of this study was a recommendation to further evaluate a proprietary system using high rate filtration supplied by Filtronics, Inc.

In February, 1982, a pilot plant to evaluate the high rate filtration system was set up. Tests were conducted for a period of four(4) days in cooperation with the South Carolina Department of Health and Environmental Control (DHEC). The performance of the pilot plant was excellent which ultimately resulted in design of the high rate filtration iron removal system.

As negotiations, engineering studies, and planning progressed, DHEC intervened concerning adequate water availability to the community versus community growth rate. The Snee Farm Plant capacity was stretched to near its maximum, and a moratorium on community growth was to be imposed if adequate water supplies were not soon found. As an interim measure, new sources were explored and Mt. Pleasant decided to drill three (3) new shallow wells for the Snee Farm System. This would increase its proposed 500 GPM pumping capacity to an 800 GPM capacity.

This resulted in an increase in high service pump capacities and an associated increase in the treatment capacity of the expanded Snee Farm treatment plant. Currently, the upgraded Snee Farm Plant is being constructed.

RAW WATER QUALITY

In order to resolve Snee Farm's water quality and quantity problems, several engineering analysis steps were taken prior to designing the expanded plant. These included observing the quality of the raw water, determining the quantity of water available, determining the most cost effective treatment method, pilot testing a new treatment method, and designing the facility.

The first step was to determine the compounds in the raw water which would require treatment in order that the finished water from the Snee Farm treatment system would meet current health and aesthetic standards. Since Snee Farm is supplied by two (2) well water sources, it was necessary to review the quality of both aquifers.

State and local quality records for both aquifers were reviewed and water samples were analyzed in order to qualify what was necessary for treatment requirements to meet the State Primary Drinking Water Regulations. ⁽¹⁾ In addition, some tests had been performed for proposed organic contaminant regulations by the EPA. The proposed organic contaminants were also reviewed.

Snee Farm is served by two (2) aquifers, one (1) deep well delivers water from the Black Mingo formation at a rate of 417 gallons per minute. The raw water from this aquifer is low in hardness (less than 60 ppm as CaCO₃) and meets all drinking water criteria, with the exception of fluoride. The fluoride concentration was found to be approximately 3.5 milligrams per liter (mg/l) which exceeded the State maximum contaminant level (MCL), of 1.6 mg/l.

The shallow wells (9 wells) deliver water from the Santee Limestone aquifer at a maximum rate of 285 gpm. The shallow wells were found to contain high concentrations of iron, hydrogen sulfide, and turbidity (Table I). These wells were the primary source of aesthetically unsuitable water in the Snee Farm area.

No trihalomethane (THM) concentrations were found to exceed regulation; however, THM were found during pilot tests and will be discussed later in this paper.

TABLE I

<u>Well Source</u>	<u>Compound Exceeding MCL</u>	<u>State & Secondary Primary MCL (mg/l)</u>	<u>Concentration Found (mg/l)</u>
Deep Well	Fluoride	1.6	3.5
Shallow Wells	Iron	0.3	0.1-10.0
	H ₂ S	TON 3.0*	0.3-1.0
	Turbidity	1.0	17.9

*TON = Taste and Odor Number

By adding additional shallow wells, it was determined the desired quantity of 800 gpm could be obtained and the fluorides in the deep wells could be blended to the desired fluoride concentration of 1.6 mg/l. In the blend of well waters; however, there still remained to be treated the iron, hydrogen sulfide, and turbidity. In order to accomplish this, it was necessary to evaluate alternative treatment methods for these compounds.

METHODS OF IRON TREATMENT

Iron occurs predominantly in natural waters, particularly in groundwater, as the soluble ferrous ion. Iron can occur in natural waters also in a complexed organic nature.

Several forms of treatment are available for iron removal. These include:

1. Stabilization with polyphosphates.
2. Ion exchange.
3. Precipitation and filtration.

As opposed to iron removal, iron may be stabilized by dispersion with polyphosphates in the treated water. Sodium hexametaphosphates have been used for this purpose using 5 mg/1 of phosphates per mg/1 of iron. However, this treatment does not appear to be applicable where iron exceeds a concentration of 1.0 mg/1. ⁽³⁾ Since the Snee Farm system at times appeared to exceed a 1.0 mg/1 concentration, and previous use of phosphate was not working well, this form of treatment did not appear to be applicable.

Iron may be removed by ion exchange medias. This practice is associated normally with treatment of waters for the removal of hardness. The Snee Farm waters could be softened with ion exchange media; however, this practice is expensive and normally not recommended for iron concentrations exceeding 0.5 mg/1. ⁽⁴⁾ The iron tends to cause the exchange media to loose its ion exchange capacity. Since Snee Farm iron concentrations exceeded 0.5 mg/1, this treatment was not recommended.

Iron may be oxidized to precipitate ferric hydroxide and subsequently removed by filtration. This type of treatment involves reacting iron with an oxidant, allowing a reaction time for the precipitation of ferric hydroxide, and subsequent filtration to remove the iron precipitant. Since this was the best treatment method available for Snee Farm and filtration is required for each oxidant, the question for Snee Farm is which was the most cost-effective oxidant and reaction system.

