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**Y-12 DEVELOPMENT DIVISION
TECHNICAL PROGRESS REPORT**

Part 6 - Environmental Technology

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HIGHLIGHTS

OXIDATION OF DEPLETED URANIUM CHIPS

Pilot tests have shown that controlled amounts of depleted uranium titanium chips can be safely oxidized in the existing equipment. Recommended operational procedures have been issued. (Page 6)

REMOVAL OF IRON FROM THE INFLUENT OF THE Y-12 STEAM PLANT WASTEWATER TREATMENT FACILITY

Soluble iron is occasionally emitted from the Steam Plant Wastewater Treatment Facility. Studies have been completed to begin developing a removal method using aeration, hydrogen peroxide, or sodium hypochlorite. Collected data suggest that adding to the facility influent a strong oxidizing agent, such as hydrogen peroxide or sodium hypochlorite, should increase the efficiency of iron removal in the facility processes; aeration of the influent should also be beneficial. (Page 15)

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ENVIRONMENTAL TECHNOLOGY

OXIDATION OF DEPLETED URANIUM CHIPS

Y. C. Childs, B. C. Padgett, H. E. Devaney, and C. W. Hancher

Summary

Shallow land burial in Bear Creek Burial Ground (BCBG) of depleted uranium and uranium alloy chips was discontinued. These materials are now being processed at the Uranium Chip Oxidation Facility (UCOF). Some of the depleted uranium chips, formerly taken to BCBG, were oxidized in 5-, 10-, 15-, and 20-lb batches to determine the optimal processing weight that would reduce the overall flameout frequency to one that complies with UCOF safety documentation. The goal of the Y-12 Plant Development Division was to reduce the flameout frequency to 1%. Batches of uranium-titanium alloy mill, mixed, and suspect chips were also processed at UCOF using modified operating procedures. Most of the depleted uranium and uranium alloy chips, except for the sawfines, were safely oxidized at UCOF with a minimum number of flameouts.

Definitions

Binary chips are made of uranium-niobium alloy.

Button-cut chips are made when "hogging" the billet. They are only produced during the machining of uranium-titanium alloy with a special tool bit. Typically, these chips are 15 mils thick, rough, broken, jagged, and steel gray.

Finished-cut chips are made from the last cut on a billet. Usually they are 5 mils thick or less, smooth, and black.

Mill-cut chips are rough cut from the milling operation. They are short, thick, curly chips that vary in thickness between 15 and 25 mils. They are usually steel gray to black.

Mixed-uranium chips result from the machine vacuum or machine cleaning operation. Their thickness ranges from 1 to 25 mils, and they are charcoal gray to black. Sometimes they are referred to as "sludge."

Ribbon-cut chips are rough cut and made when machining uranium or uranium alloy. They are typically 15 mils thick and have smooth turnings. They are the same as button-cut chips except that ribbon-cut chips are smooth.

Semicut chips are cut between a button cut, ribbon cut, and finished cut. These chips are between 5 and 15 mils thick and smooth. They may be black and shiny.

Suspect chips are finished-cut uranium or uranium-niobium alloy chips suspected of producing a flameout during the chip oxidation process.

Introduction

It was known that burial of chips would soon be unacceptable. Therefore, UCOF has begun to eliminate this practice temporarily until a recycle program is in force. On September 30, 1988, an explosion occurred at UCOF during the processing of a drum of uranium-titanium alloy chips. As a result of this incident, which did not cause any injuries and resulted in only minor damage to equipment, it was decided that all uranium-titanium alloy chips and any other type of depleted uranium chip suspected to produce a flameout or explosion will be buried in BCBG. To comply with recent changes in environmental regulations and to maximize the operation of UCOF, shallow land burial of depleted uranium chips was discontinued effective September 1, 1989. For each type of depleted uranium chip that was disposed of in BCBG, the Development Division was asked to perform field tests to identify the operating parameters that will produce minimal flameouts during the oxidation process at UCOF.

Some of the depleted uranium chips suspected of producing flameouts (suspect drums) during the oxidation process, uranium-titanium alloy chips, depleted uranium mill chips, and depleted uranium mixed chips from the machine cleaning operation were set aside for processing by Y-12 Plant Development Division personnel. The daily routine processing operation sequence has been modified for the oxidation of these chips. Suspect chips and uranium-titanium alloy chips will be shipped to UCOF in 55-gal drums. The chips will be separated on the drain table and placed into a 5-gal bucket that contains ~4 L of sanitary water. A predetermined amount of chips based on the material type will drain for 8 min and then be processed as specified in UCOF operating procedures. This experiment began with the processing of chips in 5-, 10-, and 20-lb batches to identify the maximum amount that will not produce a flameout and to ensure that the frequency of flameout complies with the UCOF safety documentation probability table.

Prior Work

Development work pertaining to the controlled oxidation of depleted uranium chips has been previously reported.¹

Presentation of Experimental Work

On August 1, 1989, Development Division personnel began processing suspect uranium chip drums. Five suspect drums of chips were chosen by UCOF operations personnel. Y-12 Development Division personnel began their operation by removing one of the drums from the metal skid that had been used to transport the drums. Next the drum was placed into a drum dumper, which hydraulically lifts and empties the drum. The liquid contained in the drum for transportation and storage was removed during

this operation. The chips were visually inspected while they were sitting on the uranium-chip feed table. Meanwhile, 4 L of water was placed in each of the 18 5-gal buckets used in this experiment. The 5-gal bucket with water was weighed and the scale zeroed so that each bucket of chips could be measured. The chips were then separated into 5-gal bucket aliquots. The weight of the buckets of chips varied between 3 and 6 lb. After all the chips had been placed into several 5-gal buckets, they were processed in 10-lb batches.

The operation began with the staging and processing of chip drums 86, 549, 242, 405, and 534 from Building 9201-5W machine shop. Each drum was drained, and the contents were divided into 5-gal buckets. Each batch of chips was drained for 8 min instead of the normal drain time of 4 min.

The data for the first day are noted in Table 1. No flames were observed. The data were evaluated, and it was decided that finished-cut and semicut chips would continue to be processed in 10-lb batches. On the second day of testing, uranium-titanium alloy chips were received at the facility. The chips were staged and processed as previously stated. One drum of uranium-titanium alloy button-cut chips produced a 1-ft flameout; however, this flame can be attributed to the adherence to and ignition of the button chips on the tray. The data for the second day are noted in Table 2. Testing continued through August 9, 1989, with the initial operating parameters. The data listed in Table 3 were evaluated, and it was agreed that the Development Division would continue these tests until a statistically acceptable frequency of flameouts was reached.

