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D. E. Eakin

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Prepared for the U.S. Department of Energy
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SUMMARY

Process waste streams from the Hanford Waste Vitrification Plant (HWVP) may require treatment for cesium, strontium, and transuranic (TRU) element removal in order to meet criteria for incorporation in grout. The approach planned for cesium and strontium removal is ion exchange using a zeolite exchanger followed by filtration. Filtration using a pneumatic hydropulse filter is planned to remove TRU elements which are associated with process solids and to also remove zeolite bearing the cesium and strontium. The solids removed during filtration are recycled to the melter feed system to be incorporated into the HWVP glass product. Fluor Daniel, Inc., the architect-engineering firm for HWVP, recommended a Pneumatic Hydropulse (PHP) filter manufactured by Mott Metallurgical Corporation for use in the HWVP. The primary waste streams considered for application of zeolite contact and filtration are melter off-gas condensate from the submerged bed scrubber (SBS), and equipment decontamination solutions from the Decontamination Waste Treatment Tank (DWTT). Other waste streams could be treated depending on TRU element and radionuclide content. Laboratory and pilot-scale filtration tests were conducted to provide a preliminary assessment of the adequacy of the recommended filter for application to HWVP waste treatment.

Previous filtration tests were conducted on laboratory and pilot-scale filters in Fiscal Year (FY) 1989 and early FY 1990 to determine filter performance at projected HWVP process conditions. Based on the results of these tests, it was shown that the proposed filtration system was expected to achieve the design volume throughput (16.3 gal/ft^2 at 1000 ppm process feed solids) and solids loading (250 g/ft^2 combined process solids and zeolite) without exceeding the design pressure drop of 40 psi while achieving very high solids removal efficiency. There was no indication that the proposed filter would not perform as projected. A simulant feed stream of $Fe(OH)_3$ at 180 ppm which is approximately the same Fe concentration as expected in the SBS, was shown to be an appropriate simulant for filtration tests. Unground zeolite, with a typical particle size of 30-50 μ, by itself was not effective as a body feed so diatomaceous earth (DE) added as a body feed was required to successfully filter the simulated waste stream. Body feed is a material added

to the feed stream being filtered to improve filtration characteristics (i.e., increased throughput at the same pressure drop).

During the tests presented in this report, specially ground IE-96 zeolite added to the simulant feed stream in the amount projected to adsorb Cs and Sr (3.04 g/L) was tested as a substitute for DE body feed. The specially ground zeolite was prepared by Union Carbide using the same grinding procedure as previously used to prepare the ground zeolite used in previous PNL adsorption tests. The zeolite was ground so that 99% of it passed through a 200 mesh sieve. This zeolite had a median particle size of 19.7 μ with 50.7% of the particles less than 20 μ, and 32.2% less than 10 μ. Process performance was determined primarily by pressure drop across the filter as a function of volume throughput and solids removal efficiency.

The results of these current tests indicate that the use of the specially ground zeolite, only in the amount required for Cs and Sr adsorption (3.04 g/L) was unacceptable, based on the design pressure drop of 40 psi. The five consecutive pilot-scale filter cycles under the projected process conditions resulted in terminal pressure drops that ranged from 33.7 to 55.7 psi with three of the five tests exceeding the required 40 psi limit. All but one of the pilot-scale tests were run at pH 9 with the other one at pH 12. The filtration characteristics were not changed significantly by changing the pH. Solids-removal efficiency during all tests was excellent and was typically about 99.9%. Based on results of laboratory and pilot-scale tests, the use of specially ground zeolite as body feed is not acceptable for HWVP operation. The design basis for HWVP should be modified to be consistent with results of these tests.

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1.0 INTRODUCTION

The Hanford Waste Vitrification Plant (HWVP) is being designed to provide a vitrification facility to immobilize Hanford high-level liquid defense waste into a borosilicate glass matrix. The high-level waste will be pretreated and transferred to the vitrification facility as a feed. In the HWVP, the waste is concentrated, chemically adjusted to make melter feed, and then converted to glass. The glass product will be sealed in canisters, which are decontaminated, and stored onsite until the canisters are shipped to a federal repository. Liquid process wastes generated in the HWVP will be incorporated into grout. In order to be incorporated into grout, the process wastes must be nontransuranic (non-TRU) and meet specific requirements for radionuclide content.

Fluor Daniel, Inc., the architect-engineering firm for HWVP, has recommended a Pneumatic Hydropulse (PHP) filter manufactured by Mott Metallurgical Corporation for reduction of process solids containing transuranic (TRU) elements and removal of zeolite used for cesium and strontium recovery. The Pneumatic Hydropulse filter achieves particulate removal by allowing the feed slurry to flow radially outward trough tubular, sintered metal elements. The filter operating cycle consists of precoating the filter element with diatomaceous earth precoat, feed slurry filtration, heel drainage, and use of a pneumatic pulse to blowdown collected solids. The Pneumatic Hydropulse (PHP) filter gets its name from this pneumatic pulse used to remove solids from the filter. The solids are discharged to a receiver tank through a valve. The particular PHP filter recommended for HWVP application is similar in construction to a vertically-mounted, single pass, shell-and tube heat exchanger, with filter elements replacing the exchanger tubes. The liquid flows radially outward through the porous walls of the elements and leaves the filter from the "shellside." Solids retained inside the elements are periodically purged through the valve in the bottom head of the unit into the receiver tank. The solids removed by filtration in HWVP will be recycled to the melter feed system for incorporation in to the HWVP glass product.

Short-term loading efficiency tests were conducted in Fiscal Year (FY) 1989 and early FY 1990 on the Fluor Daniel, Inc. selected filter (laboratory and pilot-scale) to verify operation using HWVP processing conditions. These previous tests (Eakin 1990) were conducted to provide information on operational characteristics and other performance factors that are necessary to assess the feasibility of using this equipment in a canyon with remote maintenance requirements. The present tests were conducted specifically to determine if specially ground IE-96 zeolite added in the amount to adsorb Cs and Sr would also serve as sufficient body feed in place of diatomaceous earth (DE).

This activity conducted by Pacific Northwest Laboratory (PNL) was described in the Hanford Waste Vitrification Plant Applied Technology Plan (WHC-EP-0350). This report presents the results of the filtration studies to satisfy the requirements of Deliverable 1.2.2.03.06A, "Issue Report Evaluating Filtration Parameters," described in the draft "Fiscal Year 1991 SOW for Applied Technology Tasks to be Performed by Pacific Northwest Laboratory in support of the HWVP" (WHC-SP-0638).

2.0 CONCLUSIONS AND RECOMMENDATIONS

Laboratory and pilot-scale filtration tests were conducted by Mott Metallurgical, Corporation (the filter manufacturer) to determine the adequacy of the PHP filter using only specially ground zeolite without diatomaceous earth added as body feed during filtration of the SBS simulant. The results of these current tests indicate that the use of the specially ground zeolite, only in the amount (3.04 g/L) required for Cs and Sr adsorption, was unacceptable. Additional conclusions are as follows:

- The five consecutive pilot-scale filter cycles using projected HWVP conditions had an average terminal pressure drop of 42.6 psi (range 33.7 to 55.7) with three of the five tests exceeding the required pressure drop of 40 psi.
- The laboratory-filtration tests showed an improvement in filtration characteristics (lower terminal pressure drop) when the pH was lowered from 12 to 9. The pilot-scale filtration tests did not show this improvement, although only one of the 13 runs was conducted at pH 12 with all the rest at pH 9.
- The results of the laboratory-filtration tests showed that without DE body feed the performance (volume throughput at equivalent pressure drops) of the specially-ground zeolite was better than the previously used unground zeolite. The pilot-scale filtration tests did not show any significant difference between the specially- ground zeolite and the previously used unground zeolite.
- The filtrate quality was excellent throughout the testing indicating high solids-removal efficiency. The filtrate Total Suspended Solids (TSS) levels were below 0.5 ppm for all pilot-scale tests. Based on the feed process solids of 180 ppm, the solids-removal efficiency ranged from 99.8% to 99.97% and was generally at about 99.9% or better.
- Based on results of these tests and previous work, the use of specially ground zeolite in place of diatomaceous earth for body feed is unacceptable for HWVP operation.

Based on the results of these laboratory and pilot-scale filtration tests which have shown that specially-ground zeolite without DE body feed is unacceptable, additional testing is not required. The design basis for HWVP should be modified to be consistent with results of these tests.

3.0 OBJECTIVES

The primary objective of this testing program was to provide HWVP design verification of the recommended filter performance, using specially ground zeolite, by conducting laboratory and pilot-scale filtration tests. The primary filter design objective was to achieve a terminal solids loading of 250 g/ft^2 (combined process solids and zeolite based only on a zeolite content required for Cs and Sr adsorption) at less than or equal to a 40 psi pressure drop at a 0.2 gpm/ft^2 flux rate.

Laboratory and pilot-scale filtration tests conducted in FY 1989 and early FY 1990 demonstrated that the proposed filtration system is expected to achieve the design volume throughput and solids loading without exceeding the design pressure drop while achieving very high-solids removal efficiency (1). However, these tests also demonstrated that diatomaceous earth body feed, in addition to the filter precoat, is required when using unground zeolite ion exchanger. The primary objective of these tests was to determine if specially ground zeolite added in the projected amount to adsorb Cs and Sr is an effective body feed in place of diatomaceous earth.

4.0 STUDY APPROACH

Laboratory and pilot-scale filtration tests were conducted to determine the performance adequacy of the recommended pneumatic hydropulse (PHP) filter using specially ground zeolite. Mott Metallurgical Corporation was contracted to conduct the filtration testing because the facilities and equipment were in place. Mott routinely provides similar testing support.

The previous tests (Eakin 1990) conducted by Mott showed that a feed stream containing 180 ppm $Fe(OH)_3$ was an appropriate simulant for the projected SBS stream. This 180 ppm $Fe(OH)_3$ simulant was used for both the laboratory and pilot-scale filter tests discussed in this report. Specially ground IE-96 zeolite was prepared using the same grinding parameters as were used to prepare the ground zeolite which was used in previous adsorption tests (Bray, et al. 1990). This specially ground zeolite had a median particle size of 19.7 μ with 50.7% less than 20 μ, 41% less than 15 μ, and 32.2% less than 10 μ. Laboratory-scale filtration tests were conducted using zeolite but no diatomaceous earth as body feed.

The pilot-scale tests were then conducted to confirm the adequacy of the PHP filter under repeated cycles and under conditions that approximate expected HWVP conditions. The pilot-scale filter was operated in the same mode as projected for the full-scale filter (i.e. precoated upflow and loaded downflow). The pilot-scale filter had a filtration area of 21.6 ft^2 which was almost 1/3 that of the 75 ft^2 now projected for the full-scale HWVP filter. Thus, the conditions during testing closely approximated those expected for actual HWVP operation. Laboratory- and pilot-scale filter performance was determined by measuring pressure drop across the filter and solids-removal efficiency as a function of filtrate volume throughput.

5.0 TEST EQUIPMENT AND MATERIALS DESCRIPTION

Test equipment and materials are subsequently described. Detailed descriptions of the laboratory and pilot-scale filtration test equipment and experimental design are included in Appendix A, "Laboratory Test Report No. 3 - SBS Simulant Filtration Using the Mott Hypulse LSM."

Specially ground IE-96 is prepared by grinding the granular form of IE-96 zeolite. IE-96 is a chabazite type (a hydrated sodium calcium aluminum silicate) of zeolite in the sodium form. The granular form of IE-96 is prepared by ion exchange conversion of granular IE-95 which is in the calcium form. This ion exchange process is done with the zeolite in the granular form. Therefore in order to obtain IE-96 in particle sizes less than the commercially available granules (typical size 30-50 μ) it must be specially ground whereas the IE-95 may be obtain in the original unbounded form. A clay binder is used to manufacture the granular IE-95 from the unbound form. Thus the specially ground IE-96 contains the clay binder at about the 5 wt% level. The chemical composition of IE-96 is shown in Table 5.1. Clay has a typical chemical composition of $Al_2O_3SiO_2 \cdot xH_2O$. Because of the similarities in chemical compositions, clay, when added at the 5 wt% level, will have very little impact on the chemical composition of the zeolite.