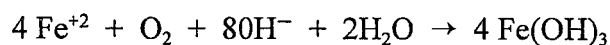
METHODS OF OXIDATION FOR IRON AND HYDROGEN SULFIDE

It was assumed that the iron content of the water exists as the ferrous ion and that iron is not organically complexed (true of most groundwaters). There are many oxidation methods available to oxidize ferrous iron to ferric hydroxide. Based on experience, the most cost-effective and common treatment methods are:

1. Aeration.
2. Chlorine addition.
3. Potassium permanganate addition.

AERATION

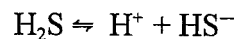
Oxidation of iron to ferric hydroxide can be accomplished by inducing dissolved oxygen into the water, whether by mechanical means or by cascading water over an air exchange medium. The following reaction takes place precipitating ferric hydroxide once the ferrous iron comes in contact with the oxygen:



The rate oxidation of iron is pH dependent and may vary in each instance due to organic complexing of the iron. The reaction rate is most rapid at a pH of 7.5. ⁽⁵⁾ Since the pH of the Snee Farm wells is between 7.6 and 7.8, it is assumed that the reaction will be complete in 15 minutes or less. Therefore, a minimum retention time of 15 minutes would be required prior to filtration. It should be noted that the reaction is subject to temperature and is frequently a slow reaction compared to other oxidants.

Following the oxidation reaction to ferric hydroxide and sufficient retention time, the precipitate may be removed by filtration. Conventional dual media filters may be used for this purpose. Addition of a small amount of coagulant may assist in the removal of the precipitant and associated turbidity.

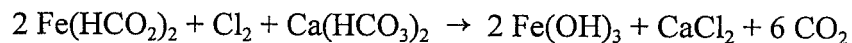
Hydrogen sulfide dissociates in water to the bisulfide ion as follows:



During the aeration process, only the sulfide present in the gaseous form is stripped from the water. However, the sulfide consistently will seek equilibrium, and with sufficient contact time all the sulfide may be removed.

CHLORINE ADDITION

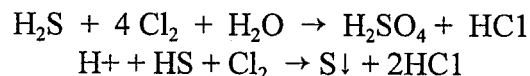
Another oxidation method which may be used is chlorine addition. Chlorine reacts with ferrous iron to precipitate ferric hydroxide by the following reaction:



The optimum pH for this reaction is 7.0. The reaction rate will vary with pH and temperature, taking up to (1) hour to totally react. Each part of iron oxidized requires 0.64 parts of chlorine. ⁽⁷⁾

Following precipitation of the iron, the ferric hydroxide will act as a coagulant and may be removed by filtration as previously described for the air oxidation system.

Chlorine also reacts with hydrogen sulfide. Unlike aeration, chlorine reacts with both the gaseous and bisulfide ion forms of sulfide. The reaction takes place to oxidize sulfide to elemental sulfur and sulfate by the following reactions:

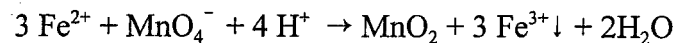


At a pH of 7.7, it is assumed that 6.4 parts of chlorine will be consumed by one part of sulfide. ⁽⁸⁾

The sulfide oxidation by chlorine may produce polysulfides which may contribute to taste and odor of the water. If polysulfides are produced as a byproduct, taste and odor control may be incorporated into the process by addition of sulfur dioxide, which reacts to form sulfate, eliminating the polysulfides. ⁽⁹⁾

POTASSIUM PERMANGANATE ADDITION

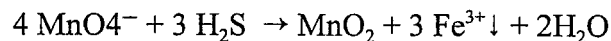
By the addition and mixing of potassium permanganate in the water stream, ferrous iron is precipitated as ferric hydroxide by the following reaction:



In theory, the reaction required 0.91 parts of potassium permanganate per part of iron. ⁽¹⁰⁾ The reaction is very rapid requiring less than 5 minutes for completion. In addition, the reaction takes place over a wide pH range.

Following precipitation of the ferric hydroxide, the water will require filtering for removal of the precipitant as previously discussed for the aeration and chlorine oxidation systems.

Hydrogen sulfide reacts with potassium permanganate yielding manganese dioxide, sulfate, and elemental sulfur.



In neutral mediums the reaction consumes 6.2 parts of potassium permanganate per part of sulfide. ⁽¹¹⁾ As the reaction shifts to an alkaline medium more sulfate is produced requiring increased dosages of permanganate.

When potassium permanganate is fed and common filter media is replaced by “Greensand” the system provides an additional operational capacity, because fluctuations in raw water iron concentrations are buffered by the “Greensand”. This eliminates the need for continuous permanganate feed adjustment during small iron concentration changes in the raw water. During periods of excessive iron the excess iron is oxidized by the “Greensand” and removed by the exchange medium. During periods of low iron concentration, the “Greensand” is regenerated by the excessive permanganate feed. This system provides excellent treatment when the raw water iron concentration fluctuates and the system receives little attention from the operator.

