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AEC RESEARCH AND DEVELOPMENT REPORT

FINAL REPORT

PRODUCTION TEST NO. 105-473-P

THE USE OF ALUMINUM SULFATE FOR 100 AREAS'

PROCESS WATER COAGULATION

By

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FINAL REPORT
PRODUCTION TEST NO. 105-473-P
'THE USE OF ALUMINUM SULFATE FOR 100 AREAS'
PROCESS WATER COAGULATION

INTRODUCTION

Increases in power levels of the Hanford Piles have resulted in increased demands for process cooling water to the extent that the present filter plants are now operating at or above their design capacity. Further power level increases requiring even more cooling water may demand the operation of the filters considerably above design capacity. It has been proposed⁽¹⁾ that by the use of aluminum sulfate, or filter alum, as a process water coagulant and activated silica as a coagulation aid, the present filter plant capacities could be increased appreciably.

In order to investigate the effects of alum-treated water on pile operation, a full-pile production test⁽²⁾ was authorized in which alum was substituted for the standard ferric sulfate coagulant. This test was started in the 100-F Area on October 10, 1951. The results of the first thirty days of operation were presented in a previous report⁽³⁾ and served as a basis for the decision to proceed with installation of the activated silica addition facility. This report presents the data, results and conclusions obtained from the start of the test until its termination on December 28, 1951, when the addition of activated silica began.

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1. Atwood, J. M., "The Effects of Alum and Activated Silica on Process Water Treatment," HW-21756, July 30, 1951.
 2. Fryar, R. M., "P. T. 105-473-P, The Use of Commercial Aluminum Sulfate for 100 Areas' Process Water Coagulation," HW-21924, August 15, 1951.
 3. Woods, W. C. A., "Interim Report No. 1, P. T. 105-473-P, The Use of Aluminum Sulfate for 100 Areas' Process Water Coagulation, Results of First Operational Period," HW-22636, November 10, 1951.

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SUMMARY

Aluminum sulfate was substituted for the standard ferric sulfate type coagulant in the 100-F Area on October 10, 1951. The effects of this coagulant on filter plant operation, process water quality, and pile operation are presented for the entire operational period of the test from October 10 to December 28, 1951.

Filter plant operation was satisfactory throughout the test period. The length of filter runs was decreased to 15 - 18 hours because of severe aluminum breakthrough. Comparable filter run times were 40 - 50 hours with ferric sulfate operation in the other 100 Area water plants. A sufficient quantity of process water meeting present quality standards was produced without difficulty at all times.

The iron content of the process water was found to be consistently 50 - 75 per cent lower than that of the water produced in the 100-B water plant under similar conditions using ferric sulfate. The residual aluminum concentration was maintained between 0.05 - 0.10 ppm except for very short periods, and it was found possible to raise the allowable residual aluminum concentration to 0.20 ppm. A five-fold increase in the amount of suspended matter in the process water, from 0.02 to 0.10 ppm, was found in cotton plug filter tests, and was apparently due almost entirely to precipitated aluminum hydroxide. Both the iron and aluminum residual in the process water corresponded closely to that determined in the cotton plug test, while the iron residual in ferric sulfate-treated water was 3 - 5 times as great as that found in the cotton plug filters. This fact may partially explain the lack of film formation during the test.

The effects of alum-treated water on pile operation were analyzed from the important aspects of film formation, corrosion of process tubes and slugs, and 107-F Retention Basin effluent water radioactivity. Film formation was determined by process tube pressure drop measurements

and by panellit pressure data. These data indicated that film was removed during the first part of the test period, after which no more film formed. Preliminary laboratory data indicate that both 2S and 72S aluminum are more corrosion resistant to alum-treated water than to ferric sulfate-treated water. The effluent water activity decreased approximately 20 per cent below the value obtained with ferric sulfate treatment at equal power levels. This reduction was almost entirely a result of decreased gamma radiation, while the beta activity remained essentially constant.

It is concluded that with river water conditions similar to those given in this report sufficient process water to meet present demands and conforming to current quality standards can be produced using aluminum sulfate as a coagulant. Furthermore, the use of alum coagulated water containing a residual aluminum concentration of 0.05 - 0.10 ppm results in negligible film formation rates and lower 107 Retention Basin effluent water activity than with ferric sulfate-coagulated water. Process tube and slug corrosion rates may also be lower with alum-coagulated water.