Table 1. Chip oxidation test day 1

Batch No.	Shop	Chip type	Chip cut	Chip drum No.	Chip weight (lb)	Description	Final temperature (°F)	Flame
1	9201-5W	D-38	Semi	86	9.6	Black, curly	275	No
2	9201-5W	D-38	Semi	86	12.3	Black, curly	176	No
3	9201-5W	D-38	Finished	549	9.9	Black, curly	387	No
4	9201-5W	D-38	Finished	549	8.0	Black, curly	157	No
5	9201-5W	D-38	Finished	549	9.0	Black, curly	365	No
6	9201-5W	D-28	Finished	242	10.1	Black, fine	273	No
7	9201-5W	D-38	Finished	242, 405	11.4	Black, fine	291	No
8	9201-5W	D-38	Finished	242, 405	11.8	Black, fine	401	No
9	9201-5W	D-38	Finished	405	9.8	Black, fine	253	No
10	9201-5W	D-38	Finished	405, 534	10.7	Black, fine	251	No
11	9201-5W	D-38	Finished	534	11.0	Black, fine	342	No
12	9201-5W	D-38	Finished	534	11.6	Black, fine	252	No

After the first 70 tests, some of the chip batch sizes were redefined. It was decided that 15-lb loads of suspect drums of U and U-Nb alloy chips, 15-lb loads of U-Ti semicut chips, and 10-lb loads of U-Ti button-cut chips would be oxidized. Testing proceeded, and flameouts with the uranium-titanium alloy chips continued. It was decided that the uranium-titanium alloy chips would be processed in 5-lb increments. Data through August 31, 1989, are detailed in Table 4 for tests 71 through 131.

Table 2. Chip oxidation test day 2

Batch No.	Shop	Chip type	Chip cut	Chip drum No.	Chip weight (lb)	Maximum temperature (°F)	Flame
13	9201-5W	D-38	Finished	266	10.6	158	No
14	9201-5W	D-38	Finished	266	10.2	399	No
15	9201-5W	D-38	Finished	266	9.0	173	No
16	9201-5W	D-38	Finished	266	9.6	169	No
17	9201-5W	D-38	Finished	329	9.6	345	No
18	9212	U-Ti	Button	470	9.9	470	No
19	9212	U-Ti	Button	557	9.0	278	No
20	9212	U-Ti	Button	557, 410	11.2	215	No
21	9212	U-Ti	Button	410	10.4	230	No
22	9212	U-Ti	Button	410	9.7	356	No
23	9212	U-Ti	Button	410	12.3	344	No
24	9212	U-Ti	Semi	585	11.0	219	No
25	9212	U-Ti	Semi	585	2.7	122	No
26	9212	U-Ti	Button	387	8.2	478	No
27	9212	U-Ti	Button	387	9.1	299	No

On August 31, 1989, the data were reevaluated to determine whether the batch sizes needed to be changed to reduce further the number of flameouts. At this time, charge sizes were limited to 10 lb for U and U-Nb alloy chips, 5 lb for U-Ti finished-cut chips, 5 lb for U-Ti semicut chips, and 5 lb for U-Ti broken chips. It was also decided that the Development Division will process mill chips and mixed-uranium chips in 5-lb batches until operational experience indicated that more or less of these materials should be oxidized in each batch. After a couple of days of processing mill chips, it was determined that they would be processed in 20-lb batches instead of 5-lb batches.

Flameouts continued to be a problem with the finished-cut chips. Also, on several occasions the machine shops mixed finished-cut chips with semicut chips. During the oxidation of this mixture, no flameouts occurred. Development Division personnel decided to try this technique with all the finished-cut chips, adding 2 lb of finished-cut chips to a drum of chips not composed of uranium-titanium alloy. No flameouts resulted from this mixture. The remaining data through September 22, 1989, are given in Table 5 for tests 132 through 253.

Results

Fifteen flameouts occurred during the Development Division tests at UCOF from August 1, 1989, to September 22, 1989. Most uranium-titanium alloy chips, except for the finished-cut chips, can be oxidized in 5-lb increments. Chip type D-38 and binary mill chips can be oxidized in 20-lb increments, uranium-titanium alloy semicut chips in 10-lb increments, and mixed-uranium chips in 5-lb increments with minimal chance of a flameout. Ten of the 15 flameouts occurred while oxidizing finished-cut chips. All types of finished-cut chips can produce a flameout during the oxidation process with as little as 4.8 lb of chips. It is believed that the finished-cut chips can be oxidized with a minimal number of flameouts if they are placed in a drum of chip type D-38 or binary rough-cut chips.

Table 3. Chip oxidation test data from August 1, 1989, to August 9, 1989

Batch No.	Chip type	Chip cut	Chip weight (lb)	Maximum temperature (°F)	Flameout	Observations
1	D-38	Semi and rough	9.60	275	No	None
2	D-38	Semi and rough	12.30	176	No	None
3	D-38	Finished	9.90	387	No	None
4	D-38	Finished	8.00	157	No	None
5	D-38	Finished	9.00	365	No	None
6	D-38	Finished	10.10	273	No	None
7	D-38	Finished	11.40	291	No	None
8	D-38	Finished	11.80	401	No	None
9	D-38	Finished	9.80	253	No	None
10	D-38	Finished	10.70	251	No	None
11	D-38	Finished	11.00	342	No	None
12	D-38	Finished	11.60	252	No	None
13	D-38	Finished	10.60	158	No	None
14	D-38	Finished	10.20	399	No	None
15	D-38	Finished	9.00	173	No	None
16	D-38	Finished	9.60	169	No	None
17	D-38	Finished	9.60	345	No	None
18	U-Ti	Button	9.90	470	No	None
19	U-Ti	Button	9.00	278	No	None
20	U-Ti	Button	11.20	215	No	None
21	U-Ti	Button	10.40	230	No	None
22	U-Ti	Button	9.70	356	Yes	Flameout
23	U-Ti	Button	12.30	344	No	None
24	U-Ti	Semi	11.00	219	No	None
25	U-Ti	Semi	2.70	122	No	None
26	U-Ti	Button	8.20	478	No	None
27	U-Ti	Button	9.10	299	No	None
28	U-Ti	Button	9.30	256	No	None
29	U-Ti	Semi	9.80	286	No	None
30	U-Ti	Semi	9.20	173	No	None
31	U-Ti	Button	9.50	268	No	None
32	U-Ti	Semi	10.70	495	Yes	Flameout
33	U-Ti	Semi	20.70	199	No	None
34	U-Ti	Button	10.20	244	No	None
35	Binary	Semi	7.90	218	No	None
36	U-Ti	Button	8.40	195	No	None
37	U-Ti	Button	8.40	163	No	None
38	U-Ti	Semi	19.20	384	No	None
39	U-Ti	Semi	22.70	310	No	None
40	U-Ti	Button	9.90	442	No	None
41	U-Ti	Button	9.20	506	No	None
42	U-Ti	Button	9.60	409	No	None
43	D-38	Finished	20.00	323	No	None
44	D-38	Finished	22.10	441	Yes	Flameout
45	U-Ti	Button	4.70	162	No	None
46	D-38	Finish	21.60	342	No	None
47	U-Ti	Button	10.50	151	No	None
48	U-Ti	Button	10.00	195	No	None
49	U-Ti	Button	10.00	339	No	None
50	U-Ti	Button	10.00	323	No	None
51	U-Ti	Button	10.20	196	No	None
52	U-Ti	Button	10.00	181	No	None
53	U-Ti	Button	10.10	175	No	None
54	U-Ti	Button	10.00	228	No	None
55	U-Ti	Button	10.50	219	No	None
56	U-Ti	Button	9.80	357	Yes	Flameout
57	U-Ti	Button	9.50	214	No	None
58	U-Ti	Button	9.80	218	No	None
59	U-Ti	Button	9.10	192	No	None
60	U-Ti	Button	9.90	222	No	None
61	U-Ti	Button	9.80	297	No	None
62	U-Ti	Button	10.20	479	No	None
63	U-Ti	Button	10.40	434	No	None
64	U-Ti	Button	9.90		No	None
65	U-Ti	Button	9.50		No	None
66	U-Ti	Button	10.50	151	No	None
67	U-Ti	Button	10.00	195	No	None
68	U-Ti	Button	10.00	339	No	None
69	U-Ti	Button	10.00	323	No	None
70	U-Ti	Button	10.20	196	No	None