ELECTROMEDIA SYSTEM

All of the oxidation-precipitation processes require filtration for removal of iron in the water supply. Whether using conventional filter media or a “Greensand” media, KHEC limits the rate of filtration at a maximum of 3.0 gpm per square foot. Filtronics offers a system using “Electromedia” (proprietary design) which absorbs the oxidized iron on the surface of the filter media and permits rates up to 15.0 gpm per square foot.

The Electromedia system uses chlorine as an oxidant followed by sulfur dioxide addition for prevention of taste and odor byproducts. A one (1) minute retention time is allowed for both the chlorine and sulfur dioxide reactions, after which the water passes over the adsorptive filter media.

The filter run time depends upon the headloss accumulation, but is controlled not to exceed eight (8) hours. The time limit is set so the ferric hydroxide floc will not permanently adhere to the media.

The filter is backwashed at a rate of 20 gpm per square foot for a period of four (4) minutes. After backwash, the filter is purged (re-washed) for a period of one (1) minute, then returned to service.

Additionally, the chlorine feed system may be positively controlled by the use of a post filter chlorine residual analyzer which permits positive control of the chlorine feed system

The primary cost advantage of the Electromedia system is its high rate filtration capability. This reduces the filter media surface area required, ultimately reducing the capital cost of the equipment required.

COST EVALUATION OF METHODS

In comparing the treatment methods, it was assumed regardless of the methods involved, that the power and operating costs would remain the same. Therefore, comparisons were made based on the analysis of capital and chemical costs only.

As shown in Table II, the lowest chemical cost was with conventional aeration which included the addition of chlorine for disinfection only. The lowest capital cost was based on using the Electromedia system, which used less equipment and floor space as a result of the reduced filter surface area.

Based on an amortized cost analysis over a three (3) year period, it was determined that the Electromedia system should be pilot tested as it applied to the Snee Farm Treatment system.

TABLE II

COST ANALYSIS

	<u>Capital Cost</u>	<u>Annual Chemical Cost</u>	<u>Annual Cost</u>
Conventional Aeration	\$239,000	\$ 241	\$100,000
Conventional Chlorine	231,000	1,546	98,000
Permanganate Greensand	230,000	10,308	106,000
Electromedia	198,000	1,546	84,000

PILOT TESTS

In February, 1982, pilot tests were run on the Snee Farm system using an Electromedia pilot plant. Tests were conducted on the shallow wells, and a blend of both deep and shallow well waters at rates up to 15.0 gpm per square foot.

The pilot test unit consisted of the following:

1. Chlorine reaction vessel with approximately a one(1) minute detention time.
2. Sulfur dioxide reaction vessel with approximately a one (1) minute detention time.
3. Chlorine feed system.
4. Sulfur dioxide feed system.
5. One (1) pressure filter with a two (2) square feet surface area including Electromedia I filter media.
6. Automatic control valves.
7. Flow meters for filter rate of flow and backwash rate of flow.

Three (3) pilot filter runs were conducted over the course of a week. Each run consisted of filtering different combinations of deep and shallow well waters at filter rates from 10 to 15 gpm per square foot. The filter runs were conducted in periods up to eight (8) hours. After each run the filter was backwashed at a rate of 20 gpm per square foot for a period of four (4) minutes. Prior to initiating the next run, the filter was purged to waste (rewash) for a period of one minute. The filtering test runs and typical effluent analysis are shown in Table III.

TABLE III

<u>PILOT FILTER TEST RUNS</u>						
<u>Run</u>	<u>Filter Rate (gpm/ft²)</u>	<u>Length of Run (hrs)</u>	<u>Source Water</u>	<u>Chlorine Feed Rate (ppm)</u>	<u>Filtered Iron (ppm)</u>	<u>Filtered Turbidity (NTU)</u>
1.	15.0	5	Shallow Wells	2.1	0.05	0.30
2.	11.5	7-1/2	Shallow Wells	1.5	0.05	0.24
3.	10.0	8	Blended Water	1.0	0.05	0.25

The test results consistently showed that influent iron concentrations ranging from 0.6-2.8 mg/l were reduced to effluent concentrations below 0.05 mg/l. Chlorine feed rates are shown in Table III. All tests used a sulfur dioxide feed rate of 0.10 mg/l. Taste and odor tests of the effluent water indicated no taste or odor problems. Influent turbidities ranged from 0.88 to 15.7 NTU. These were consistently reduced to filter effluent turbidities ranging from 0.16 to 0.53 NTU. Typical test results are shown in Figures 1, 2 and 3.

During the course of the test runs, DHEC sampled simultaneous to field testing. Laboratory test analyses by DHEC confirmed field test results.

Following testing it was concluded that filtration rates up to 15 gpm per square foot would adequately treat the Snee Farm well waters for iron, taste and odor, and turbidity as originally desired. However, as a safety factor it was decided to design for a 10 gpm per square foot rate with provisions made for future rates up to 15 gpm per square foot.