TABLE 5.1. Composition of Zeolite IE-96 (Includes Clay Binder)

Component	Wt%
SiO_2	68.23
Al_2O_3	17.17
Na_2O	8.28
K_2O	.46
MgO	.75
CaO	.81
Fe_2O_3	3.83
TiO_2	.47

Source: Sharp 1988.

Laboratory-Scale Tests

Laboratory-scale filter feasibility tests were performed using the Mott 70 MM disc test filter (0.031 ft^2 area) having a nominal 2.0 micron pore size porous metal filter. The laboratory filter equipment arrangement is shown in Figure 5.1. The filter was pre-coated with a diatomaceous earth slurry at 1 gpm/ft^2 to a final 0.1 lb/ft^2 precoat solids loading by pumping from the precoat tank. The feed solution was then pumped through the filter at 0.2 gpm/ft^2 (the projected design rate). Information recorded during testing were flowrate, pressure drop, temperature, cycle time, volumetric throughput, weight of backwash slurry, and filtrate turbidity. Filtrate turbidity was determined using a Hach Turbidimeter. Filtrate quality (solids content) was evaluated via Millipore analysis using 0.45 micron paper. The filter aid (diatomaceous earth) evaluated was Manville Standard Super Cell. Specially ground IE-96 zeolite was obtained from Union Carbide having a median particle size of 19.7 μ.

Pilot-Scale Tests

The pilot-scale filtration system is shown in Figure 5.2 The system consists of a pre-coat slurry feed tank and pump; a concentrate makeup and feed system; a slurry feed tank and flow control loop; the filter; a sampling filtrate receiver; and a slurry backwash receiver. The test system was assembled to provide for a precoating operation and a continuous makeup of feed slurry. Due to the large volume of water to be filtered and treated, and the limited space and disposal facilities available, filtrate from both the precoat and feed was recycled and reused.

The flowrate to the filter was controlled by speed control on the delivery pump. The feed slurry flow was controlled by a set point single loop controller which adjusted the speed of a centrifugal pump. The pre-coat flow is set by air flow to an air powered diaphragm pump. This flow was set once and did not require readjustment since the precoating was always done at the same flow and pressures. The concentrate flow to the slurry tank was manually controlled with a valve. Concentrate flow was set, and the tank volume was closely monitored to measure flow rate. The pilot-scale filter consisted of (7) tubular porous metal elements of 2.5 inch outside diameter, 59.75 inch

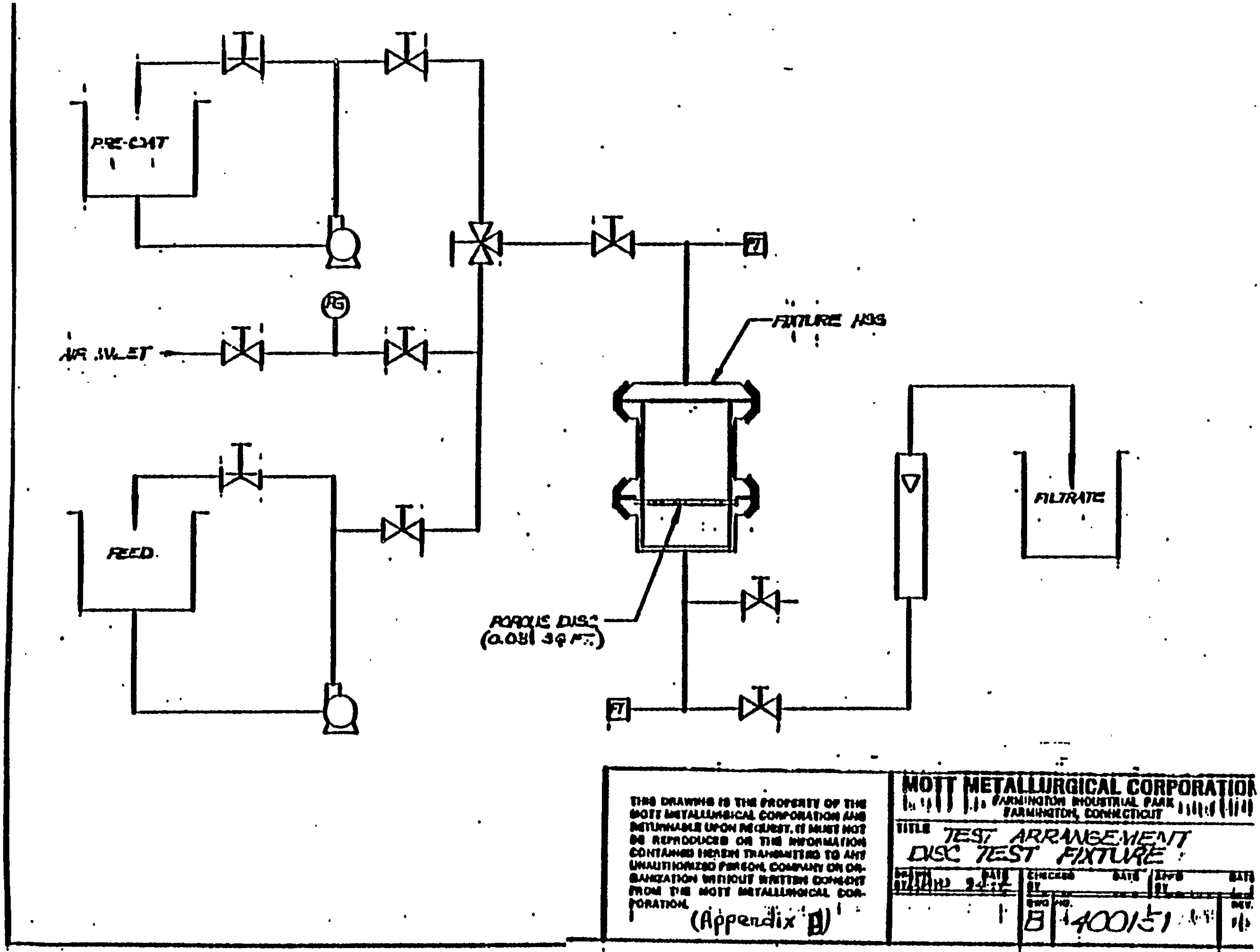
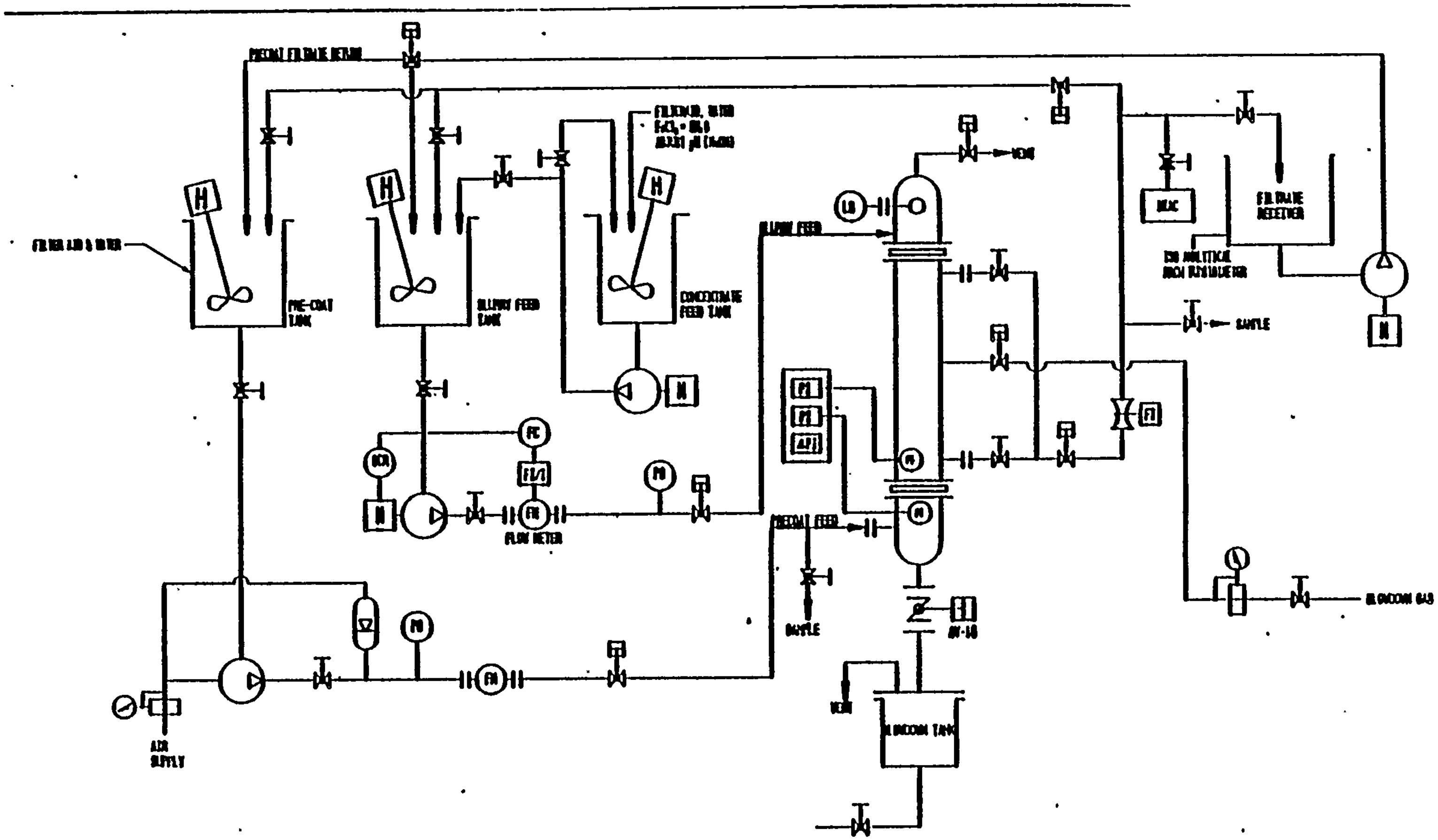


FIGURE 5.1. Test Arrangement Disc Test Fixture



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TITLE PROCESS FLOW SCHEMATIC- SBS SIMILANT FILTRATION TEST

MATERIAL | FINISH | DWG SCALE: NONE PLOT SCALE: 5 | SHT 1 OF 1

USE ON DWG NO. | DWG. NO. B 400249 | REV —

(Appendix B)

FIGURE 5.2. Process Flow Schematic - Pilot-Scale Filtration Test

porous length, made from porous 316L stainless steel with a rating of 2 micron filtration capability. The filtration area is 21.6 ft^2 based on the elements inside diameter of 2.375 inch diameter. These elements were installed within a 10 inch diameter housing as a tube bundle assembly between two vessel flanges.

6.0 TEST DESCRIPTION

The general procedures for the laboratory and pilot-scale filtration tests are described in this section. Additional detail is provided in Appendix A.

The general procedure for the laboratory scale test was to first precoat the filter at 1 gpm/ft^2 to a final diatomaceous earth (DE) loading of 0.1 lb/ft^2. The feed was pumped to the filter at 0.2 gpm/ft^2, and the filtrate collected. The feed rate was continued until a maximum of 45 psi pressure drop was reached (40 psi was the desired terminal pressure drop) or the entire "desired" volume of feed (1900 cc) gave the equivalent total solids loading (zeolite needed for adsorption only and process solids) of 250 g/ft^2 which was used by Fluor-Daniel as the basis for design calculations. After termination of feed flow, the filter cake was dewatered at the terminal differential pressure by passing air through the filter. Then the filter housing was inverted and pressurized at 20 psi above the terminal differential pressure to backwash the filter. The filter was visually inspected and reassembled for the next test cycle.

All of the laboratory filtration tests were conducted at the projected HWVP operating temperature range of 110-130°F using 0.1 lb/ft^2 DE precoat and feed containing the projected amount of zeolite (for Cs and Sr removal) of 3.04 g/L. The feed contained 180 ppm $Fe(OH)_3$ simulant, and filtration tests were conducted at pH 9 and 12. None of the laboratory tests included DE as body feed. The amount of zeolite was increased from the initial 3.04 g/L to 4.04, 5.04, and 6.04 g/L.