Table 4. Chip oxidation test data from August 10, 1989, to August 31, 1989

Batch No.	Chip type	Chip cut	Chip weight (lb)	Maximum temperature (°F)	Flameout	Observations
71	U-Ti	Button	10.00	239	No	None
72	U-Ti	Button	10.20	386	No	None
73	U-Ti	Button	10.40	468	Yes	Flameout
74	U-Ti	Button	10.00	310	No	None
75	U-Ti	Button	12.60	429	No	None
76	U-Ti	Button	10.60	540	No	None
77	D-38	Finished	9.20	221	No	None
78	U-Ti	Finished	12.50	678+	Yes	Flameout
79	U-Ti	Finished	9.50	599	Yes	Flameout
80	U-Ti	Button	11.30	277	No	None
81	U-Ti	Button	10.90	229	No	None
82	U-Ti	Button	11.10	468	No	None
83	U-Ti	Button	9.90	250	No	None
84	U-Ti	Button	5.50	163	No	None
85	U-Ti	Ribbon	3.20	127	No	None
86	U-Ti	Semi	6.10	196	No	None
87	D-38	Finished	19.10	292	No	None
88	D-38	Finished	19.00	194	No	None
89	U-Ti	Finished/semi	6.00	175	No	None
90	U-Ti	Finished/semi	5.20	176	No	None
91	U-Ti	Finished/semi	5.70	201	No	None
92	D-38	Finished	23.50	830	No	None
93	U-Ti	Semi/ribbon	23.00	220	No	None
94	U-Ti	Semi/ribbon	21.50	160	No	None
95	D-38	Finished	23.00	690	Yes	Flameout
96	D-38	Finished	5.70	315	No	None
97	D-38	Finished	8.90	222	No	None
98	D-38	Finished	10.00	215	No	None
99	U-Ti	Semi	8.10	174	No	None
100	D-38	Finished	12.60	725	Yes	Flameout
101	U-Ti	Semi	7.60	307	No	None
102	U-Ti	Broken/button	9.70	142	No	None
103	U-Ti	Broken/button	9.80	116	No	None
104	U-Ti	Broken/button	11.90	238	No	None
105	U-Ti	Semi	9.70	137	No	None
106	U-Ti	Semi	12.90	145	No	None
107	U-Ti	Semi	22.90	300	No	None
108	U-Ti	Semi	18.00	180	No	None
109	D-38	Finished	28.50	215	No	None
110	D-38	Finished	20.00	208	No	None
111	D-38	Finished	22.00	240	No	None
112	U-Ti	Semi	5.70	142	No	None
113	U-Ti	Semi	5.50	158	No	None
114	U-Ti	Semi	5.80	149	No	None
115	U-Ti	Semi	3.10	139	No	None
116	D-38	Finished	7.80	656	Yes	Flameout
117	U-Ti	Semi/rough	4.20	121	No	None
118	U-Ti	Finished	5.00	452	Yes	Flameout
119	U-Ti	Semi/rough	4.00	125	No	None
120	U-Ti	Finished	4.90	361	Yes	Flameout
121	U-Ti	Finished	5.70	416	No	None
122	U-Ti	Semi/rough	5.10	368	Yes	Flameout
123	U-Ti	Finished	4.80	398	Yes	Flameout
124	U-Ti	Semi/rough	4.60	134	No	None
125	U-Ti	Finished	4.50	252	No	None
126	U-Ti	Semi/rough	5.30	230	No	None
127	U-Ti	Semi/rough	5.90	325	No	None
128	U-Ti	Semi/rough	4.90	351	No	None
129	U-Ti	Semi/rough	5.00	119	No	None
130	U-Ti	Semi/rough	5.00	134	No	None
131	U-Ti	Semi/rough	5.40	227	No	None

Table 5. Chip oxidation test data from September 1, 1989, to September 22, 1989

Batch No.	Chip type	Chip cut	Chip weight (lb)	Maximum temperature (°F)	Flameout	Observations
132	U-Ti	Finished	6.20	766	Yes	Double Flameout
133	Binary	Mill	4.90	111	No	None
134	U-Ti	Mixed	3.00	100	No	None
135	U-Ti	Mixed	3.30	104	No	None
136	D-38	Mill	4.20	110	No	None
137	U-Ti	Semi	6.40	139	No	None
138	Binary	Mill	4.80	111	No	None
139	D-38	Mill	5.30	116	No	None
140	D-38	Mill	4.00	113	No	None
141	U-Ti	Mixed	6.50	113	No	None
142	U-Ti	Semi	6.60	146	No	None
143	U-Ti	Mixed	3.50	113	No	None
144	Binary	Mill	4.90	104	No	None
145	Binary	Mill	3.50	100	No	None
146	U-Ti	Semi	4.00	168	No	None
147	Binary	Mill	5.50	113	No	None
148	Binary	Mill	5.50	117	No	None
149	Binary	Mill	5.20	113	No	None
150	D-38	Mill	5.40	115	No	None
151	Binary	Mill	5.40	115	No	None
152	Binary	Mill	4.80	104	No	None
153	D-38	Mill	4.00	112	No	None
154	Binary	Mill	5.20	119	No	None
155	Binary	Mill	5.30	110	No	None
156	Binary	Mill	5.30	112	No	None
157	Binary	Mill	4.90	110	No	None
158	Natural uranium	Rough/semi	35.00	189	No	None
159	U-Ti	Finished/semi	6.90	123	No	None
160	U-Ti	Finished/semi	5.00	121	No	None
161	U-Ti	Finished/semi	4.60	125	No	None
162	U-Ti	Finished	4.50	284	No	None
163	U-Ti	Finished	4.30	228	No	None
164	U-Ti	Semi	5.60	154	No	None
165	U-Ti	Finished/semi	5.60	118	No	None
166	U-Ti	Semi	5.10	181	No	None
167	U-Ti	Finished/semi	5.20	403	No	Flameout
168	U-Ti	Finished/semi	4.90	464	No	None
169	U-Ti	Semi	5.20	121	No	None
170	U-Ti	Semi	5.20	123	No	None
171	U-Ti	Semi	4.70	199	No	None
172	U-Ti	Semi	5.60	140	No	None
173	U-Ti	Button	5.80	158	No	None
174	D-38	Ribbon	6.00	149	No	None
175	U-Ti	Button	5.40	203	No	None
176	U-Ti	Button	5.40	204	No	None
177	U-Ti	Ribbon	7.00	251	No	None
178	U-Ti	Ribbon	7.90	222	No	None
179	U-Ti	Button	4.90	176	No	None
180	U-Ti	Button	4.90	166	No	None
181	U-Ti	Button	5.00	153	No	None
182	U-Ti	Button	5.00	207	No	None
183	U-Ti	Button	5.10	182	No	None
184	U-Ti	Semi	5.40	116	No	None
185	U-Ti	Semi	6.70	127	No	None
186	U-Ti	Button	5.10	185	No	None
187	U-Ti	Button	5.50	187	No	None
188	U-Ti	Button	5.50	186	No	None
189	U-Ti	Button	5.00	122	No	None
190	U-Ti	Finished	2.00	286	No	None
191	U-Ti	Finished	2.00	251	No	None
192	U-Ti	Finished	2.00	290	No	None
193	U-Ti	Finished	2.20	210	No	None
194	U-Ti	Finished	2.20	284	No	None
195	U-Ti	Finished	2.00	234	No	None