TRIHALOMETHANES

During the course of pilot testing, filter effluent analyses unexpectedly showed high trihalomethane (THM) concentrations. Samples analyzed by DHEC resulted in a THM concentration of 138.8 micrograms per liter ($\mu\text{f}/1$) after a six (6) day formation potential test.

The maximum contaminant level (MCL) for the average concentration of THM's in the distribution system is not to exceed 0.10 milligrams per liter (mg/l) ($100 \mu\text{g}/1$) as established by the Environmental Protection Agency (EPA) and DHEC.⁽¹¹⁾ Since the sample taken by DHEC indicated high concentrations of THM's, a more definitive study was undertaken in the Snee Farm Water System.

The objectives of the study were twofold. First, to observe existing THM concentrations in the Mt. Pleasant water distribution system. Second, to insure the new high rate iron removal system proposed would not result in excessive THM concentration levels.

Figure -1
BLENDED WATER
10 GPM / sf

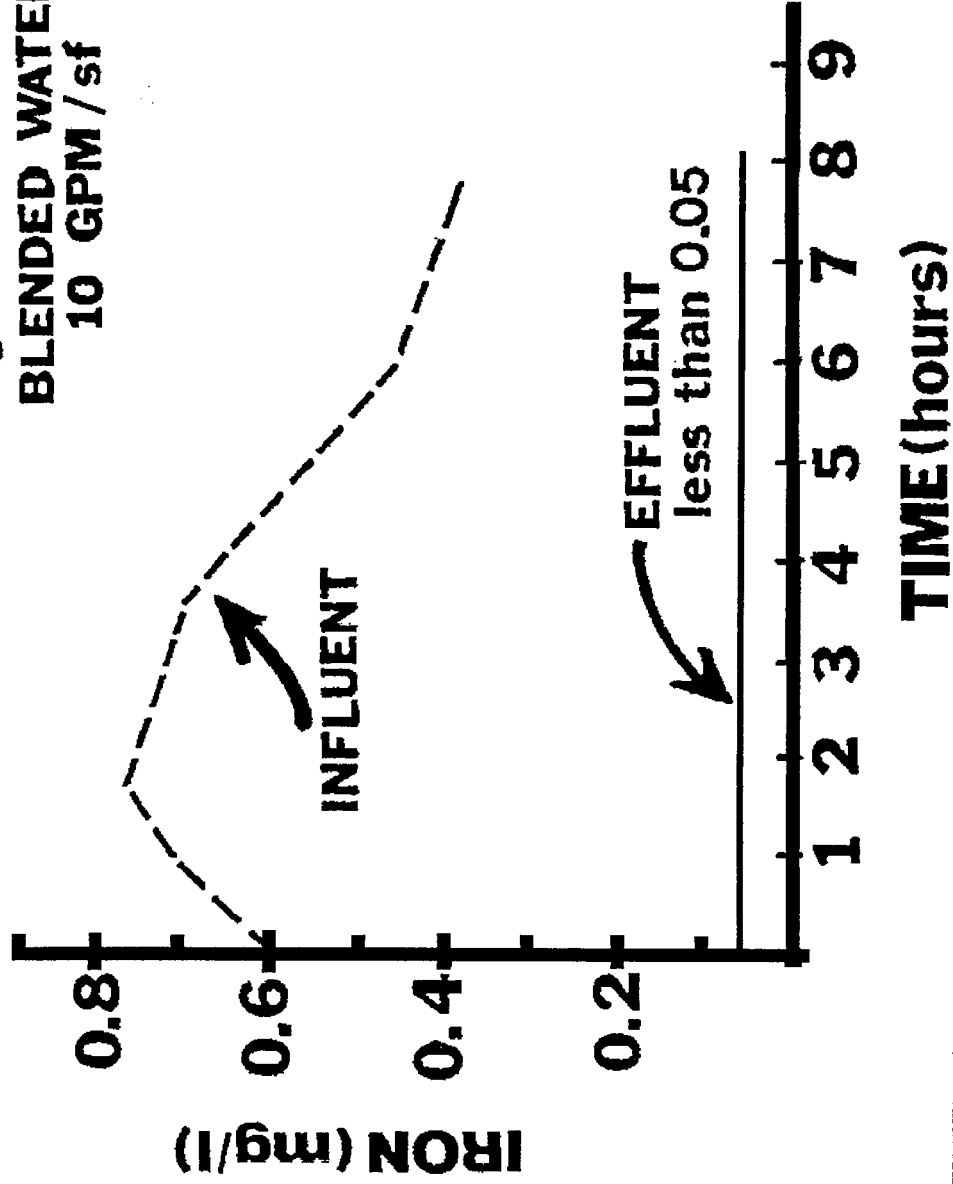


Figure - 2
SHALLOW WELLS
15 GPM\sf

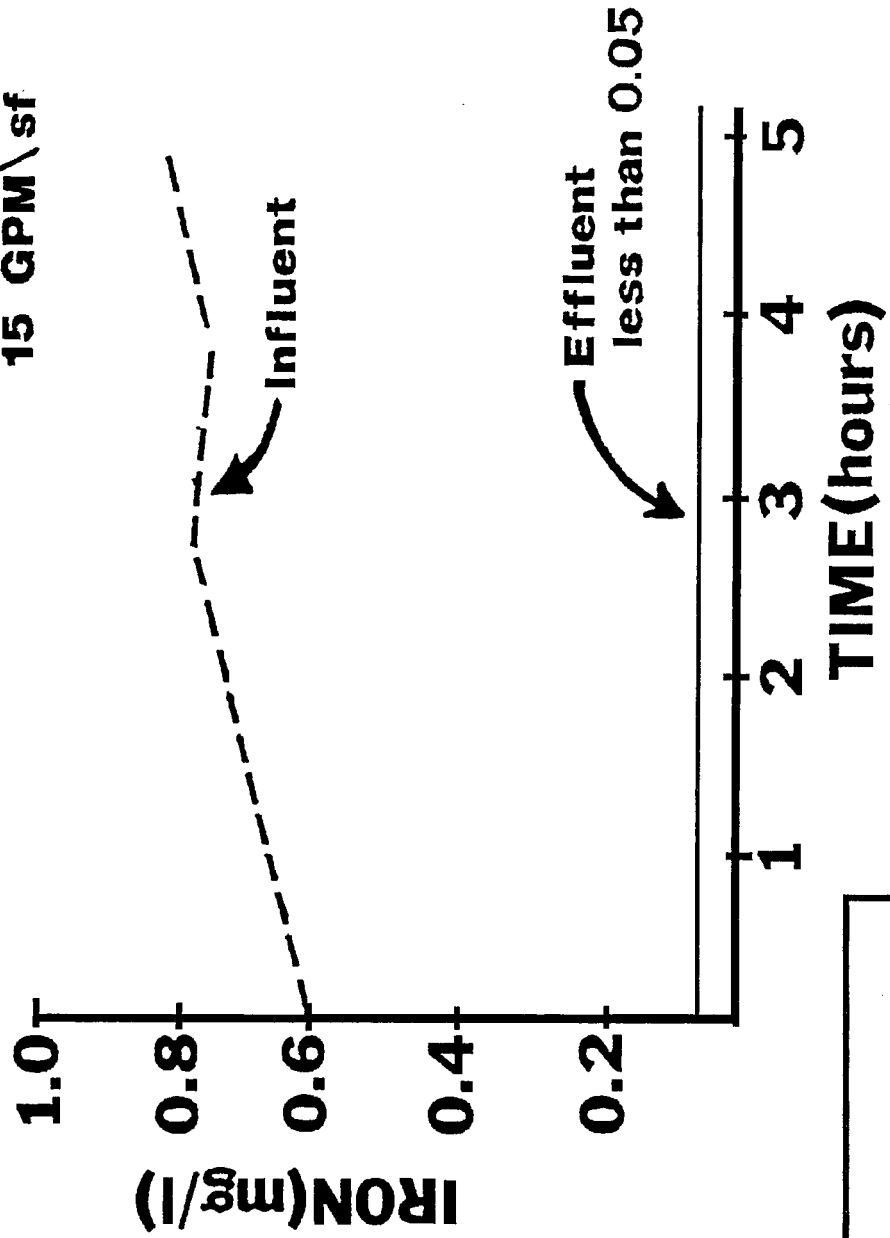
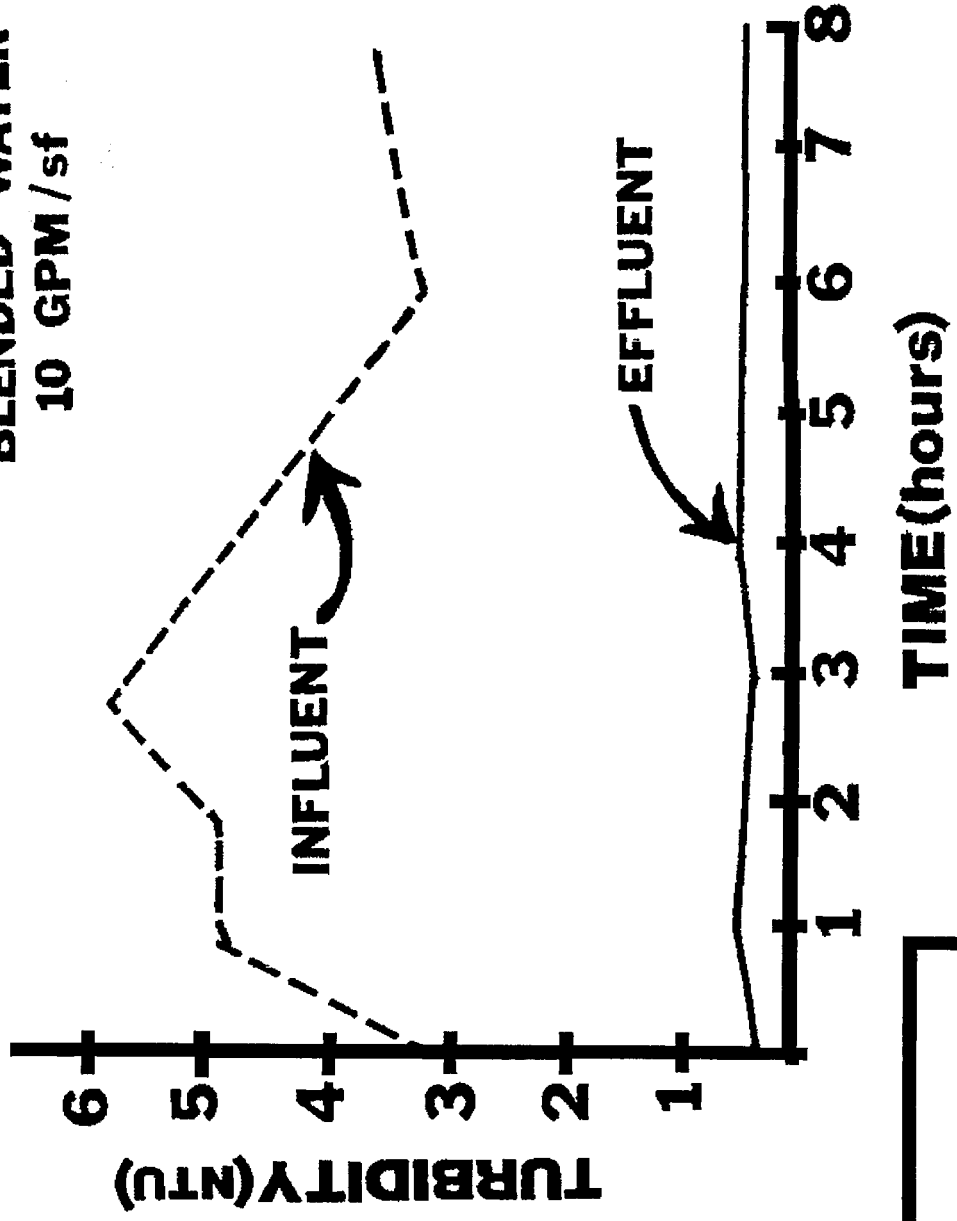