The procedure for the pilot-scale filtration test was to precoat the filter with a dilute slurry (0.65 wt%) flowing at 1 gpm/ft^2 in the up-flow mode to a final DE loading of 0.1 lb/ft^2. The filtrate was returned to the pre-coat feed tank and was recycled through the filter until the precoat solution was clear, and the precoat DE had been loaded on the filter. The feed slurry tank pump was then started without interruption of flow to maintain pre-coat integrity. The feed flow was adjusted to maintain the terminal pressure obtained during the pre-coat cycle. The feed flow was gradually decreased to the desired flow rate of 0.2 gpm/ft^2, and the clean filtrate returned to the feed makeup tank. The feed was filtered in the downflow mode. The feed flow was continued until the pressure drop reached 50 psi (the desired pressure drop was 40 psi) or the desired volume throughput based on solids loading had been reached. The desired volume of 354 gallons was the volume of feed solution that would give the "projected" solids loading capability of the filter at 250 g/ft^2 combined process solids at 1000 ppm and zeolite at 3.04 g/L. The previous filtration tests had shown that the 180 ppm $Fe(OH)_3$ simulant gave filtration results equivalent to the SBS at 1000 ppm total process solids. The feed flow was then terminated and the filter backflushed with 45 psi air. The filter was then returned to the operation mode for the next cycle.

The conditions for pilot-scale testing were:

1) 3.04 g/L zeolite at pH 9 with 0 and 1.0 g/L DE body feed at pH 9

2) 4.04 g/L zeolite with no DE body feed at pH 9 and 12

3) 5.04 g/L zeolite with no DE body feed at pH 9

4) 6.04 g/L zeolite with no DE body feed at pH 9

7.0 RESULTS OF LABORATORY FILTRATION TESTS

The results of the laboratory filtration tests are subsequently discussed. Additional detail is provided in Mott's report, "Laboratory Test Report No. 3 - SBS Simulant Filtration Using the Mott Hypulse LSM" included in Appendix A. All laboratory filtration tests were conducted using a diatomaceous earth (DE) precoat of 0.1 lb/ft^2 with no DE body feed and 180 ppm $Fe(OH)_3$ as simulant feed. The filtration tests were run until the "desired" throughput of 1900 cc's was achieved or the maximum terminal pressure drop of about 45 psi was reached (desired terminal pressure drop was 40 psi). The results of the laboratory-scale tests are summarized in Table 7.1.

TABLE 7.1. Summary of Laboratory Filtration Tests

Test	Test Condition	Total Volume Throughput (cc's)[a]	Terminal ΔP (psi)[b]
1	3.04 g/L zeolite, pH=12	1340	45
2-1	4.04 g/L zeolite, pH=12	860	45
2-2	4.04 g/L zeolite, pH=12	1010	46.5
3-1	5.04 g/L zeolite, pH=12	1130	47
3-2	5.04 g/L zeolite, pH=12	1080	46
4	6.04 g/L zeolite, pH=12	1510	47
5	6.04 g/L zeolite, pH=9	1600	25[c]
6	5.04 g/L zeolite, pH=9	2000	41.5

All tests conducted using 0.1 lb/ft^2 DE precoat but no DE body feed and 180 ppm $Fe(OH)_3$ as simulant feed.

(a) Desired throughput = 1900 cc's.
(b) Desired terminal pressure drop = 40 psi
(c) Ran out of feed during test run

Test 1 started with an initial zeolite (specially ground) concentration of 3.04 g/L which is the amount that has been projected as required for Cs and Sr adsorption for SBS waste treatment. The initial pH tested was 12. The volume throughput of 1340 cc's was less than the desired throughput of 1900 cc's and the terminal pressure drop of 45 psi exceeded the desired pressure drop of 40 psi. During the previous testing using unground zeolite under similar conditions (180 ppm $Fe(OH)_3$, pH=12) but with 3 g/L of DE body feed, the pressure drop was 16 psi at a throughput of 1900 cc's. At 180 ppm $Fe(OH)_3$ and pH=12 but without DE body feed, the throughput was 660 cc's at 40 psi during the previous testing using unground zeolite. Thus, the performance of the specially ground zeolite was better than the previously used unground zeolite but was less satisfactory than the previous use of DE body feed.

Tests 2-1 through 4 then evaluated increasing the amount of specially-ground zeolite from the initial level of 3.04 g/L to 4.04 g/L (tests 2-1 and 2-2), 5.04 g/L (tests 3-1 to 3-2), and 6.05 g/L (test 4) all at a feed pH of 12. Increasing the amount of zeolite apparently improved the filtration characteristics with a throughput of 1510 cc's being achieved at a terminal drop of 47 psi in test 4. Although the results of test 1 do not necessarily fit this trend, these results may not be fully representative as repetitive runs were not conducted. The purpose of these laboratory tests was not to optimize conditions or statistically obtain repetitive data but to obtain information for conducting the pilot-scale filter tests.

Lowering the pH from 12 to 9 improved the filtration characteristics. At a zeolite concentration of 6.04 g/L, the throughput was 1600 cc's at a pressure drop of only 25 psi at pH=9 (test 5) compared to 1510 cc's and a pressure drop of 47 psi at pH=12 (test 4). At a zeolite concentration of 5.04 g/L, the throughput was 2000 cc's at 41.5 psi in test 6 (pH=9) compared to 1130 cc's at 47 psi in test 3-1 (pH=12), and 1080 cc's at 46 psi in test 3-2 (pH=12). Although more zeolite was used in test 6 than the projected required amount of 3.04 g/L, the volume throughput of 2000 cc's at 41.5 psi was very close to the desired throughput of 1900 cc's at less than or equal to 40 psi pressure drop.

Because previous testing had shown improved performance of the pilot-scale filter compared to the laboratory disc filter, testing proceeded to the pilot-scale filter although results were not as good as those previously achieved using DE body feed.

The filtration solids-removal efficiency was not determined for the laboratory-scale filter tests. However, as shown in Table 7.2, the filtrate for all tests had extremely-low turbidity values (a light scattering measurement) indicating very high-solids removal efficiency. The exception being Test 1 which had a composite filtrate Nephometic Turbidity Unit (NTU) reading of 3.2 which may have resulted from less than adequate precoating (although the exact reason is unknown). The solution turbidity was measured in Nephometic Turbidity Units (NTU's) using a Hach Turbidimeter. The higher the turbidity reading in NTU's, the more turbid (unclear) the solution is, indicating a higher solids content.

The results of the laboratory filtration tests showed that:

1) Without the addition of diatomaceous earth body feed or extra zeolite, the desired volume throughput and solids loading was not achieved without exceeding the design pressure drop under projected process conditions

TABLE 7.2. Summary of Composite Filtrate Turbidity

Test	Composite Filtrate Turbidity
1	3.2 NTU's[(a)]
2-1	1.7
2-2	1
3-1	1.1
3-2	0.86
4	0.68
5	0.31
6	0.91

(a) Nephometic Turbidity Units using Hach Turbidimeter

2) The specially-ground IE-96 apparently performed better than the previously used zeolite when used without DE body feed but did not perform as good as when DE body feed was added to the unground zeolite.

3) Based on previous experience that the pilot-scale filter performed better than the laboratory-scale filter (lower pressure drop at equivalent throughput) testing the use of specially ground zeolite should proceed to the pilot-scale filter.

8.0 RESULTS OF PILOT-SCALE FILTRATION TESTS

The results of the pilot-scale filtration tests are discussed below. Some additional discussion is provided in Mott's report, "Laboratory Test Report #3 - SBS Simulant Filtration Using the Mott Hypulse LSM," included in Appendix A.

The results of the pilot-scale filtration tests are summarized in Table 8.1. The pilot-scale filtration tests were conducted using the 180 ppm $Fe(OH)_3$ feed simulant. The initial tests were conducted at pH=9 and used 6.04 g/L specially-ground zeolite which was the maximum amount used in the laboratory-scale tests. The desired throughput at these conditions was 354 gallons at a desired terminal pressure drop of less than or equal to 40 psi. Tests 1-1 and 1-2, using these conditions, gave considerably different results, respectively, having terminal pressure drops of 46.0 psi (at 337 gallons throughput) and 20.5 psi (at 369 gallons throughput). The variation from cycle to cycle was attributed by Mott to slurry concentration variation from pumping the concentrated feed to the slurry feed tank. These initial tests are used to indicate directions that subsequent testing should take and, once apparent satisfactory conditions are found, then repetitive cycles are run to determine "typical" filtration characteristics. Thus, Mott did not run repetitive cycles at these conditions to determine an "average" pressure drop.

Tests 2 through 5 evaluated decreasing the amount of zeolite from 6.04 g/L to 5.04, 4.04, and 3.04 g/L. The results of Test 2 at 5.04 g/L zeolite and pH of 9, showed a throughput of 363 gallons at only 20 psi terminal pressure drop. Test 3 then increased the pH to 12 and reduced the zeolite needed to 4.04 g/L. The resulting pressure drop of 48.3 psi at a throughput of 352 gallons exceeded the desired maximum pressure drop of 40 psi. Changing the pH to 9 in Test 4 did not significantly change the filtration characteristics as the terminal pressure drop was 48.3 psi at a throughput of 382 gallons.

Tests 5-1 through 5-5 were then conducted under the same conditions using the 3.04 g/L zeolite projected as required for Cs and Sr adsorption at a pH of 9. These five cycles had an average pressure drop of 42.6 psi with a

TABLE 8.1. Summary of Pilot-Scale Filtration Tests

Test	Zeolite, g/L	DE Body Feed, g/L	Nominal pH	Throughput, Gal.	Terminal ΔP
1-1	6.04	0	9	337	46.0
1-2	6.04	0	9	369	20.5
2	5.04	0	9	363	20.0
3	4.04	0	12	352	49.2
4	4.04	0	9	382	48.3
5-1	3.04	0	9	365	33.7
5-2	3.04	0	9	367	44.0
5-3	3.04	0	9	363	55.7
5-4	3.04	0	9	365	44.7
5-5	3.04	0	9	363	35.1
6-1	3.04	1.0	9	365	20.0
6-2	3.04	1.0	9	363	44.2
6-3	3.04	1.0	9	389	23.3

range from 33.7 to 55.7 psi at an average throughput of about 365 gallons. This average pressure drop is only slightly greater than the desired 40 psi but indicates that the use of specially ground zeolite without DE body feed is unacceptable based on this criteria. These results are significantly less satisfactory than those previously obtained when body feed of 0.5 and 3.0 g/L DE, used with unground zeolite, resulted in terminal pressure drops of only 4.2 and 3.8 psi, respectively.

The improvement in filtration characteristics is shown by the results of Tests 6-1 through 6-3 where 1.0 g/L DE was added as body feed. With the exclusion of Test 6-2 (which had a higher-than-expected terminal pressure drop attributed by Mott to be caused by improper mixing in the concentrate feed tank) the average pressure drop with the 1.0 g/L DE body feed was 21.7 psi.

The results of previous pilot-scale filter tests (Eakin 1990) are shown in Table 8.2. During previous tests the terminal pressure drop across the filter was 45.0 psi without any DE body-feed (test #4) using unground zeolite. This is comparable to the average of 42.6 psi for the current tests 5-1

TABLE 8.2. Summary of Previous Pilot-Scale Filtration Tests

Test	$Fe(OH)_3$, ppm	Zeolite[a], g/L	DE Body Feed, g/L	Nominal pH	Desired Throughput, gal.	Actual Throughput, gal.	Term. ΔP, psi
1	180	3.04	3.0	9	354	355	3.8
2	90	1.52	1.5	9	709	862	5.8
3	180	3.04	0.5	9	354	391	4.2
4	180	3.04	0	9	354	363	45.0
5	360	3.04	1.0	9	354	388	44.0
6	180	3.04	0.5	12	354	381	5.0
7	30	0.51	0.5	9	2124	2376	7.0

(a) Unground zeolite with typical particle size of 30-50 μ (Eakin 1990).

through 5-5 using specially-ground zeolite which had the same conditions except for the differences in zeolite. The previously used unground zeolite had a typical particle size of 30-50 μ compared to the median particle size of 19.7 μ for the specially ground zeolite used in the current tests. The addition of 0.5 g/L DE bodyfeed in previous test #3 lowered the terminal pressure drop to 4.2 and the addition of 3.0 g/L DE bodyfeed reduced it to 3.8 psi. This is considerably less than the 20.0, 44.2, and 23.3 psi experienced in current tests 6-1,6-2,and 6-3 which all contained 1.0 g/L DE bodyfeed. Based on this limited information the previously used unground zeolite appears to perform better than the specially-ground zeolite when both are used with DE bodyfeed. However, the results of both the current and the previous testing confirm the need for DE bodyfeed when filtering the HWVP simulated SBS stream.