Table 5. (Continued)

Batch No.	Chip type	Chip cut	Chip weight (lb)	Maximum temperature (°F)	Flameout	Observations
196	U-Ti	Finished	2.50	390	No	None
197	U-Ti	Button/Finished	4.10	127	No	None
198	U-Ti	Button	5.60	117	No	None
199	U-Ti	Button	5.50	186	No	None
200	U-Ti	Button	6.20	219	No	None
201	U-Ti	Button	6.30	304	No	None
202	U-Ti	Rough	5.70	114	No	None
203	U-Ti	Rough	6.00	118	No	None
204	U-Ti	Rough	6.00	120	No	None
205	U-Ti	Rough	5.30	120	No	None
206	U-Ti	Rough	5.30	123	No	None
207	U-Ti	Rough	6.70	125	No	None
208	U-Ti	Rough	5.20	127	No	None
209	U-Ti	Rough	5.30	133	No	None
210	U-Ti	Rough	5.80	135	No	None
211	Binary	Mill	16.40	173	No	None
212	Binary	Mill	15.50	199	No	None
213	U-Ti	Button	5.50	137	No	None
214	D-38	Mixed	2.50	124	No	None
215	U-Ti	Semi	3.10	108	No	None
216	U-Ti	Semi	5.00	142	No	None
217	U-Ti	Button	5.80	149	No	None
218	U-Ti	Button	5.00	168	No	None
219	U-Ti	Button	5.20	267	No	None
220	U-Ti	Button	6.30	134	No	None
221	U-Ti	Button	5.50	140	No	None
222	D-38	Mixed uranium	5.20	132	No	None
223	U-Ti	Button	5.10	154	No	None
224	D-38	Mixed uranium	6.10	133	No	None
225	U-Ti	Mixed uranium	5.10	150	No	None
226	D-38	Mixed uranium	5.10	130	No	None
227	U-Ti	Mixed uranium	5.10	122	No	None
228	U-Ti	Mixed uranium	5.20	124	No	None
229	U-Ti	Mixed uranium	5.10	108	No	None
230	U-Ti	Mixed uranium	5.00	124	No	None
231	U-Ti	Mixed uranium	5.50	140	No	None
232	U-Ti	Mixed uranium	5.30	113	No	None
233	U-Ti	Mixed uranium	5.40	144	No	None
234	U-Ti	Mixed uranium	5.30	130	No	None
235	U-Ti	Ribbon	6.40	139	No	None
236	U-Ti	Ribbon	6.40	139	No	None
237	U-Ti	Ribbon	6.40	138	No	None
238	U-Ti	Ribbon	5.70	124	No	None
239	Binary	Mixed uranium	6.50	114	No	None
240	Binary	Mixed uranium	5.00	114	No	None
241	Binary	Mixed uranium	5.10	112	No	None
242	Binary	Mixed uranium	5.40	118	No	None
243	Binary	Mixed uranium	7.10	130	No	None
244	Binary	Mixed uranium	6.50	119	No	None
245	U-Ti/Binary	Mixed uranium	3.20	114	No	None
246	Binary	Mixed uranium	4.40	134	No	None
247	Binary	Mixed uranium	5.00	120	No	None
248	Binary	Mixed uranium	5.00	133	No	None
249	Binary	Mixed uranium	4.50	112	No	None
250	U-Ti	Button mix	3.90	142	No	None
251	U-Ti	Button mix	5.00	172	No	None
252	U-Ti	Button mix	5.60	228	No	None
253	U-Ti	Button mix	5.00	205	No	None

Conclusions

On the basis of the experimental data, the following conclusions can be made:

1. Most chips of uranium-titanium alloy, except for finished-cut chips, can be oxidized in 5-lb increments with minimal chance of a flameout.
2. Semicut chips of uranium-titanium alloy can be oxidized in 10-lb batches with minimal chance of a flameout.
3. Mixed-uranium chips (sludge) can be oxidized in 5-lb increments with minimal chance of a flameout.
4. Mill-cut chips can be oxidized in 20-lb increments with minimal chance of a flameout.
5. Finished-cut chips that were placed in 2-lb drums containing rough-cut chips, chip type D-38, and binary chips did not produce a flameout.
6. One way that larger quantities of chips of uranium-titanium alloy and finished-cut chips will be able to be processed is by using a spin dryer to remove some of the entrained liquid, which burns and produces a flameout.

Future Work

Future studies of oxidizing finished-cut chips mixed with rough-cut chips will be made to determine whether a statistically satisfactory flameout frequency can be reached. The removal of entrained water from chips of uranium-titanium alloy and finished-cut chips will be evaluated when the prototype spin dryer is fabricated to determine whether large quantities of these materials can be processed with a minimal probability of producing a flameout. Processing the materials discussed in this report will continue until enough data are gathered to support the recommendations of the UCOF safety documentation.

REMOVAL OF IRON FROM THE INFLUENT OF THE Y-12 STEAM PLANT WASTEWATER TREATMENT FACILITY

H. E. Devaney

Summary

It was hypothesized that iron ions of two oxidation states, ferrous (Fe^{2+}) and ferric (Fe^{3+}), were included in the influent to Steam Plant Wastewater Treatment Facility (SPWTF). The Fe^{3+} ions readily formed insoluble ferric hydroxide [$\text{Fe}(\text{OH})_3$] when subjected to the high pH (~ 10.5) of the facility neutralization tanks, whereas the Fe^{2+} ions formed slightly soluble ferrous hydroxide [$\text{Fe}(\text{OH})_2$], therefore increasing the iron contamination in the facility effluent. Experimental matrices shown in Tables 6-9 were designed. Seventy-five experiments were performed to investigate the effects of attempts to oxidize the Fe^{2+} ion to the Fe^{3+} ion in the SPWTF influent by aeration, the addition of hydrogen peroxide (H_2O_2), a combination of the previous two, and the addition of sodium hypochlorite (NaOCl). The SPWTF plant processes were then simulated, and the resulting effluents were sampled for cation analyses. Results from colors of resulting precipitates and filtrates and analytical data on filtrates suggested a positive effect of H_2O_2 addition, NaOCl addition, and aeration on the simulated SPWTF processes.