Figure - 3
BLENDED WATER
10 GPM/sf



THEORY

THM's in drinking water have been determined to be detrimental to human health.⁽¹¹⁾ As a result, the regulatory agencies have established 0.10 mg/1 as a MCL.

THM's are formed during the treatment process by the reaction of chlorine with naturally occurring organics in the raw water supply. These naturally occurring organics may be humic and/or fulvic acids or other compounds not yet determined. These compounds generally have become known as THM precursors.

THM's do not form instantaneously. Instead the chlorine-precursor reaction takes place over a period of time, proceeding rapidly at first, with a decreasing rate of reaction as time proceeds. Resulting THM concentrations are dependent upon pH, temperature, and retention time. Generally THM formation is only slightly dependent upon chlorine dose. Since free chlorine residuals generally are maintained in water treatment distribution systems, THM's are formed at the treatment plant and continue to form in the distribution system.⁽¹²⁾

For the foregoing reasons, regulations applicable to THM concentrations are determined in the distribution system. The method for determining THM concentrations in the distribution system have been established by the EPA. It requires collecting four samples per treatment plant, three samples representative of averaged, and again averaged for quarterly samples, the annual average concentration must be less than 0.10 mg/1.

SNEE FARM RAW WATER TRIHALOMETHANE FORMATION

Deep and shallow well THM raw water formation potential curves were developed for the Snee Farm System. The object of the test was to enable prediction of THM concentrations in the plant finished water.

On April 29, 1982, raw water samples were collected from the deep and shallow wells at Snee Farm. These samples were chlorinated with a free chlorine residual by the addition of calcium hypochlorite (30mg/1 dose). At periodic time intervals aliquots were taken and sodium thiosulfate was added to eliminate the free chlorine residual, thus stopping THM formations in the aliquots. The test results in instantaneous THM concentrations for a given water for the particular unit of time. The test results for the Snee Farm system are shown in Table IV.

The shallow well sample was collected with all the wells being on with the exception of Well No. 4. The THM formation results are plotted in figure 4, showing the time formation of THM's at Snee Farm. DHEC's sample results are shown on the plot and have been found to be consistent with the test results (sample taken during pilot study, 02/25/82). The test results also indicate no significant difference in the shallow and deep well THM formations; therefore, blending the water would not effect a change in finished water THM formations.

As shown in Figure 4, a detention time in the distribution system from the point of chlorine addition of less than 25 hours will result in THM concentrations less then 100 $\mu\text{g}/1$. Therefore, it remained to be determined if the average Snee Farm distribution system retention time was less then 25 hours. This is discussed later in the paper.