The summary of filtrate quality and solids removal efficiency is shown in Table 8.2. The material balance is based only on the process-solids simulant excluding zeolite and DE precoat and assumes that all of the filtrate solids are process solids simulant, thereby giving the most conservative solids-removal efficiency measurement. The filtrate quality was excellent throughout the testing. The filtrate TSS (Total Suspended Solids) levels were below 0.5 ppm for all pilot-scale tests. Based on the feed process solids of 180 ppm, the solids-removal efficiency ranged from 99.8% to 99.97% and were generally at about 99.9% or better. Filtrate turbidity ranged from 0.05-1.0 NTU's. Testing using the Mott Hypulse LSM filter has always shown excellent

TABLE 8.3. Material Balance Summary

Test	Feed Process Solids, ppm	Filtrate Turbidity (NTU)	Filtrate Solids (ppm)	% Solids Removal
1-1	180	0.06-0.25	0.23	99.87
1-2	180	0.06-0.15	0.11	99.93
2-1	180	0.05-1.00	0.98	99.73
3-1	180	0.05-0.07	0.11	99.93
4-1	180	0.05-0.20	0.12	99.93
5-1	180	0.08-0.12	0.11	99.93
5-2	180	0.06-0.09	--	--
5-3	180	0.06-0.10	--	--
5-4	180	0.08-0.10	--	--
5-5	180	0.06-0.13	0.062	99.97
6-1	180	0.07-0.18	--	--
6-2	180	0.06-0.32	0.36	99.8
6-3	180	0.06-0.15	--	--

solids removal efficiency. The solids were easily removed from the filter by the backflush using the 40-45 psi pulse of air. The recovery pressure drop measured after backflushing always returned to near that measured for the clean filter indicating no fouling of the media after repeated cycles.

The results of these pilot-scale tests indicate that:

1) The use of the specially-ground zeolite only in the amount (3.04 g/L) required for Cs and Sr adsorption, was unacceptable.

2) The pressure drop for five consecutive pilot-scale filter cycles conducted using projected process conditions ranged from 33.7 to 55.7 psi, and three of the five tests exceeded the required 40 psi limit.

3) In all cases, the results were significantly less satisfactory than those previously obtained when DE body feed was used.

9.0 REFERENCES

Bray, L. A., K. J. Carson, R. J. Elovich, and D. E. Eakin. 1990. HWVP Transuranic Process Waste Treatment by Ion Exchange. HWVP-90-1.2.2.04.04A, Pacific Northwest Laboratory, Richland, Washington.

Eakin, D. E. 1990. HWVP Transuranic Waste Treatment Laboratory and Pilot-Scale Filtration Tests. HWVP-90-1.2.2.04.04B, Pacific Northwest Laboratory, Richland, Washington.

Sharp, S. D. 1988. Liquid Transuranic Waste Handling Final Study Report. FLU.V/HWVP-88-208, Fluor Daniel, Inc., Irvine, California.

APPENDIX A

LABORATORY TEST REPORT NO. 3 - SBS SIMULANT FILTRATION USING THE MOTT HYPULSE LSM

mott MOTT METALLURGICAL CORPORATION
Farmington Industrial Park
Farmington, CT 06032
Telephone: (203) 677-7311
Telex: 99374 MOTTMETAL Fax: 203-674-1489

Controlled Porosity For Precision Products

LABORATORY TEST REPORT

Report #3
Tested October 15-27, 1990

OBJECTIVE:

Evaluate the performance of the Mott Hypulse LSM using 2.0 micron porous media in the filtration of SBS simulant contaminant using $Fe(OH)3$ at 180 PPM concentration and ground zeolite 1E at pH 9&12 . Elements were precoated at 1.0 GPM/ft² Manville celite.

CUSTOMER:

Battelle
Pacific Northwest Laboratories
P.O. 999
Richland, WA. 99352

SUMMARY:

Satisfactory results were obtained in the filtration of 180 PPM Fe(OH)3 at ph 9 using 3.04 g/l ground zeolite 1E-96 and NO DE bodyfeed. 5 cycles were run with no indication of fouling of the media. Thruput was 16.8 gal/ft² to a terminal Delta P of 33.7-44.7PSI. Average flux was 0.2 GPM/ft². Filtrate was visibly clear. Composite filtrate was less than 0.5 PPM TSS.

REFERENCE:
ET NO: ______
ACCT NO: ______
WO NO: 34972
IQ NO: 75163
PN NO: ______
FN NO: 665
INSIDE SALES: ______

BY: L. Stange
L. Stange

APPROVED: R. Sekellick
R. Sekellick

DIST: LHM, VJP, KJJ, SALESMAN, RSS, LAB FILE (2), #034, BATTELLE

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1 Title Page

LABORATORY TEST REPORT # 3

BATTELLE DISC TESTING AND PILOT LSM TESTING USING MOTT 2 MICRON ELEMENTS

TESTED OCTOBER 15 - 27 , 1990

Customer: Battelle
Pacific Northwest Laboratories
P.O. Box 999 Battelle Blvd.
Richland , Washington 99352

WO# 34972
IQ# 75163
FN 665

Representative: David E. Eakin

MMC Sales Representative: Set Point Control
Bill Stahl (509)946-3505

1.1 Preface

This test report represents the third phase of the ongoing evaluation of the Mott Hypulse LSM tubular precoat filter for use in the Hanford Waste Vitrification Facility for immobilizing high-level liquid defense waste into borosilicate glass matrix.

A previous report was issued from the Mott Test Laboratory in October and November of 1989 covering the initial disc phase testing and pilot scale testing.

The objective of this test is to determine whether specially ground Zeolite (used to absorb Cs and Sr) can be used effectively in place of the DE bodyfeed.

The current phase testing utilized both the Mott 70 MM disc test filter (.031 ft2) and the Mott 10" Pilot filter (21.6 ft2, 7 element LSM filter). 2.0 Micron media was used in the evaluation.

The filter was precoated using 0.1#/ft2 Mansville Celite. Tests were conducted with SBS simulant Fe(OH)3 wastewater contaminant at a concentration of 180 PPM and a pH of 9 and 12. Zeolite concentrations of 3.04, 4.04, 5.04 and 6.04 grams/liter were evaluated. Tests using 1.0 gram/liter DE filteraid bodyfeed and 3.04 g/l Zeolite were also conducted for comparison purposes.

2 Summary Mott Hypulse LSM Testing

The Mott Hypulse LSM pilot filter was tested for a total of 13 cycles over a 7 day period using simulant contaminant. Precoat flux was 1 gpm/ft2 with the filter being fed with an upflow configuration. The feed was introduced to the filter in a downflow configuration at a flowrate of 0.2 gpm/ft2 to simulate process conditions.

The performance objectives of this test program were:

1.) Evaluate the performance of the tubular precoat filter with respect to thru-put, pressure drop, and filtrate quality using ground Zeolite in place of DE bodyfeed at various concentrations.

2.) Determine the backwash effectiveness of the media for repeated cycle testing.

The Mott Hypulse LSM used in these tests is a tubular precoat filter having 21.6 ft2 area. It consists of seven (7) sintered stainless steel elements , 2.5 inches in outside diameter, 316L, 60 inches long. The elements are rated at 2 micron nominal retention. The patented LSM filters on the inside of the element. The double open ended element design is especially effective with high specific gravity solids. Some of the high density solids flow downward without collecting in the elements, resulting in longer cycles.

The filter was precoated with 0.1#/ft2 Manville Celite (Standard Super-Cel). Simulant feed containing 180 PPM iron hydroxide was tested at pH levels of 9 and 12.

Previous testing indicated that the DE bodyfeed was necessary to maintain cake permeability. Recent pilot tests using the LSM configuration indicate that ground Zeolite can be used without bodyfeed DE with higher terminal pressures (46-49 PSI). Terminal pressure drop was typically lower using a DE bodyfeed (20-23 PSI).

Test results indicate that the minimum amount of Zeolite could be used (3.04 g/l) and thruputs of 16.8 gal/ft2 were maintained. Five (5) cycles were conducted on pH 9 solution using 3.04 grams per liter Zeolite with no evidence of fouling of the media. Terminal pressures ranged from 33.7 - 55.7 PSI. Filtrate quality for all testing was less than 0.5 PPM TSS.

Three cycles were run using 1.0 g/l DE Bodyfeed along with 3.04 g/l Zeolite and pH 9. Thruputs of 16.8 gal/ft2 were easily maintained. Terminal pressure for a typical cycle was 20-23 PSI. Filtrate quality was less than 0.5 PPM TSS.

Throughout testing there was never any indication of media fouling. The recovery pressure drop at the start of Test 1-1 was 0.9 PSI and was 1.0 PSI at the end of Test 6-3. This is within measurement sensitivity. Fluctuations from cycle to cycle are the results of the residue remaining in the lower housing after blowdown.

Post test evaluation also indicated zero fouling as determined by clean flow measurements using water and bubble point evaluation of the media.

A key consideration to the success of the filter is the uninterrupted flow transition from precoating to feed slurry. This is essential in maintaining the precoat integrity and effectiveness. Also, the absolute integrity of the sintered stainless steel media and low (40-50 PSI) terminal pressure differential eliminated significant breakthru of precoat solids.

The filtrate quality was exceptional throughout testing. TSS (Total Suspended Solids) levels were below .5 PPM TSS. Filtrate turbidity ranged from .05 - 1.0 NTU'S. Evaluation using a Hiac Royco Particle Counter for on-line evaluation of the filtrate indicated that maximum particulate breakthrough was seen during the precoat cycle. 93% of the particles were 0.5 micron or less. Once the precoat was established about 98 % of the particulate breakthrough was 0.5 micron or less.

The very extensive testing conducted to date has always produced desirable results and indicates a very acceptable and beneficial application of the Mott Hypulse LSM in SBS Contaminant filtration. The next phase of testing with a pilot scale unit at the customers facility.

DATA SUMMARY TABLE #1
BATTELLE LSH TESTING H0134972
MOTT 2 MICRON POROUS ELEMENTS 21.6 FT2 AREA

Test #	1-1	1-2	2-1	3-1	4-1	5-1	5-2	5-3	5-4	5-5	6-1	6-2	6-3
Fe(OH3) PPM	180	180	180	180	180	180	180	180	180	180	180	180	18
FeCl grams/liter	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.4
Zeolite grams/liter	6.04	6.04	5.04	4.04	4.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.0
DE Bodyfeed grams/liter	None	None	None	None	None	None	None	None	None	None	1.00	1.00	1.0
Feed pH	9	9	9	12	9	9	9	9	9	9	9	9	[illegible]
Thruput Liters	1370	1400	1370	1336	1446	1382	1389	1370	1381	1370	1381	1370	147
Thruput Gallons	362	370	362	353	382	365	367	362	365	362	365	362	39
Thruput gallons	338	370	362	353	382	365	367	362	365	362	365	362	39
gal/ft2 at .2 gpm/ft2	15.6	17.1	16.8	16.3	17.7	16.9	17.0	16.8	16.9	16.8	16.9	16.8	18.
Precoat Time Minutes	20	20	20	20	20	20	20	20	20	20	20	20	2
Feed (time to .2 gpm/ft2) Minutes	5	10	15	10	8	10	9	10	8	10	5	8	
Feed (time at 0.2 gpm/ft2) Minutes	85	80	80	85	87	75	81	80	82	86	80	67	7
Feed Total Running Time Minutes	90	90	95	95	95	85	90	90	90	96	85	75	8
Average Feed Flowrate gpm/ft2 at 0.2 gpm/ft2	0.18	0.21	0.21	0.19	0.20	0.23	0.21	0.21	0.21	0.19	0.21	0.25	0.2
Recovery Pressure Drop PSI	0.9	1.4	1.9	1.5	1.9	1.1	0.9	2.0	1.9	1.9	0.9	1.7	1.
Precoat PSI Start	1.5	1.4	2.0	1.7	4.0	1.0	1.6	2.8	2.4	3.6	1.8	2.7	3.
Precoat PSI End	2.2	2.7	3.7	2.6	5.3	2.6	2.5	3.0	2.9	2.9	3.2	3.0	3.
Feed PSI Start	2.3	5.0	3.0	3.2	3.7	2.6	2.3	3.3	3.5	6.0	3.2	2.7	2.
Feed PSI End	46.0	20.5	20.0	49.2	48.3	33.7	44.0	55.7	44.7	35.1	20.0	44.2	23.
Filtrate Quality PPM	0.23	0.11	0.48	0.11	0.12	0.11	–	–	–	0.062	–	0.36	–
Filtrate Turbidity NTU													
Max. NTU	0.25	0.15	1.00	0.07	0.20	0.12	0.09	0.10	0.10	0.13	0.18	0.32	0.1
Min NTU	0.06	0.06	0.05	0.05	0.05	0.08	0.06	0.06	0.08	0.06	0.07	0.06	0.0