Recommendations are made to continue the use of aluminum sulfate in 100-F Area using activated silica as a coagulation aid, under P. T. 105-503-E,⁽⁴⁾ and to study the film formation properties of alum-coagulated water.

DETAILS AND RESULTS

A. Filter Plant Operation

Analyses of the river water showed very little change in the quality of the raw water, and the temperature of the river showed the normal decrease from about 15°C to 7°C during the test period. Operation of the 183-F filter plant was normal throughout the test period. After more precise standards for the aluminum analytical method were established,

4. Fryar, R. M., "P. T. 105-503-E, The Use of Activated Silica as a Coagulation Aid for Aluminum Sulfate," HW-22755, November 19, 1951.

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the aluminum residual in the filtered water was found to be 5 - 7 times higher than previously reported, the correct amount being 0.05 - 0.10 ppm. Since there had been no apparent harmful effects on pile operation with this higher residual, a supplement to the production test was issued⁽⁵⁾ authorizing an increase in the allowable aluminum residual concentration from 0.05 ppm to 0.20 ppm. The higher aluminum residual permits the use of less aluminum sulfate, and a 50 per cent reduction in the amount of alum, from 25 to 12 ppm, was found to be possible. Since the coagulation process can then be carried out at a higher pH, the amount of lime added to the clearwells necessary to raise the pH to process standards was also reduced from 7.5 ppm to 3.0 ppm. Thus a considerable saving in operating cost was effected, and greater flexibility in the operation of the filter plant was permitted.

Table I gives the pertinent operating data for the 183-F Filter Plant. Operation of the similar 183-B Filter Plant with ferric sulfate coagulant is shown for comparison.

5. Woods, W. C. A., "P. T. 105-473-P, Supplement A, The Use of Commercial Aluminum Sulfate for 100 Areas' Process Water Coagulation," HW-22907, December 5, 1951.

TABLE I

	183-F Average [*] 11-9-51 to 12-28-51	183-B Average 11-9-51 to 12-28-51
<u>Normal Flow Rate, gpm</u> ^{**}	41,000	39,800
<u>Chemical Feed</u>		
Coagulant, ppm	12.8	3.5
Lime, ppm	3.0	0.6
<u>Filter Operation</u>		
Average filter rate, gpm/sq. ft.	2.85	2.80
Filter runs, hrs.	15	48
Head loss, ft.	3.4	7
Coagulation pH	7.4	7.8
<u>River Water Analysis</u> ^{***}		
Total Solids	91	89.0
pH	8.16	8.15
Iron	0.05	0.075
Turbidity	3.0	3.8
Manganese	0.009	0.012

* For operation previous to 11-9-51, see HW-22636

** Normal flow is the average flow rate excluding shutdown days

*** Concentrations expressed in ppm

Although the filter rates for both areas were very nearly the same, the length of filter runs in the 100-F Area were about one-third those in the 100-B Area. This reduction was necessary because of excessive breakthrough of aluminum from individual filters. In some cases, 0.3 - 0.6 ppm of aluminum were detected in the effluent from an individual filter before it was removed from service and backwashed.

B. Process Water Quality

The quality of the process water remained essentially constant throughout the entire test period. The one significant exception was a

noticeable reduction of the iron residual, which decreased gradually from about 0.015 ppm at the start of the test to 0.005 ppm after about forty-five days. This value was maintained during the remainder of the test. The iron concentration of the river water remained essentially constant throughout the test, as did the residual iron concentration in the 100-B process water.

Table II presents an average of the process water analyses from 100-F Area and a comparison with analyses from 100-B Area.

TABLE II

100-F AND 100-B PROCESS WATER ANALYSES*

11-9-51 to 12-28-51

	<u>100-F**</u>	<u>100-B**</u>
Total Fe	0.005	0.015
Total Al	0.05	---
pH	7.65	7.65
Sodium Dichromate	1.8	1.8
MO Alkalinity	56	56
Calcium	23	20
Magnesium	4.5	4.6
Sulfate	20	15

* For operation previous to 11-9-51, see HW-22636
 ** Concentrations expressed in ppm

In order to determine the presence of small amounts of uncoagulated turbidity in the process water, a small stream of process water is passed at a constant rate through a cotton plug filter until a sufficient amount of residue has been obtained. The filter is then removed and ashed, the residue analyzed, and the results calculated as parts per million in the process water. Immediately after the start of the test, these filters were found to contain about five times as much undissolved matter as had been previously experienced with ferric sulfate-coagulated water. Analysis showed that

this residue was principally aluminum, as hydrous aluminum oxide; iron in smaller amounts, as hydrous ferric oxide; and silica, probably as small, uncoagulated turbidity particles.