TABLE IV

SNEE FARM TRIHALOMETHANE FORMATION POTENTIAL

DEEP WELL

<u>SAMPLE</u>	<u>FREE CHLORINE RESIDUAL EXPOSURE (HRS)</u>	<u>THM CONCENTRATION (µG/1)</u>
1	0.083	12.9
2	0.25	17.8
3	1.0	34.3
4	7.75	51.0
5	21.25	85.3
6	70.75	68.8

SHALLOW WELL

<u>SAMPLE</u>	<u>FREE CHLORINE RESIDUAL EXPOSURE (HRS)</u>	<u>THM CONCENTRATION (µG/1)</u>
1	0.083	5.93
2	0.25	17.3
3	1.0	28.0
4	7.75	15.7
5	20.75	51.1
6	70.25	149.0

TRIHALOMETHANE IN MT. PLEASANT DISTRIBUTION SYSTEM

Five samples representative of each of three Mt. Pleasant water treatment systems were collected April 29, 1982. The object of the test was to determine the average THM concentration in each of the distribution systems.

Samples were collected in the distribution system from residential and commercial taps. After a sample was taken, soduim thiosulfate was added in order to maintain an instantaneous THM concentration until the sample was analyzed. The distribution system sampling results are shown in Table V.

As determined, the average concentration in each of the plant systems was approximately 8 µg/1 which is well below the established MCL for THM's. These concentrations were extremely low compared with DHEC's sample.