Introduction

In early 1988, SPWTF was placed into operation to purify six waste solution streams emitted by the Y-12 Steam Plant before releasing them to the East Fork of Poplar Creek. As seen from Fig. 1, the waste streams are as follows:

1. boiler blowdown,
2. boiler drainage,
3. ion exchange regeneration waste,
4. carbon filter backwash,
5. demineralizer regeneration waste, and
6. coal pile runoff.

As Fig. 1 shows, SPWTF collects the six waste streams in two concrete basins; feeds the waste to two neutralization tanks, where a calcium hydroxide [$\text{Ca}(\text{OH})_2$] slurry is added until the solution reaches a pH of ~ 10.5 ; and precipitates many of the cation contaminants (mostly consisting of iron). The waste slurry is pumped to a mixing tank, where a polymer is added, and is then passed on to a Limella Clarifier. Sludge settles to the bottom of the clarifier, and the treated waste solution passes to a final pH adjusting tank, where the pH is adjusted from ~ 10 to ~ 7 with the addition of sulfuric acid. The iron concentration of the effluent is frequently monitored. If it is < 1.0 mg/L, it is released into the East Fork of Poplar Creek. If the iron concentration is > 1.0 mg/L, the solution is recycled through the treatment plant. The waste sludge collects on a cylindrical vacuum filter and is transported to the burial ground.

Table 6. Experiments for the investigation of the effects of aeration and H₂O₂ on feed samples A and B

Experiment No.	Quantity of H ₂ O ₂ added	Solution aerated	pH after adjusting with Ca(OH) ₂
1B (A)	None	No	None added
2B	None	Yes	None added
3B	None	No	7 to 8
4B	None	Yes	7 to 8
5B (A)	None	No	10 to 11
6B	None	Yes	10 to 11
7B	0.3 mL of 10%	No	7 to 8
8B	0.3 mL of 10%	Yes	7 to 8
9B	0.3 mL of 10%	No	10 to 11
10B	0.3 mL of 10%	Yes	10 to 11
11B	0.2 mL of 30%	No	10 to 11
12B	0.6 mL of 30%	No	10 to 11
13B	0.2 mL of 30%	Yes	10 to 11
14B	0.6 mL of 30%	Yes	10 to 11
15B	None	No	None added
16B	Blank sample; ~50 mL of ~6 M hydrochloric acid		

Since its startup in early 1988, SPWTF has experienced periods of effluent iron concentration that exceeded the Y-12 Plant National Pollution Discharge Elimination System (NPDES) Permit No. TN 0002968, Discharge No. 503, which allowed the effluent to be contaminated with no more than 1.0 mg/L of iron. Table 10, which is a tabulation of effluent data taken from NPDES discharge reports during 8 months in 1988, shows that the iron concentration varied from a maximum of 3.78 mg/L to a minimum of <0.01 mg/L. The problem was brought to the attention of the Y-12 Plant Development Division Environmental Group in early 1989, and an investigation was begun.

Presentation of Experimental Work

Referring to Tables 6 through 9, the four experimental matrices tabulated were followed in explaining the possibility of decreasing the iron concentration of the SPWTF effluent by oxidizing Fe²⁺ ions that may exist in the influent to the Fe³⁺ state, which would form a more insoluble precipitate, Fe(OH)₃, when processed by the facility. An initial influent sample A was taken from the SPWTF south basin and was used in the first two experiments, 1A and 5A (see Table 6). Sample A was too dilute in contaminants; therefore, feed samples (B, C, D, and E) for the remaining experiments were taken from the coal pile runoff ditch (see Fig. 1), which yielded solutions much higher in contaminant concentrations.

Table 7. Experiments for investigating effects of aeration and H_2O_2 on feed sample C

Experiment No.	Quantity of 30% H_2O_2 added (mL)	Solution aerated	pH after adjusting with $Ca(OH)_2^a$
17C	None	No	None added
18C	None	Yes (60 min)	5
19C	None	Yes (60 min)	6
20C	None	Yes (60 min)	7
21C	None	Yes (60 min)	8
22C	None	Yes (60 min)	9
23C	None	Yes (60 min)	10
24C	None	Yes (60 min)	11
25C	0.6	No	5
26C	0.6	No	6
27C	0.6	No	7
28C	0.6	No	8
29C	0.6	No	9
30C	0.6	No	10
31C	0.6	No	11
32C	0.6	Yes (60 min)	8
33C	0.6	Yes (60 min)	10
34C	0.6	Yes (60 min)	11
35C	None	No	None added
36C	None	Yes (24 h)	6
37C	None	Yes (24 h)	10

^apH adjusted with 15% $Ca(OH)_2$.

For each experiment, 1 L of coal runoff solution was measured into an Erlenmeyer flask containing a magnetic stirrer. The pH of the solution was initially recorded and continuously monitored throughout the experiment. For experiments calling for the addition of H_2O_2 or $NaOCl$, the reagent was added and the pH recorded; for those requiring aeration, the solution was then aerated for the required time. For solutions requiring pH adjustment with $Ca(OH)_2$, the reagent was added until the required pH was attained. All treated influents were vacuum filtered through a 1/4-in.-thick layer of filter aid on Whatman No. 40 filter paper. The filtrates were collected in 1-L polyethylene bottles, and the precipitates were held in separate polyethylene bags. Each filtrate was filtered through a ceramic filter and its volume measured. The collected precipitate remaining in the original storage bottle and that on the ceramic filter were dissolved in hydrochloric acid. The solution volume was measured and added to the original filtrate. The diluted, acidified solutions were sampled for cation analyses.

Table 8. Experiments for investigating effects of aeration and H₂O₂ on feed sample "D"

Experiment No.	Quantity of 30% H ₂ O ₂ added (mL)	Solution aerated	pH after adjusting with Ca(OH) ₂ ^a
38D	None	No	None added
39D	None	Yes (60 min)	5
40D	None	Yes (60 min)	6
41D	None	Yes (60 min)	7
42D	None	Yes (60 min)	8
43D	None	Yes (60 min)	9
44D	None	Yes (60 min)	10
45D	None	Yes (60 min)	11
46D	0.6	No	5
47D	0.6	No	6
48D	0.6	No	7
49D	0.6	No	8
50D	0.6	No	9
51D	0.6	No	10
52D	0.6	No	11
53D	0.6	Yes (60 min)	8
54D	0.6	Yes (60 min)	10
55D	0.6	Yes (60 min)	11
56D	None	No	None added
57D	None	Yes (24 h)	6
58D	None	Yes (24 h)	10

^apH adjusted with 15% Ca(OH)₂.

Results

The analytical data of all experiments performed on the collected influent feed samples appear in Tables 11, 12, 13, and 14. As noted before, five feed samples (A, B, C, D, and E) were used in the experiments; tests 1A and 5A were run on sample A, which was taken from the SPWTF South Basin. Sample A was too dilute for a worst-case analysis; therefore, the remaining tests were performed using feed samples B, C, D, and E, which were taken from the coal pile runoff collection ditch (see Fig. 1). Following is a discussion of the collected experimental data.

Processed Feed Sample B (Table 11). Sample B was amber and had a pH range from 2.42 to 2.70. It contained 744 mg/L of iron, 89.9 mg/L of aluminum, 1.4 mg/L of nickel, 3.4 mg/L of zinc, and other impurities. When the sample was aerated without any additional treatment, no changes were observed. A pH adjustment to 7, with aeration, reduced the iron to a level of 2.4 mg/L, but left an amber color. The aluminum and other

Table 9. Experiments comparing the effects of H_2O_2 and NaOCl on feed sample E.