Comparison of the results of these tests with analyses of the process water showed that the amount of iron and aluminum in the residue from the filters corresponded within the analytical error to the amount of these materials in the process water. In ferric sulfate-treated water, however, the cotton plug iron is 1/3 to 1/5 of the process water iron. These results are shown in Table III.

TABLE III
COTTON PLUG AND PROCESS WATER ANALYSES*
Ferric Sulfate Coagulated Water

<u>IRON</u>			
<u>Dates</u>	<u>Area</u>	<u>Cotton Plug</u>	<u>Process Water</u>
7/13-8/23	100-F	0.004	0.015
8/23-9/11	100-F	0.006	0.015
10/10-10/30	100-B	0.006	0.020
11/7-11/12	100-B	0.003	0.020
11/21-12/5	100-B	0.006	0.020
8/25-9/13	100-H	0.004	0.020
10/11-10/25	100-H	0.008	0.020
11/23-12/6	100-H	0.008	0.020

* Concentrations expressed in ppm

TABLE III (Cont'd)
COTTON PLUG AND PROCESS WATER ANALYSES*

Alum Coagulated Water, 100-F

<u>Dates</u>	<u>Cotton Plug</u>	<u>Process Water</u>	<u>Cotton Plug</u>	<u>Process Water</u>
10/24-10/31	0.009	0.009	----	----
11/1-11/9	0.009	0.008	----	----
11/10-11/20	0.006	0.007	0.03**	0.01**
11/21-12/4	0.002	0.008	0.02**	0.01**
12/5-12/14	0.008	0.009	0.10	0.07
12/14-12/29	0.004	0.005	0.04	0.05

*Concentrations expressed in ppm

**Analyses in error

The time intervals shown give the length of a cotton plug filter run. The values for process water were calculated on the same time basis.

It can be shown by simple solubility product calculations that both the iron and aluminum in process water are not present to an appreciable extent in ionic form. They are, in fact, present as colloidal or suspended hydrous oxides, as is demonstrated by the fact that they can be removed in the cotton plug filter. Thus, these results show that the iron residue present in alum-treated water is apparently much larger in physical size than in ferric sulfate water and this size difference is a result of the water treatment process. This fact, together with the smaller iron residual concentration, may be at least a partial explanation of the lack of film formation encountered at the F-Pile, especially since iron has been found to be a major constituent of film.

C. Pile Operation

The most important aspect of this production test was the determination of the effects of alum treated water on pile operation. It was anticipated before the start of the test that the principal effects would be a change in film formation rates and in the radioactivity of the 107-F Retention Basin effluent water. Corrosion was not believed to be a problem, and preliminary laboratory data obtained during the course of the test tended to confirm this contention.

The rate of film formation can be measured by the change in the pressure drop through a process tube, that is, by the increase in pressure difference between a point immediately downstream from the orifice, and the outlet nozzle. Tube pressure drop data can be obtained at the F-File on eight central zone tubes. Daily pressure drop data, converted to standard temperature and flow conditions, are shown in Figure 1. Since the outlet pressure remains essentially constant, an increase of panellit pressure will also serve as an indication of film formation. Daily panellit pressure readings for each orifice zone are presented in Figure 2. These pressures are an average of a number of tubes in each zone, which were distributed throughout each zone in order to obtain a representative average over the pile.

Both sets of data show the usual increase in pressure drop and panellit-pressure due to film formation when ferric sulfate-coagulated water was used from August 25 through October 9. Since the start of the production test on October 10, 1951, at least some of the film present on the tubes was removed during the period between October 10 and about November 15, 1951. Thereafter, no significant change took place, with the exception of the period between November 20, and December 4, 1951, showing that the ferric sulfate type film was not replaced by a new type of film peculiar to alum-treated water. It was not necessary to purge at any time during the eleven-week test because of these favorable film formation rates.