2.1 Filtration Test Data Summary

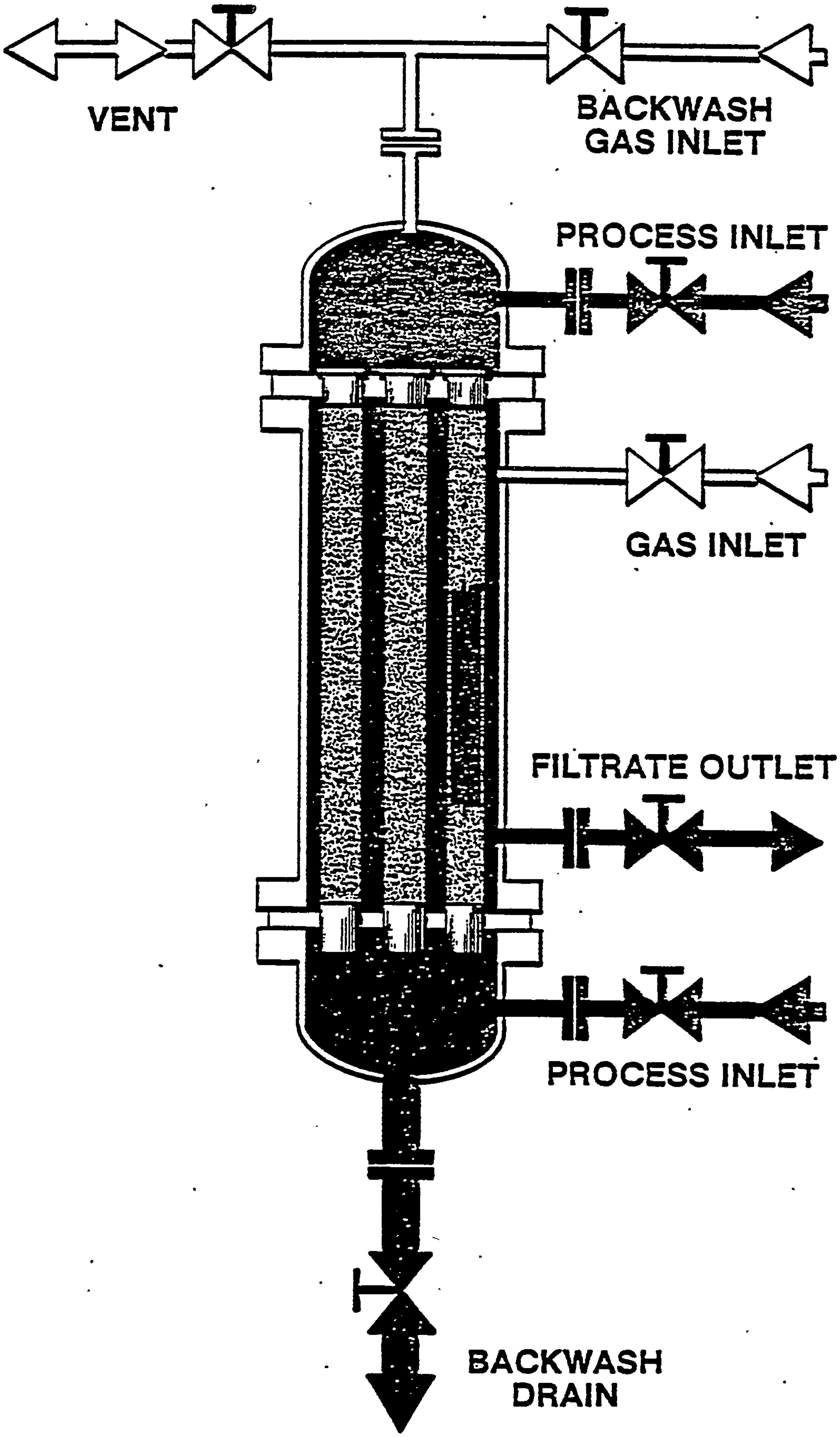
3 Filter Assembly : Mott Hypulse LSM

The filter used in this test is a Mott Hypulse LSM (Multimode) Pilot Filter. The Multimode configuration was chosen because it allowed precoating in the conventional method (upward flow) and feeding with a downward flow which allowed the heavier solids to settle out in the bottom of the vessel.

Filtrate exit was from the lower portion of the vessel minimizing the amount of liquid generated during backwash.

The filter consists of (7) tubular elements of 2.5 inch outside diameter, 59.75 inch porous length, made from porous 316L stainless steel with a rating of 2 micron filtration capability. The filtration area is 21.6 ft.2 based in the elements I.D. of 2.375 inch diameter. These element are installed within a 10 inch diameter housing as a tube bundle assembly between two vessel flanges.

The housing consists of three pieces: an upper head, a lower head, and a main body housing. The assembly is described in Figure 1.



HYPULSE™ LSM FILTER
*Patent pending

MOTT METALLURGICAL CORPORATION
FARMINGTON INDUSTRIAL PARK
FARMINGTON, CONNECTICUT

Figure #1

4 Filter Specifications: Mott Hypulse LSM

Description : 10 inch Hypulse LSM

Elements : Number (7)
Rating : 2 Micron
Dimensions : 2.5 inch OD, .062 wall
61.97 OAL

Seals : Viton O'ring

Filtering Area: 3.09 ft.2 each, 21.6 ft.2 total

Element Bubble Point , Inches of Water

#	1	2	3	4	5	6	7
New	22.2	24.0	21.0	21.0	21.4	21.2	23.0
End Test (Oct 89)	21.0	21.0	22.0	23.0	21.0	23.0	22.0
Begin Test (Oct 90)	23.0	21.0	21.0	23.0	21.4	22.0	22.0
End Test (Oct 90)	22.0	21.0	22.4	23.0	23.0	21.2	23.0

Housing : 10 inch diameter with a upper dished head, a lower head reduced to a 4 inch discharge. Flanged connections. Element and tube sheet assembly contained between the lower head and the upper head of the main body of the housing.

Volumes: Upper head , 0.46 ft.3
Main body , 2.96 ft.3
Lower head , 0.77 ft.3
Total 4.19 ft.3

Materials: Elements : 316 LSS
Housing: 304 SS
Tube Sheet : 304 SS
Seals : Viton
Gaskets: BlueGuard

Clean Flow Pressure Drop

Flow, GPM/ft.2	Diff. Pressure PSID	After 10 Cycles
0.2	0.8	.8
0.5	1.0	.9
1.0	1.1	1.0
1.5	1.2	1.3

5 System Assembly and Operation : Mott Hypulse LSM

5.1 Equipment Assembly

The test system was assembled to provide for a precoating operation and a continuous makeup of feed slurry. Due to the large volume of water to be filtered and treated, and the limited space and disposal facilities available, filtrate from both the precoat and feed was recycled and reused.
The process is described in Figure 2.

The system consists of a precoat slurry feed tank and pump ; a concentrate makeup an feed system ; a slurry feed tank and flow control loop ; the filter ; a sampling filtrate receiver ; and a slurry backwash receiver.

The flowrate to the filter was controlled by speed control on the delivery pump. The feed slurry is controlled by a set point single loop controller which adjusts the speed of a centrifugal pump. The precoat flow is set by air flow to an air powered diaphragm pump. This flow was set once and did not require readjustment since the precoating was always done at the same flow and pressures.
The concentrate flow to the slurry tank was manually controlled with a valve. Concentrate flow was set and tank volume was closely monitored.

Filtrate was recycled to the feed tank except for periodic samples taken to evaluate composite filtrate quality.

The system was controlled by an Omron Programmable Sequence Controller. Time is the primary variable which determines when valves open and close except for a filter pre-fill which terminates by a level switch. Pressures were sensed by transducers and indicated by digital meters.

A complete piping schematic is included in the Appendix.

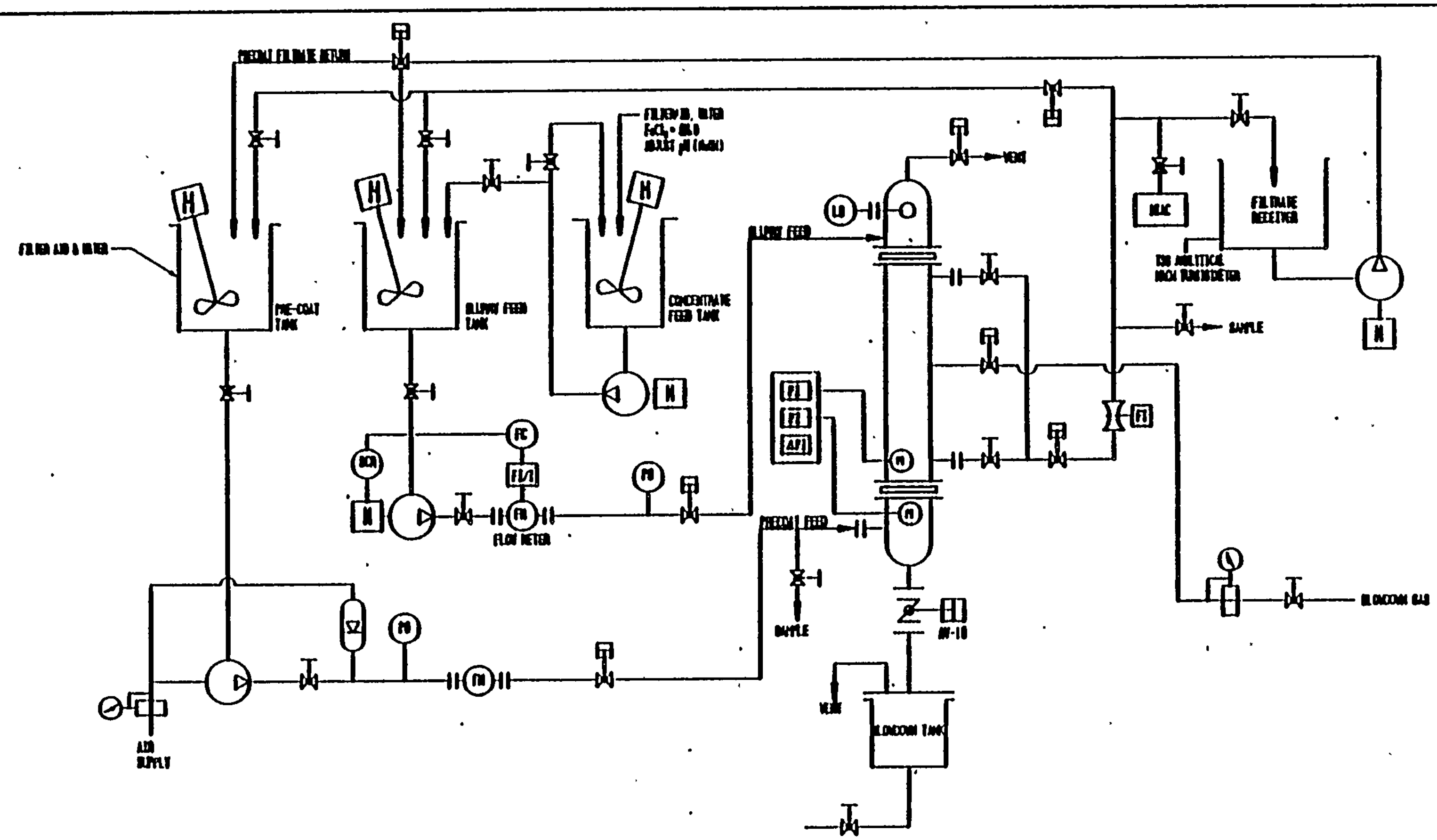


FIG. 2

DATE	EN	SYM	REVISION RECORD	DR	CK
11/30/89	3498	—	REL FOR INFO	DJO	LS

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FARMINGTON INDUSTRIAL PARK
FARMINGTON, CT. 06032

TITLE PROCESS FLOW SCHEMATIC- SBS SIMILANT FILTRATION TEST

MATERIAL | FINISH | DWG SCALE: NONE PLOT SCALE: .5 | SHT 1 OF 1

USE ON DWG NO. | DWG. NO. B 400249 | REV —

5.2 Operational Procedures:

The precoat and feed make-up tank were heated up to about 120 degrees F for testing purposes.