Experiment No.	Quantity of 5% NaOCl added (mL)	Quantity of 30% H_2O_2 added (mL)	pH after adjusting with $Ca(OH)_2^a$
59E	None	None	None added
60E	1.0	None	6
61E	0.5	None	6
62E	2.0	None	6
63E	3.0	None	6
64E	4.0	None	6
65E	5.0	None	6
66E	None	0.1	6
67E	None	0.2	6
68E	None	0.4	6
69E	None	0.8	6
70E	None	1.6	6
71E	None	1.6	10
72E	None	None	6
73E	None	None	10
74E	2.0	None	10
75E	2.0	None	11

^apH adjusted with 15% $Ca(OH)_2$.

impurities were effectively removed at a pH of 7 to 8. When the pH was raised from 10 to 11, the iron was removed to <0.3 mg/L, but the aluminum level remained at 2.2 to 3.2 mg/L. Adding H_2O_2 at a pH of 10 to 11 removed the iron to <0.7 mg/L, but the aluminum remained at 1.4 to 5.9 mg/L. In general, samples that were not oxidized with H_2O_2 yielded precipitates that were olive green when $Ca(OH)_2$ was added. At pH levels >10 , the precipitation of solids appeared to be complete as compared with other tests. Tests using H_2O_2 gave a deep amber precipitate, which was indicative of a $Fe(OH)_3$ solid. At a pH of 7 to 8, a slight greenish tint was noticed in the filtrates, but the water was clear at a pH of 10 to 11.

Processed Feed Sample C (Table 12). Sample C was unique compared with samples A, B, D, and E. It was mostly clear with a slight greenish tint, whereas A, B, D, and E had a strong amber color indicative of a high Fe^{3+} concentration. Its color probably resulted from the fact that it was taken ~24 h after a moderate rainfall and was probably very dilute in Fe^{3+} ions. Experimental results suggested that most of the iron present in the sample was in the Fe^{2+} state. Its pH ranged from 2.70 to 2.92. It contained 205 mg/L of iron, 30 mg/L of aluminum, 0.6 mg/L of nickel, and other contaminants.

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FLWSHEET FOR STEAM PLANT WASTEWATER TREATMENT FACILITY

Fig. 1. Flowsheet for Steam Plant Wastewater Treatment Facility.

Table 10. Iron concentration of SPWTF effluent taken from NPDES^a discharge monitoring reports

Time period		Iron concentration (mg/L)		
From	To	Minimum	Average	Maximum
4-1-88	4-30-88	0.10	0.20	0.30
5-1-88	5-31-88	0.10	0.20	0.30
6-1-88	6-30-88	<0.01	<0.11	0.40
7-1-88	7-31-88	0.07	0.46	3.78
8-1-88	8-31-88	0.10	0.20	0.40
9-1-88	9-30-88	0.10	0.40	0.70
10-1-88	10-31-88	0.10	0.20	0.30
11-1-88	11-30-88	0.10	0.50	3.10

^aNational Pollution Discharge Elimination System.

The main objectives of processing sample C were to explore the effects of aeration, H₂O₂ addition, and pH variation with calcium hydroxide Ca(OH)₂ on the removal of iron from the influent. All tests that were aerated produced the dark green precipitate of probable Fe(OH)₂, therefore indicating very little oxidation of Fe²⁺ to Fe³⁺ even after a 24-h aeration period. A pH of ~9 was required to remove the iron in aerated samples to a level below the detection limit of 0.1 mg/L. Specimens to which H₂O₂ had been added produced very dense amber precipitates of probable Fe(OH)₃, even at a pH as low as 5, at which the iron level was undetectable. In general, the simulated effluents from the aeration tests had a green tint, and those from the H₂O₂ tests were clear, indicating very efficient precipitation of iron with H₂O₂. Because of the amphotonic nature of aluminum, its concentration varied, reaching a high of 3.14 mg/L at a pH of ~10. Magnesium reached an undetectable concentration at a pH of 11. Other cation contaminants were mostly precipitated completely as the pH was increased.

Processed Feed Sample D (Table 13). Sample D was deep amber, which was indicative of a high Fe³⁺ concentration. It contained 674 mg/L of Fe, 117 mg/L of Al, 265 mg/L of Mg, 2.6 mg/L of Ni, and other contaminants. The pH of the sample ranged from a low of 2.51 to a high of 2.74. The primary objective of processing the sample was to repeat the results obtained for sample C; therefore, the same experimental matrix was used. Because there was a large difference in the properties of the two samples, an exact replication was not made. In general, aerated samples produced precipitates that were olive green when treated with Ca(OH)₂. This color probably indicates a mixture of Fe(OH)₃ (deep amber) and Fe(OH)₂ (dark green). The filtrates from these tests had a green tint until the test pH reached ~10, when they became clear. The

Table 11. Experimental data from processing feed samples A and B

Test No.	H ₂ O ₂ added (mL)	Solution aerated	pH of original feed solution	pH after adding Ca(OH) ₂	Precipitate color	Filtrate (effluent) color	Cation analyses for simulated effluent (mg/L)						
							Fe	Al	Ca	Mg	Mn	Ni	Zn
1A	0	No	2.66			Light amber	37.5	4.5	185	31.5	0.8	<0.05	0.1
5A	0	No	2.57	10.25	Light amber	Clear	<0.1	0.2	386	3.9	<0.005	0.1	<0.02
1B	0	No	2.70			Amber	744	89.9	255	140	9.6	1.4	3.4
2B	0	Yes (60 min)	2.42			Amber	632	89.5	253	137	9.4	1.3	3.1
3B	0	No	2.50	7.25	Olive	Green tint	13	0.1	1027	133	6.4	<0.05	0.1
4B	0	Yes (60 min)	2.47	7.63	Olive	Clear	2.4	0.1	1156	107	1.9	<0.05	<0.02
5B	0	No	2.45	10.88	Olive	Green tint	0.3	2.2	1142	0.3	<0.005	<0.05	<0.02
6B	0	Yes (60 min)	2.47	10.36	Olive	Clear	<0.1	3.2	1199	0.8	<0.005	<0.05	<0.02
7B	0.3 ^a	No	2.66	7.38	Olive	Green tint	6.9	0.2	1047	127	3.8	<0.05	0.07
8B	0.3 ^a	Yes (60 min)	2.44	7.34	Olive	Green tint	1.8	0.2	1376	143	4.1	<0.05	<0.02
9B	0.3 ^a	No	2.65	10.28	Olive	Green tint	<0.1	1.7	1106	1.3	<0.005	<0.05	<0.02
10B	0.3 ^a	Yes (60 min)	2.42	10.49	Amber	Clear	<0.1	1.8	1577	0.9	<0.005	<0.05	<0.02
11B	0.2 ^b	No	2.60	10.33	Olive	Clear	0.7	5.9	1045	1.0	<0.005	<0.05	<0.02
12B	0.5 ^b	No	2.60	10.90	Deep amber	Clear	<0.1	3.5	1142	9.6	<0.005	<0.05	0.04
13B	0.2 ^b	Yes (60 min)	2.46	10.94	Amber	Clear	0.4	4.6	1162	0.4	<0.005	<0.05	0.05
14B	0.6 ^b	Yes (60 min)	2.45	10.85	Deep amber	Clear	<0.1	1.4	1258	0.4	<0.005	<0.05	<0.02
15B	0	No	2.47			Amber	652	85	267	148	10.2	1.5	3.1
16B	Blank sample; ~50 mL of ~6 M hydrochloric acid						<0.1	<0.06	0.1	<0.1	<0.005	<0.05	<0.02

^aTen percent H₂O₂ added to solution.^bThirty percent H₂O₂ added to solution.