FIG. 1
105-F TUBE PRESSURE DROPS
○--○ SERIES 1
□--□ SERIES 2

FIG. 2
105-F PANELLIT PRESSURES
GAPS IN CURVES INDICATE DOWNTIME

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Although the mechanism of film formation has not been definitely established, the best theory available explains the deposition of the film as a result of electrostatic attraction between the negative charge on metal surfaces in contact with flowing water, and positively charged colloidal particles of iron and other materials. If the size of the particles is greatly increased, the surface-area-to-mass ratio will be decreased. Since the charges on the particle are on the surface, the charge-to-mass ratio is likewise greatly decreased. Thus, it would be expected the particles would not be deposited to as great extent by virtue of their decreased charge-to-mass ratio and increased momentum in the flowing stream.

Figure 3 shows the iron concentration in the process water, iron concentration as determined by cotton plug analyses, and process tube pressure drop data. It can be seen that between August 25 and September 15, 1951, there was about 0.009 ppm difference between the process water iron and the cotton plug iron. During this period, film formation rates as measured by tube pressure drop increase were about 0.7 psi/day. During the period between September 15 and October 9, 1951, the pile did not operate continuously for long enough periods of time to establish film formation rates. No cotton plug analyses were available between September 18 and October 24.

During the period October 24 to November 20, the two iron analyses agreed very closely, and a decrease in tube pressure drop of about 0.4 psi/day was observed. Between November 20 to December 4, 1951, the pressure drop increased slightly, and the iron analyses were different by 0.006 ppm. After December 4, 1951, until the termination of the test, the pile did not operate continuously for sufficiently long periods of time to accurately establish pressure drop data. The data obtained show that the pressure drop remained essentially constant, and the two iron analyses also agreed very closely. It would thus appear that the physical size of the iron particles may be more important from a film formation aspect than

FIG. 3
PROCESS TUBE PRESSURE DROP
PROCESS WATER IRON CONCENTRATIONS

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the concentration of the iron, especially in view of the two-fold variation in iron concentration during the course of the test. Thorough investigations of the colloidal properties of the iron and aluminum residuals resulting from the two treatment methods may result in a better understanding of the film formation problem.

The gamma activity of the 107-F Retention Basin effluent showed a similar decrease throughout the test period, although there was little change in the beta activity. These data are shown in Figure 4. The sudden increase in both total activity and gamma activity between November 14 and 23, 1951, is due to a change in 107 Building basins. Radioactive sludge present in the bottom of the basin placed in service November 14, 1951, was distributed in the water during this period. As soon as this sludge was eliminated from the basin the activity readings returned to normal.

Preliminary laboratory corrosion data were obtained during the test.⁽⁶⁾ These results were obtained in a reflux type test using boiling water, and are shown in Table IV.

TABLE IV

CORROSION RATES OF SLUG JACKET ALLOY AND 72S IN
FERRIFLOC AND ALUM COAGULATED PILE PROCESS WATER

<u>Material</u>	<u>Corrosion Rate, mils/month</u>	
	<u>Alum Water</u>	<u>Ferric Sulfate Water</u>
Slug Jacket Alloy	0.0135	0.0250
72S Aluminum	0.0177	0.0783

Neither material showed visible evidence of corrosion in alum-treated water, while both showed dark corrosion product films in ferric sulfate-

6. R. S. Dalrymple to R. M. Fryar, "Corrosion of Aluminum in Alum Coagulated Process Water," HW-23314, January 22, 1952.

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treated water. These data should be used only for comparison, and are not indicative of corrosion rates which may be obtained in flowing systems. In-pile corrosion data are not yet available because of insufficient exposure time.

CONCLUSIONS

On the basis of the data presented in this report, the following conclusions can be made concerning the use of filter alum as a process water coagulant.

1. Present demands for process water meeting current quality standards can be produced by the present 100-Area filter plants with river water conditions similar to those in this test.
2. The presence of 0.05 - 0.10 ppm aluminum in the process water is not detrimental to pile operation.
3. Film formation rates are negligible compared to those obtained with ferric sulfate-coagulated water.
4. The total activity of the effluent water from the 107 Retention Basin is lower for the same power level than with ferric sulfate water.
5. The corrosion of process slugs and tubes may be less than in ferric sulfate water.

RECOMMENDATIONS

The following recommendations are made:

1. The use of alum as a process water coagulant should be continued on a production test basis in 100-F Area with the addition of activated sodium silicate as a coagulation aid.
2. A fundamental study of the film-forming properties of alum-treated water should be initiated to determine the reason for the negligible film formation rate when using this type of water.

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