5.2.1 Make-up Water

The water used in the test was Mott tap water filtered thru a 0.2 micron Gelman cartridge filter. The precoat and slurry make-up water were heated to about 120 degrees F for testing purposes. 1 cc/gal of 5% Hydrogen Peroxide was added to the make up water to prevent bacterial growth.

5.2.2 Iron Precipitation

The test contaminant was precipitated iron, hydroxide form. Ferric Chloride ,(FeCl3*6H2O), technical grade, was added to the concentrate tank in the desired quantities. The pH was adjusted to 9 or 12 with caustic. If the pH was over the desired amount it was dropped back down with HCl.

5.2.3 Precoat Make-up

The desired quantity of Manville Celite was added at the beginning of each cycle to the precoat makeup tank. Filtrate was recirculated to the precoat tank for 20 minutes to clear the tank. 983 grams of DE were added to 40 gallons of water. Slurry concentration was 0.65% .

5.2.4 Concentrate Makeup

Approximately 9 gallons of concentrate slurry was made up for each cycle. Ferric chloride was added to the water and the pH adjustment was made. The Zeolite was added and the pH was rechecked and adjusted if required.

5.2.5 Feed Slurry Make-up Tank

The feed slurry tank starts at each cycle with 50 gallons volume. Fe(OH3) and Zeolite are added to maintain the desired filter feed concentration as makeup water is added.

5.2.6 Slurry Backwash

A sample of the slurry backwash was retrieved for analytical evaluation and the volume was recorded.

5.2.7 Filtrate Analysis

Analytical evaluation of the filtrate was performed via Millipore analysis using 0.45 micron paper. A 1/2 gallon sample was collected during a cycle as an composite sample and is assumed to be representative of the cumulative filtrate for the cycle.

Filtrate turbidities were monitored throughout testing using a Hach Turbidimeter.

On line sampling was conducted using a Hiac Royco Particle Counter.

5.2.8 Gas Consumption

Air usage is monitored for each cycle and is reported as a volume and rate consumed.

5.3 Test Procedure

1. Pre-fill the filter with clean water until the high level switch trips.

2. Make up slurries in the concentrate and feed slurry makeup tank. Adjust to desired pH level. Average mix time about 20 minutes.

3. Make up 0.65% precoat slurry with Manville Celite.

4. Precoat the filter with 0.1#/ft2 DE flowing at 1 gpm/ft2. Return filtrate to the precoat tank. Run for 20 minutes to clear tank.

5. Switch the feed slurry tank without interruption of flow to maintain precoat integrity. Adjust the flow of the feed slurry tank to maintain the terminal pressure seen in the precoat cycle. Gradually decrease to 0.2 gpm/ft2 feed flowrate. Recycle filtrate to the feed makeup tank.

6. Run cycle for target cycle length. If the differential pressure drop reaches 50 PSID, reduce the feed flow to hold 50 PSID.

7. Terminate feed flow.

8. Close filtrate outlets.

9. Pressurize the filter to 45 PSI thru shell (filtrate) side.

10. Blowdown filter

11. Close up filter and prefill as in Step 1.

6 Conclusions : Mott Hypulse LSM Testing

Satisfactory results were obtained in the filtration of $Fe(OH)_3$ at a concentration of 180 PPM $Fe(OH)_3$ using the Mott Hypulse LSI and 2 Micron porous media. Zeolite was tested at concentrations of 6.04, 5.04, 4.04 and 3.04 grams/liter IE-96. Repeat cycle testing (5 cycles) were conducted using 3.04 g/l Zeolite and no DE bodyfeed. Three cycles were run using 3.04 g/l Zeolite and 1.0 g/l DE bodyfeed.

Test results indicate that a 0.1#/ft2 precoat of Manville Celite (Standard Super-Cel) was effective in protecting the media from the simulant contaminant. The ground Zeolite was effective as a bodyfeed. Optimum results were obtained with a pH range of 9. Higher pressure drop was obtained with pH 12.

Testing with the Hypulse LSM (Multimode) using feed in the downflow configuration demonstrates that there is settling of the solids and the amount of Zeolite could be reduced.

Testing indicates that this is an excellent application for the Mott Hypulse LSM. The double open ended design with slurry feed in the downflow configuration performed effectively.

Flowrate of 0.2 gpm/ft2 were easily maintained in all tests.

Recovery pressure drop indicates that there was no fouling of the media after repeated cycling. A slurry backwash was effective in removing all of the solids from the element with a 40-45 PSI pulse of air.

Filtrate was visibly clear. Composite filtrate quality determined via Millipore analysis using 0.45 micron paper was 0-.36 PPM TSS. Filtrate turbidity measured using a Hach Turbidimeter ranged from .05 - 1.0 NTU'S.

Particle count data using a Hiac Royco indicate that 98% of the particulate passed thru the filter were 0.5 micron or less. Optimum breakthrough was during the precoat cycle.

7 Discussion of the results : Mott Hypulse LSM Testing

7.1 General Operation

The Mott Hypulse LSM Multimode Tubular Precoat Filter has demonstrated its capability to filter SBS Simulant contaminant at 180 PPM $Fe(OH)_3$ at pH 9 and 12 and deliver high quality filtrate of less than 0.2 PPM TSS.

Previous testing has demonstrated the effectiveness of the precoat at protecting the porous metal elements, and of the bodyfeed filteraid at extending the cycle life. Depending on the solids load in the waste stream, optimum cycle thruput was as follows:

7.2 Summary of Pressure Drop, Thru-put and Solids Loading

Iron Hydroxide $Fe(OH)_3$ 180 PPM Concentration

Test #	pH	Thruput Gal/ft2	Terminal PSI	Zeolite gms/l	DE gms/l
1-1	9	15.6	46.0	6.04	0
1-2	9	17.1	20.5	6.04	0
2	9	16.8	20.0	5.04	0
3	12	16.3	49.2	4.04	0
4	9	17.7	48.3	4.04	0
5-1	9	16.9	33.7	3.04	0
5-2	9	17.0	44.0	3.04	0
5-3	9	16.8	55.7	3.04	0
5-4	9	16.9	44.7	3.04	0
5-5	9	16.8	35.1	3.04	0
6-1	9	16.9	20.0	3.04	1.0
6-2	9	16.8	44.2	3.04	1.0
6-3	9	18.0	23.3	3.04	1.0

Table #3

Thruput optimization was not evaluated in these tests. Thru-put was based on batch size. Flowrate of 0.2 gpm/ft.2 were easily maintained. Optimization of feed flowrate was not evaluated.

7.2.1 Discussion of the Test Results

The following graphs show the rate of rise in the differential pressure verses cycle time minutes for the various feed concentratons. The slurry was feed to the filter at 0.2 gpm/ft2.

Variations from cycle to cycle are attributed to slurry concentration variation pumping the concentrated feed to the slurry make-up tank.
In all cases the entire volume of feed in the concentrate tank was transfered to the Slurry Make-up tank and filtered. See the material balance summary for concentration levels.

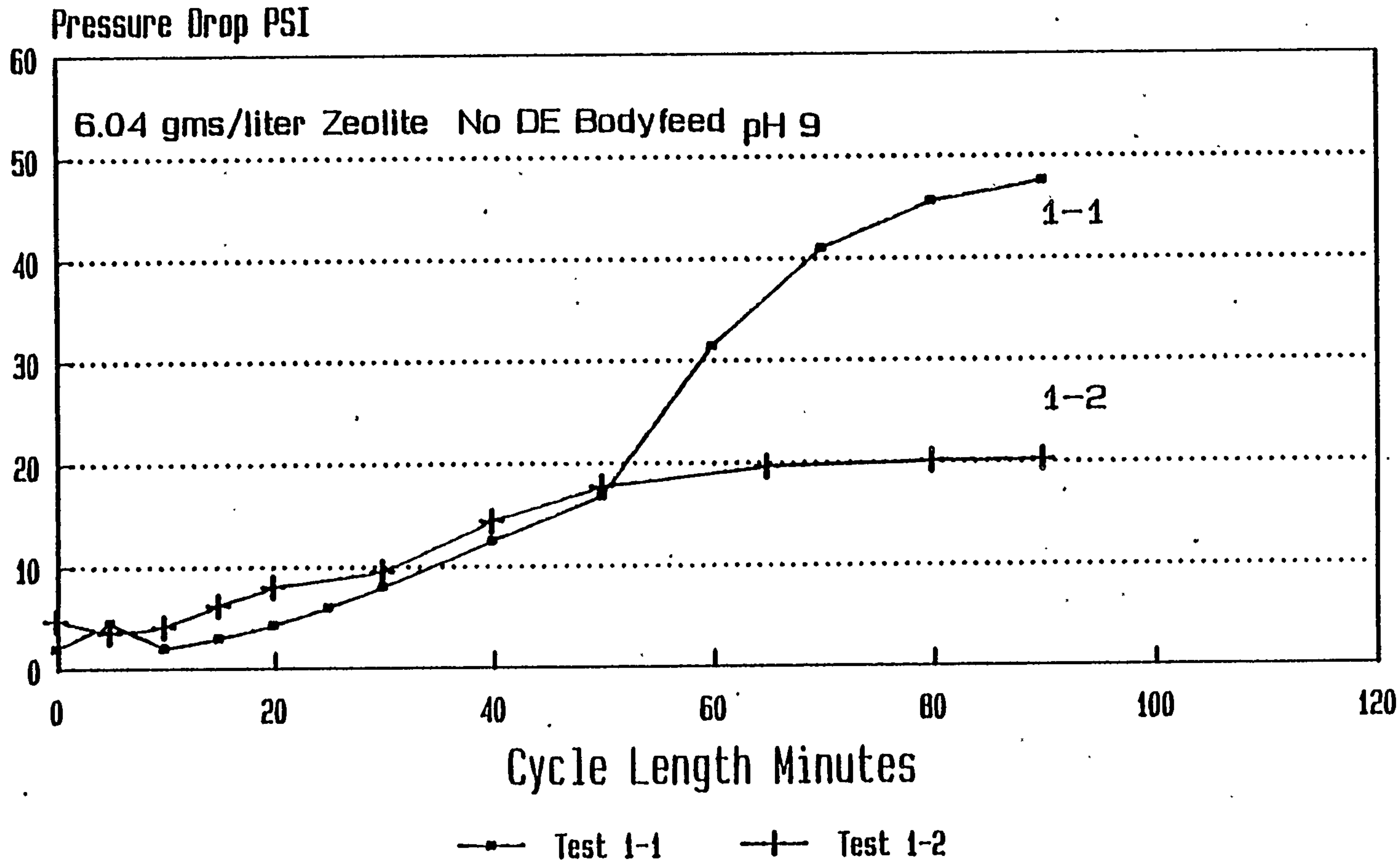
The results of Tests 1-1 and 1-2 are shown in Graph #1. Zeolite concentration was 6.04 g/l with pH 9.

Graph #2 shows the results of tests 2,3 and 4. Test #2 was run using 5.04 g/l Zeolite and pH 9. Test 3 used 4.04 g/l Zeolite and pH 12. Test 4 used 4.04 g/l Zeolite and pH 9.

Graph #3 is the results of the 5 cycles run in test #5. Zeolite concentration is 3.05 g/l with pH 9.

Graph #4 is the results of the 3 cycles run in Test #6 which was run using a DE bodyfeed along with 3.04 g/l Zeolite and pH 9.