Table 12. Experimental data from processing feed sample C

Test No.	30% H ₂ O ₂ added (mL)	Solution aerated	pH of original feed solution	pH after adding Ca(OH) ₂	Precipitate color	Filtrate (effluent) color	Cation analyses for simulated effluents (mg/L)						
							Fe	Al	Ca	Mg	Mn	Ni	Zn
17C	0	No	2.77			Green tint	205	29.7	231	53.1	3.4	0.6	1.7
18C	0	Yes (60 min)	2.76	5.05	Greenish amber	Green tint	160	0.17	363	47.8	3.1	0.46	1.2
19C	0	Yes (60 min)	2.79	5.97	Deep olive	Green-yellow	114	0.11	409	47.6	3.0	0.37	0.3
20C	0	Yes (60 min)	2.84	7.03	Dark green	Green tint	0.2	0.08	553	38.0	0.4	<0.04	0.01
21C	0	Yes (60 min)	2.80	8.05	Dark green	Green tint	0.4	0.2	663	42.0	0.2	<0.04	0.03
22C	0	Yes (60 min)	2.78	9.10	Dark green	Green tint	<0.1	0.27	698	13.9	<0.005	<0.04	0.26
23C	0	Yes (60 min)	2.81	10.05	Dark green	Clear	<0.1	0.11	561	0.48	<0.005	<0.04	0.01
24C	0	Yes (60 min)	2.79	11.05	Dark green	Green tint	<0.1	0.91	818	<0.01	<0.005	<0.04	0.03
25C	0.6	No	2.74	5.00	Light amber	Clear	<0.1	1.09	461	47.9	2.4	0.45	1.1
26C	0.6	No	2.71	6.12	Light amber	Clear	<0.1	0.09	568	54.3	1.8	0.35	0.08
27C	0.6	No	2.74	7.16	Deep amber	Clear	<0.1	0.16	710	51.6	0.3	0.07	0.03
28C	0.6	No	2.71	8.01	Deep amber	Clear	<0.1	0.11	607	46.6	<0.005	<0.04	0.02
29C	0.6	No	2.70	8.96	Deep amber	Clear	<0.1	1.03	622	9.1	<0.005	<0.04	0.02
30C	0.6	No	2.74	9.98	Deep amber	Clear	<0.1	3.14	582	1.8	<0.005	<0.04	0.02
31C	0.6	No	2.70	10.98	Deep amber	Clear	0.35	1.53	706	<0.1	<0.005	<0.04	0.03
32C	0.6	Yes (60 min)	2.89	8.02	Deep amber	Clear	<0.1	0.30	877	48.3	0.01	0.07	0.03
33C	0.6	Yes (60 min)	2.92	10.01	Deep amber	Clear	<0.1	1.44	744	1.6	<0.005	<0.04	0.02
34C	0.6	Yes (60 min)	2.92	10.97	Deep amber	Clear	0.36	3.81	759	0.12	<0.005	<0.04	0.03
35C	0	No	2.91			Yellow	236	27.5	201	48.0	3.1	0.55	1.5
36C	0	Yes (24 h)	2.82	6.03	Dark green	Green-yellow tint	12.1	0.09	529	46.1	1.8	<0.04	0.03
37C	0	Yes (24 h)	2.83	10.05	Dark green	Green tint	<0.1	0.50	877	0.6	<0.005	<0.04	0.02

Table 13. Experimental data from processing feed sample D

Test No.	30% H ₂ O ₂ added (mL)	Solution aerated	pH of original feed solution	pH after adding Ca(OH) ₂	Precipitate color	Filtrate color (effluent)	Cation analyses for simulated effluents (mg/L)						
							Fe	Al	Ca	Mg	Mn	Ni	Zn
38D	0	No	2.74			Amber	674	117	630	267	15.2	2.6	7.0
39D	0	Yes (60 min)	2.73	5.03	Olive-amber	Green tint	155	0.11	1380	270	14.1	1.5	2.1
40D	0	Yes (60 min)	2.72	6.03	Deep olive	Green tint	112	0.09	1575	275	14.0	1.0	0.7
41D	0	Yes (60 min)	2.71	7.00	Deep olive	Green tint	19	0.14	1638	264	8.6	0.15	0.09
42D	0	Yes (60 min)	2.71	8.01	Deep olive	Green tint	0.6	0.13	1726	210	1.4	<0.04	0.04
43D	0	Yes (60 min)	2.69	9.01	Deep olive	Green tint	<0.1	0.11	1865	88	0.05	<0.04	0.04
44D	0	Yes (60 min)	2.70	10.04	Deep olive	Clear	<0.1	1.6	2092	1.4	<0.005	<0.04	0.04
45D	0	Yes (60 min)	2.66	10.98	Deep olive	Clear	<0.1	0.46	1930	0.4	<0.005	<0.04	0.04
46D	0.6	No	2.74	5.03	Light amber	Clear	<0.1	0.20	1610	277	6.8	1.5	2.6
47D	0.6	No	2.72	6.05	Light amber	Clear	<0.1	0.15	1739	255	2.5	0.47	0.2
48D	0.6	No	2.71	6.97	Light amber	Clear	<0.1	0.19	1637	264	2.7	0.33	0.09
49D	0.6	No	2.73	8.04	Light amber	Clear	<0.1	0.09	1726	207	0.12	<0.04	0.05
50D	0.6	No	2.73	9.01	Light amber	Clear	<0.1	0.76	1903	101	<0.005	<0.04	0.04
51D	0.6	No	2.73	10.04	Light amber	Clear	<0.1	6.5	2167	1.3	<0.005	<0.04	0.05
52D	0.6	No	2.73	11.02	Light amber	Clear	<0.1	0.4	1956	0.25	<0.005	<0.04	0.04
53D	0.6	Yes (60 min)	2.70	8.01	Light amber	Clear	<0.1	0.08	1731	221	0.05	<0.04	0.04
54D	0.6	Yes (60 min)	2.71	10.00	Light amber	Clear	<0.1	4.5	1981	2.7	<0.005	<0.04	0.04
55D	0.6	Yes (60 min)	2.73	10.98	Light amber	Clear	<0.1	0.45	1940	0.25	<0.005	<0.04	0.04
56D	0	No	2.51			Amber	615	121	651	276	16.5	2.7	8.2
57D	0	Yes (24 h)	2.66	6.02	Olive-amber	Clear	1.0	0.2	1701	244	4.1	0.1	0.06
58D	0	Yes (24 h)	2.53	9.99	Light amber	Clear	<0.1	6.8	1764	1.0	<0.005	<0.04	0.06