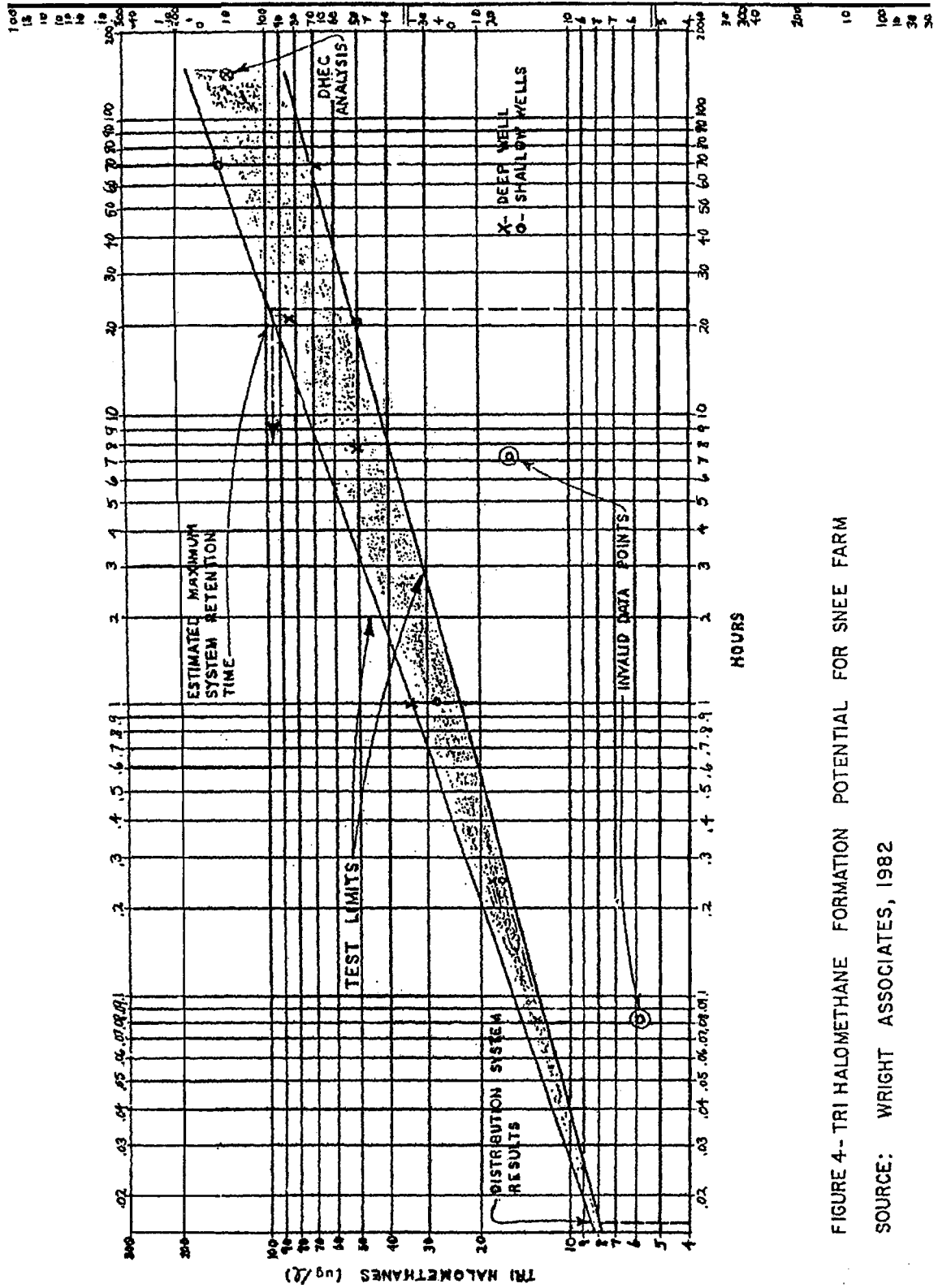


FIGURE 4- TRI HALOMETHANE FORMATION POTENTIAL FOR SNEE FARM
SOURCE: WRIGHT ASSOCIATES, 1982

SNEE FARM SYSTEM RETENTION TIME

One of the initial concepts of determining THM's in the Snee Farm distribution system was to obtain a relative approximation of the average retention time in the system. By plotting the average THM value against the formation potential curve, and approximate retention time is normally obtained. However, in this test, as shown in Figure 4, the method results in a retention time of 0.015 hours (0.9 min.). Obviously this retention period for Snee Farm is absurd.

TABLE V

DISTRIBUTION SYSTEM TRIHALOMETHANE CONCENTRATIONS

	<u>LOCATION</u>	<u>THM CONCENTRATION (μG/l)</u>
PLANT 1	Harbour Gate	4.6
	Live Oak	10.9
	North Point	5.14
	Sea Island	7.13
	-----	13.2
	Average	8.19
PLANT 2	Creekside	5.63
	Hardies	8.55
	Heritage	13.2
	Village	3.47
	Cooper Estates	11.0
	Average	8.37
SNEE FARM	Farm Quarter	7.24
	Candlewood	5.53
	Snee Farm Gardens	3.67
	Loyalist	13.9
	Casseque	9.64
	Average	8.0

What the results indicate is an insufficient contact period between the precursors and a free chlorine residual. The reason for the low THM concentrations in the distribution system has been determined. Ammonia is present in the raw water; therefore, when chlorine is added a combined residual occurs and a free chlorine residual never exists. Therefore, the THM concentrations currently found in Mt. Pleasant are very low. The proposed Filtronics system will not maintain a combined chlorine residual. Instead it will maintain a free chlorine residual; therefore, an approximate retention time for the proposed Snee Farm iron removal system was necessary. Assuming the plant will operate at a minimum of 500 gallons per minute (gpm) for a period of 16 hours per day, the average plant flow would be 333 gpm. This approximates the plant records which show a low consumption day of 470, 000 gallons.

The maximum system capacity, based on prechlorination prior to the Snee Farms ground storage tank is :

Ground Storage Tank	100,000 gallons
Elevated Tank	300,000
Estimated Piping	<u>50,000</u>
	450,000 gallons

Based on a flow of 333, the system's retention time is approximately 22.5 hours. As shown on Figure 4, this corresponds to a system THM average of 95 ug/l, which is below the MCL. In practice, the system's retention time probably will be less than calculated due to channelization and increased daily flow. Therefore, the THM concentrations are expected to be less than estimated here.

CONCLUSION

High rate filtration for iron removal proved to be a cost effective and viable alternative for the Snee Farm water treatment system. The system currently is being constructed for design filtration rates of 10 gpm per square foot for a capacity of 800 gallons per minute. It is anticipated that rates up to 15 gpm per square foot will be attainable for future expansion, with effluent iron concentrations less than 0.05 ppm.

In conjunction with the high rate filtration pilot test, results proved hydrogen sulfide test and odors would be reduced, the turbidity would be reduced to acceptable standards and the system could be easily operated.

Additional studies proved that although trihalomethanes were formed, the concentrations found in the distribution system would be less than the maximum contaminant level.

The plant currently is under construction with completion anticipated in the near future. Results of the study indicate the new plant will meet all drinking water standards and provide additional water for the City of Mt. Pleasant.

FOOTNOTES

- (1) S.C. Department of Health and Environmental Control, Division of Water Supply; "State Primary Drinking Water Regulation", May, 1981.
- (2) Environmental Protection Agency, Federal Register, February 7, 1978.
- (3) American Water Works Association, "Water Quality and Treatment", 3rd Edition, 1971, pp. 387-388.
- (4) Al-Layla, M.A.; Ahmad, S.; Middlebrooks, E.J., "Water Supply Engineering Design", Ann Arbor Sci, 1978, p.257.
- (5) American Water Works Association, "Water Quality and Treatment", 3rd Edition, 1971, pp. 390-392.
- (6) Environmental Protection Agency, "Sulfide Control in Sanitary Sewerage Systems", October, 1974.
- (7) White, G.C., "Handbook of Chlorination", Van Nostrand-Reinhold Co., 1972, pp. 208-210.
- (8) White, G.C., "Handbook of Chlorination", Van Nostrand-Reinhold Co., 1972, p.387
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- (10) Rubin, A.J., "Chemistry of Water Supply Treatment and Distribution", Ann Arbor Science, 1975, p. 129.
- (11) Environmental Protection Agency, Federal Register, November 29, 1979.
- (12) Symons, J.M.; "Interim Treatment Guide for the Control of Chloroform and Other Trihalomethanes", Report to Municipal Environmental Research Laboratory, Cincinnati, Ohio, 1976.