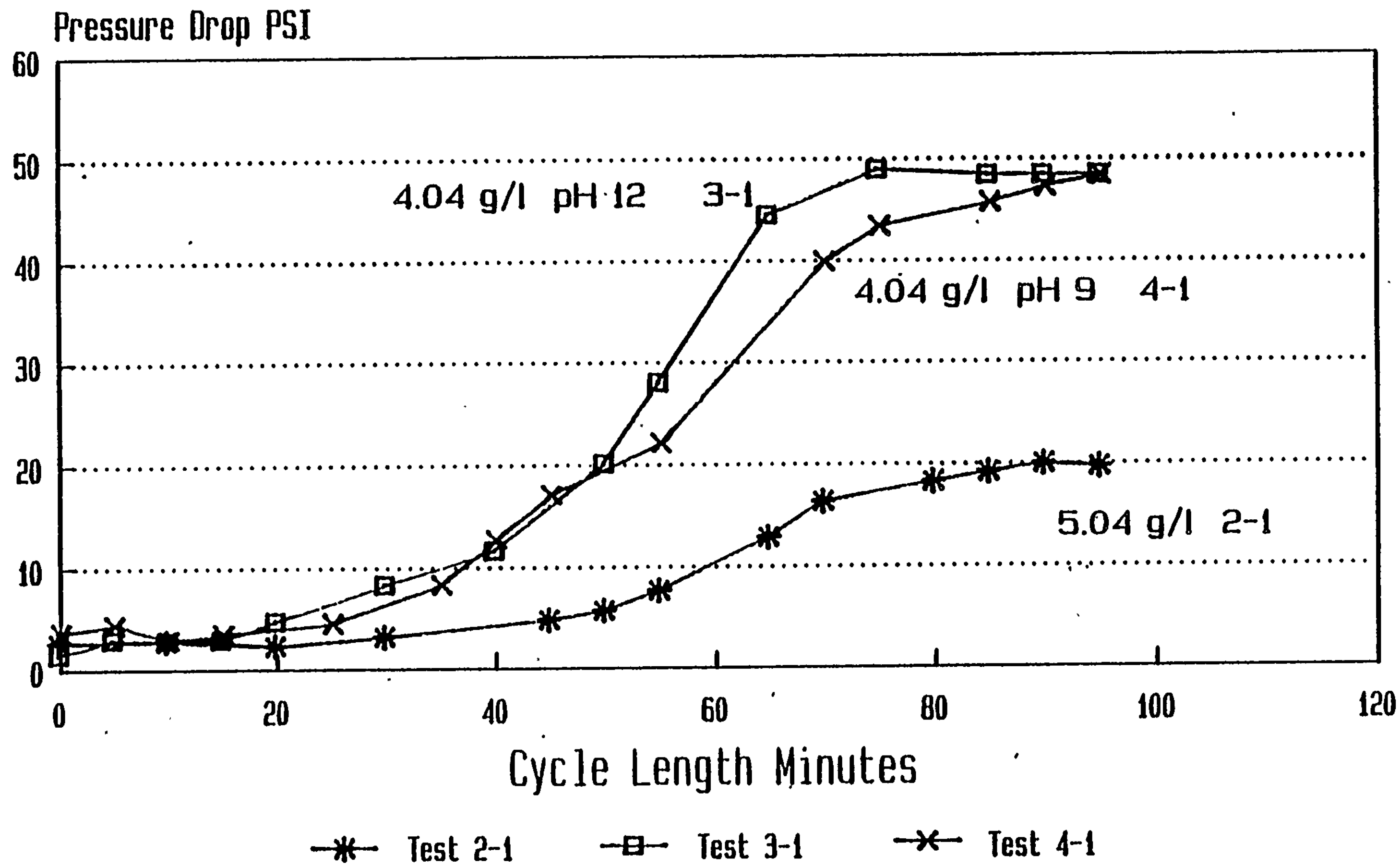
Battelle Hypulse LSM Testing WO# 34972
Mott 2.0 Micron Media 21.6 Ft2 Area
180 PPM Fe (OH) 3 and Ground Zeolite IE-96



Tested 10/15/90
Precoat 0.1 #/ Ft2

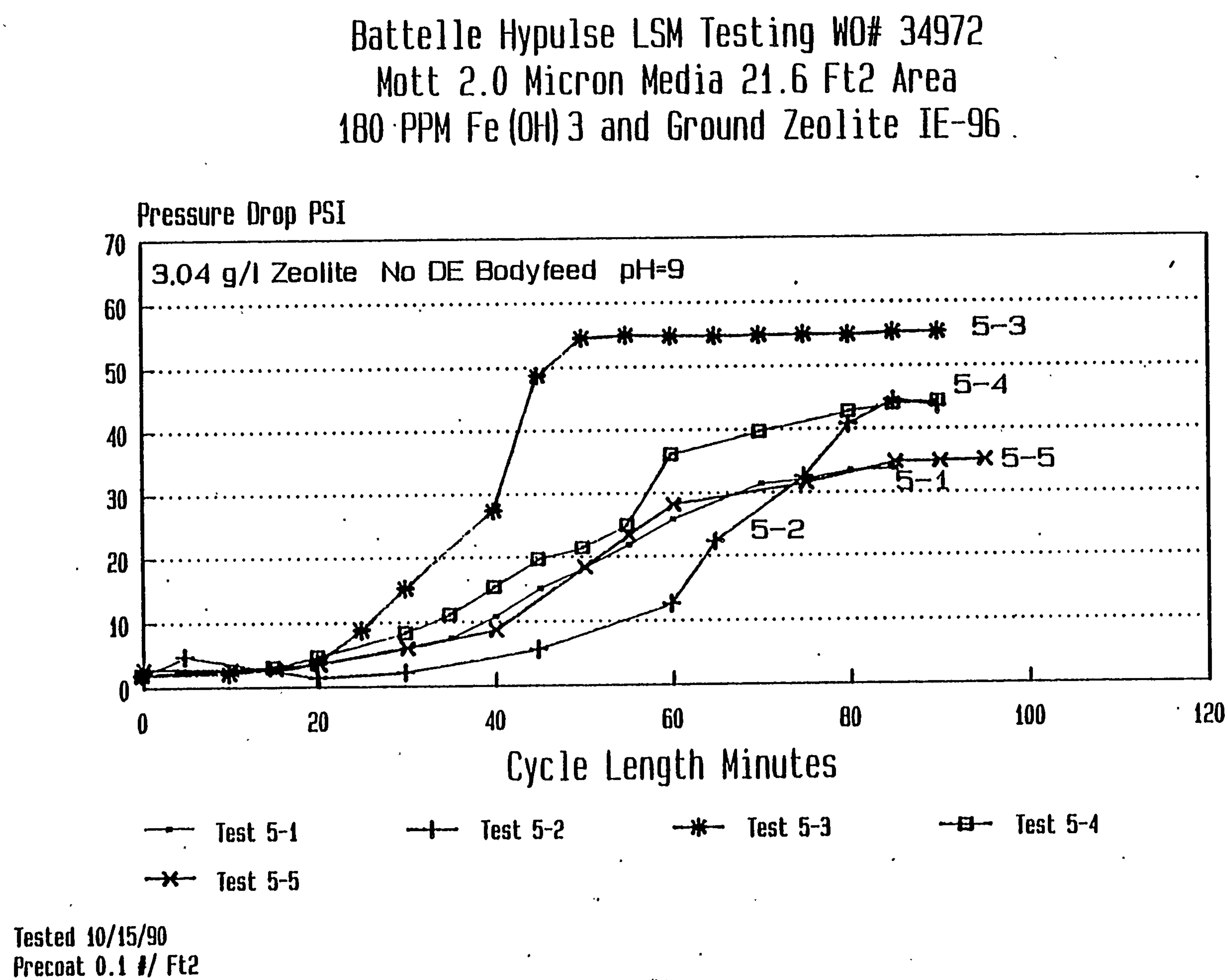
Graph 1

Battelle Hypulse LSM Testing WO# 34972
Mott 2.0 Micron Media 21.6 Ft2 Area
180 PPM Fe (OH) 3 and Ground Zeolite IE-96



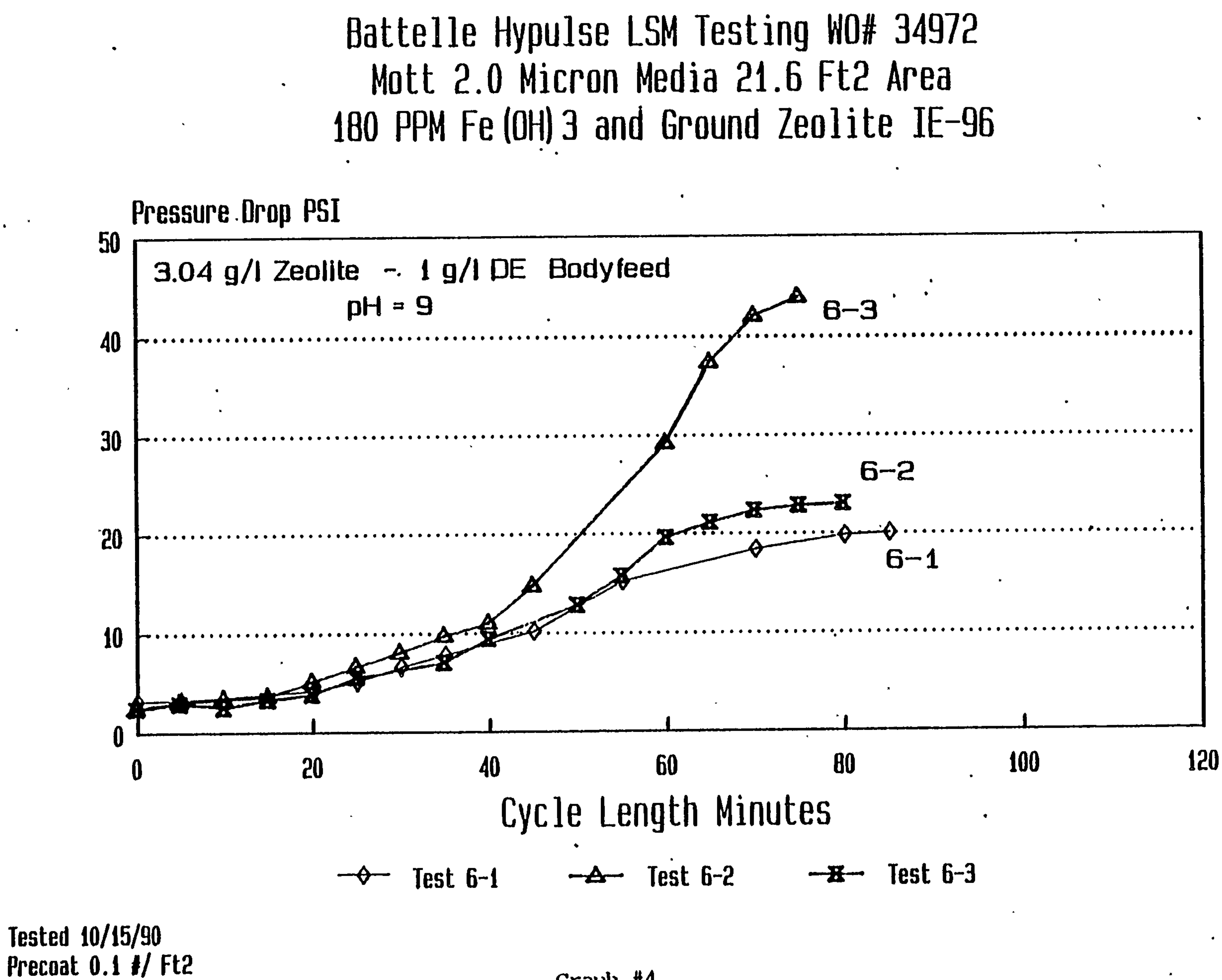
Tested 10/15/90
Precoat 0.1 #/ Ft2

Graph #2



Battelle Hypulse LSM Testing WO# 34972
Mott 2.0 Micron Media 21.6 Ft2 Area
180 PPM Fe (OH) 3 and Ground Zeolite IE-96
Pressure Drop PSI
3.04 g/l Zeolite No DE Bodyfeed pH=9
70
60
50
40
30
20
10
0
20
40
60
80
100
120
5-3
5-4
5-5
5-1
5-2
Cycle Length Minutes
Test 5-1
Test 5-2
Test 5-3
Test 5-4
Test 5-5
Tested 10/15/90
Precoat 0.1 #/ Ft2

Graph #3


Battelle Hypulse LSM Testing WO# 34972
Mott 2.0 Micron Media 21.6 Ft2 Area
180 PPM Fe (OH) 3 and Ground Zeolite IE-96
Pressure Drop PSI
3.04 g/l Zeolite - 1 g/l DE Bodyfeed
pH = 9
50
40
30
20
10
0
0
20
40
60
80
100
120
6-3
6-2
6-1
Cycle Length Minutes
Test 6-1
Test 6-2
Test 6-3
Tested 10/15/90
Precoat 0.1 #/ Ft2

Graph #4

7.3 Blowdown Technique

The blowdown solids level and the recovery yield are a function of the blowdown technique. All cycles were backwashed with the same method using a slurry backwash technique. The backwash solids concentration ranged from 5-9% solids and were a pumpable consistency.