Table 14. Experimental data from processing feed sample E

Test No.	30% H ₂ O ₂ added (mL)	5% NaOCl added (mL)	pH of original feed solution	pH after adding Ca(OH) ₂	Precipitate color	Filtrate (effluent) color	Cation analyses for simulated effluents (mg/L)							
							Fe	Al	Ca	Mg	Mn	Ni	Zn	Na
59E	0	0	2.39			Amber	570	62	388	96	6.9	1.2	4.5	45
60E	0	0.5	2.53	6.01	Olive-amber	Green tint	21	0.9	1137	96	5.4	0.4	0.3	81
61E	0	1.0	2.54	6.01	Light amber	Green tint	10.6	0.1	1158	100	6.2	0.5	0.5	125
62E	0	2.0	2.55	6.00	Light amber	Clear	<0.1	0.1	1113	98	2.5	0.5	0.3	183
63E	0	3.0	2.55	6.03	Light amber	Clear	<0.1	0.1	1310	104	<0.005	0.4	0.2	362
64E	0	4.0	2.48	6.02	Light amber	Clear	<0.1	0.1	1167	103	<0.005	0.5	0.2	465
65E	0	5.0	2.54	6.05	Light amber	Clear	0.6	0.1	1155	102	<0.005	0.6	0.4	604
66E	0.1	0	2.55	6.04	Light amber	Clear	0.1	0.5	1171	99	2.5	0.4	0.3	40
67E	0.2	0	2.54	6.04	Light amber	Clear	<0.1	0.1	1193	96	1.8	0.3	0.2	40
68E	0.4	0	2.54	5.98	Light amber	Clear	<0.1	0.1	1144	100	3.6	0.6	0.4	43
69E	0.8	0	2.55	6.01	Light amber	Clear	<0.1	0.1	1222	95	2.2	0.4	0.2	40
70E	1.6	0	2.56	6.02	Light amber	Clear	0.9	1.7	1189	97	2.5	0.4	0.2	41
71E	1.6	0	2.51	10.01	Light amber	Clear	0.8	2.3	1285	1.9	<0.005	<0.04	0.1	40
72E	0	0	2.48	6.02	Light amber	Clear	0.6	0.1	1216	95	4.0	0.3	0.2	40
73E	0	0	2.41	10.02	Light amber	Clear	<0.1	4.9	1295	1.1	<0.005	<0.04	0.04	40
74E	0	2.0	2.49	10.01	Light amber	Clear	<0.1	3.9	1273	1.5	<0.005	<0.04	0.04	197
75E	0	2.0	2.48	10.98	Light amber	Clear	<0.1	0.6	1348	<0.1	<0.005	0.04	0.05	197

iron concentration of the filtrates fell below the detection limit at a pH of 9 for aerated samples. All tests in which H_2O_2 was used produced dense, amber precipitates and clear filtrates even at the low pH of 5. Again, the amphoteric properties of aluminum caused the filtrate aluminum concentration to vary, reaching a high of 6.8 at a pH of 10. Other contaminants decreased in concentration as the pH was raised with $\text{Ca}(\text{OH})_2$.

Processed Feed Sample E (Table 14). Sample E also exhibited the strong amber color of high concentrations of Fe^{3+} ions. Its pH varied from 2.39 to 2.56 during the experimental processing. Contaminants included 570 mg/L of Fe, 62 mg/L of Al, 96 mg/L of Mg, 1.2 mg/L of Ni, as well as other impurities.

The primary objective of processing sample E was to compare the effects of the oxidation properties of NaOCl and H_2O_2 upon iron removal in the SPWTF-simulated processes while the pH was held constant with $\text{Ca}(\text{OH})_2$. As the NaOCl concentration was increased from about ~25 to 250 mg/L in the influent oxidation treatment, the iron contaminant was precipitated from the influent to below the detection level of 0.1 mg/L at a hypochlorite concentration of ~100 mg/L as the pH was held essentially constant at 6 with $\text{Ca}(\text{OH})_2$. At a NaOCl concentration of ~250 mg/L, the filtrate iron contamination started increasing, possibly as the result of ferric chloride formation. The H_2O_2 concentration was varied from ~30 mg/L to ~480 mg/L in tests 66E to 70E while holding the pH essentially constant at 6 with $\text{Ca}(\text{OH})_2$. Iron contamination in the filtrate became undetectable at a H_2O_2 concentration of ~60 mg/L, but at ~480 mg/L of H_2O_2 concentration, the iron started redissolving. In general, all tests using H_2O_2 and NaOCl produced heavy precipitates of the amber-colored $\text{Fe}(\text{OH})_2$ and mostly clean filtrates, indicating an efficient precipitation of contaminants. A more efficient reduction of influent contaminants is produced by H_2O_2 .

Conclusions

The following tentative conclusions can be made:

1. A significant concentration of Fe^{2+} ions exists in the SPWTF influent, and this concentration probably varies with amounts of rainfall. This conclusion is drawn from the data presented from the experimentation with feed Sample C. About 24 h after a rainfall, high concentrations of Fe^{2+} ions leach from the coal pile and collect in the SPWTF South Basin. After weeks of exposure to dissolved oxygen, sunlight, and other factors, many of the Fe^{2+} are oxidized to the Fe^{3+} state; therefore, iron contamination in the influent is a mixture of Fe^{3+} and Fe^{2+} ions whose concentration continuously varies.
2. Adding a strong oxidizing agent, such as H_2O_2 or NaOCl , to the SPWTF influent should significantly improve the iron-collecting efficiency of the facility because practically all iron would be collected as the insoluble $\text{Fe}(\text{OH})_3$. A better choice of oxidizing agents is H_2O_2 because it is essentially nonpolluting.

3. Aeration helps to some extent in oxidizing Fe^{2+} ions to the Fe^{3+} state, but the technique appears very inefficient.

Future Work

No future work is planned.

METRIC CONVERSIONS

PRESSURE		VOLUME		AMOUNT OF SUBSTANCE (Leaks, Outgassing)	
psi	MPa	in ³	mm ³	cc-atm	μmoles
10,000	60.0	10.00		10,000	400,000
8000	50.0	8.00		8000	300,000
6000	40.0	6.00	100,000	6000	
5000	30.0	5.00	80,000	5000	200,000
4000		4.00	60,000	4000	
3000	20.0	3.00	50,000	3000	
			40,000		100,000
2000		2.00	30,000	2000	80,000
	10.0		20,000		60,000
	8.0				50,000
1000	6.0	1.00		1000	40,000
800	5.0	0.80		800	30,000
600	4.0	0.60	10,000	600	
500	3.0	0.50	8000	500	20,000
400		0.40	6000	400	
300	2.0	0.30	5000	300	
			4000		10,000
200		0.20	3000	200	8000
	1.0	0.10			6000
	0.80		2000		5000
100	0.60	0.10		100	4000
80	0.50	0.08		80	3000
60	0.40	0.06	1000	60	
50	0.30	0.05	800	50	2000
40		0.04	600	40	
30	0.20	0.03	500	30	
			400		1000
20		0.02	300	20	800
	0.10		200		600
	0.08				500
10		0.01		10	

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