A full evaluation of the blowdown possibilities was not conducted in these tests. Filtrate was drained from the lower filtrate drain of the vessel. At the time of backwash the filtrate valve was closed, the housing was pressurized to 40 - 50 PSI and the filter was backwashed.

7.3.1 Blowdown Gas Requirement:

The quantity of gas and the required flowrate necessary to operate the filter was measured for each cycle. The blowdown pressure is 35 PSI and starts with the filter at pressure when the discharge butterfly valve opens. Gas flow to the filter is maintained for 3 seconds after the valve opens. Gas consumption is based on total gas required to pressurize the filter and the 3 second blow. Gas flowrate are the flows thru the elements in 3 second time. Data for the selected cycles is listed in the table below.

Blowdown Gas Requirements

Test#	Consumption		Flowrates	
	SCF	SCF/Ft2	SCFM	SCFM/FT2
1-1	4.63	0.21	92.60	4.29
1-2	4.04	0.19	80.80	3.74
2-1	3.66	0.17	73.20	3.39
3-1	4.07	0.19	81.40	3.77
4-1	5.86	0.27	117.21	5.43
5-1	3.79	0.18	75.89	3.51
5-2	3.79	0.18	75.89	3.51
5-3	3.33	0.15	66.60	3.08
5-4	3.21	0.15	64.20	2.97
5-5	3.12	0.14	62.40	2.89
6-1	3.55	0.16	71.00	3.29
6-2	3.43	0.15	66.8	3.09
6-3	2.90	0.13	58.00	2.69

7.4 Filtrate Quality

Filtrate was visibly clear. Composite filtrate quality determined via Millipore analysis using 0.45 micron paper was 0.151 PPM TSS. Filtrate turbidity measured using a Hach Turbidimeter ranged from .05 -1.0 NTU'S.

Particle count data using a Hiac Royco indicate that 99% of the particulate breakthrough was 0.5 micron or less. The results of representative samples are listed in the Table #4.

Evaluation of Filtrate Quality using the Hiac Royco and Comparison of Turbidity using a Hach Turbidimeter

Test #	Elapsed Time	Channel #	1	2	3	4	5	6	Turbidity NTU
	Minutes	Micron	0.5	1	2	5	10	15	
1-2 Precoat	8	Cumm. Count	360824	6536	2635	166	0	0	
Start Feed	4		657669	9119	1978	202	6	3	0.15
	31		559790	6328	2906	667	3	0	0.08
	48		254304	6345	2802	712	6	1	0.06
	59		403049	6517	2909	692	0	0	
	75		165038	7328	3487	708	5	1	
2-1 Precoat	13		341178	7869	3229	478	42	25	0.14
Feed	15		447168	7644	4162	660	4	2	1.00
	26		416144	4870	3076	946	9	0	
	48		56402	3315	2173	862	4	0	0.05
	70		597712	4319	2701	707	3	1	0.06
	86		373848	5187	3357	912	6	1	0.05
3-1 Precoat	10		409808	4654	1603	294	20	11	
Feed	12		720240	894	454	169	2	0	0.05
	39		122555	924	337	81	2	1	0.06
	56		47705	781	210	59	0	0	0.07
	78		481482	553	159	42	2	1	0.05
	89		27578	444	128	26	0	0	
4-1 Precoat	8		148040	4749	1327	394	73	42	0.05
Feed	10		400102	3268	1376	180	3	0	0.20
	21		85876	3128	1819	467	3	1	0.05
	32		79034	2311	1330	342	2	1	0.05
	60		25709	1873	1116	322	1	0	0.06
	71		19561	1805	962	254	1	0	0.09
5-1 Precoat	13		720017	2225	751	188	31	17	0.09
Feed	9		133292	1516	696	168	6	4	0.10
	26		404472	1390	554	158	2	0	
	42		572376	1263	445	98	0	0	0.09
	59		165890	1176	406	91	4	0	0.09
	75		44527	838	298	59	3	1	0.08
5-2 Precoat	9		61679	2313	1051	260	20	10	0.06
Feed	11		94588	406	175	52	2	0	0.07
	27		110072	394	152	41	0	0	0.08
	49		111406	339	119	25	1	0	0.08
	66		249576	402	109	24	0	0	0.08
	88		77435	221	74	18	0	0	0.09
5-3 Precoat	17		-	-	-	-	-	-	0.06
Feed	16		179283	767	185	25	0	0	0.07
	32		305149	645	220	65	12	6	0.07
	49		332275	1016	297	90	7	3	0.08
	80		57888	325	119	30	5	1	0.10
	96		37364	279	92	29	2	1	0.10
5-4 Precoat	9		47693	1500	563	163	32	19	0.08
Feed	11		102675	946	342	95	6	0	0.10

Table #4

Test#	Time	Micron	0.5	1	2	5	10	15	NTU
	28		720240	371	141	39	3	0	0.10
	45		34848	271	98	28	2	2	
	62		34538	250	74	9	2	1	
	34		5249	91	38	7	0	-0	
5-5									
Precoat	48		31195	348	147	41	9	3	0.08
Feed	11		287449	347	152	61	15	11	0.09
	23		573261	270	62	17	5	4	0.11
	66		81046	326	66	17	1	1	0.13
	78		67488	1393	226	24	0	0	0.12
	95		64656	1329	468	163	25	12	0.12
6-1									
Precoat	11		377358	1953	568	178	29	15	0.07
Feed	13		648684	2499	262	34	6	2	0.17
	29		692154	1897	233	42	6	1	0.14
	40		450450	1592	191	33	7	3	
	57		390351	1303	262	58	12	6	
	73		641983	1029	190	37	3	2	0.08
6-2									
Precoat	17		426540	1781	449	69	6	2	0.09
Feed	14		531704	888	138	8	1	0	0.08
	31		292792	1728	130	12	2	1	0.06
	42		403504	1467	257	65	14	12	
	53		720240	679	98	32	7	0	
	64		491548	1394	368	99	17	3	0.06
6-3									
Precoat	15		231792	7619	2789	971	189	96	0.08
Feed	17		231165	542	96	13	1	1	0.06
	34		358507	485	110	23	4	3	0.15
	44		167400	616	103	17	3	2	
	56		73547	711	167	22	4	2	
	67		301636	732	173	27	6	4	0.10

Table #4

7.5 Recovery Pressure Drop and Anticipated Life

During the course of the testing the tendency to foul the elements was monitored by the change in the initial pressure drop (recovery pressure) at the start of each cycle.

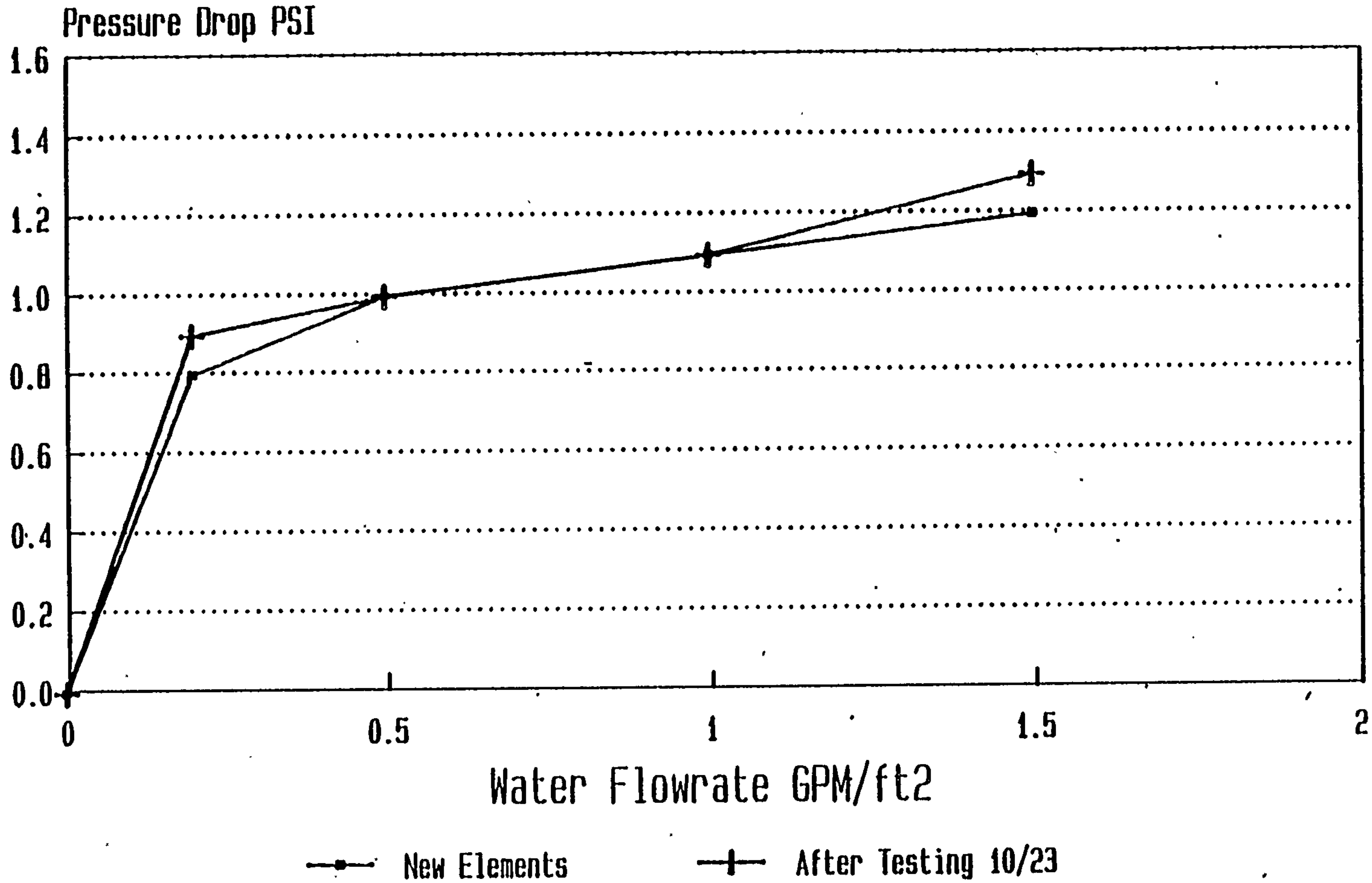
The filter was pre-filled at a flowrate of 1 gpm/ft2 prior to the
start of the precoat cycle and the pressure drop was recorded. Variations in the recovery pressure drop are the result of a residual contaminant remaining in the lower housing after backwash.

Clean flow pressure drop indicates that there was no fouling of the media at the completion of the testing. Test results indicate that there was a 0.1 PSI variation in the recovery pressure drop at the end of Test 6-3 which is within the accuracy of the instrumentation. See graph #5.

Bubble point data recorded on the elements before and after testing also shows that there was no fouling of the media.

Test results indicate that the slurry backwash effectively removed the solids from the elements. Visual examination of the elements at the end of Test 7 shows that the elements were free of residual precoat material and iron hydroxide. There was evidence of slight rust on the element which is expected using 316L with high levels of chloride in the solution. The filter specifications are for Alloy 20 for this application.

Battelle Hypulse LSM Testing WO# 34972
Mott 2 Micron Elements 21.6 Ft2 Area
Clean Flow Data using Filtered Water



Tested 10/23/90

Graph #5

7.6 Material Balance :

Material balance was performed via Millipore analysis on a representative sample from individual test conditions. Analytical measurements were taken throughout testing from the concentrate feed tank, feed slurry make-up tank ,backwash tank and the filtrate stream.

The entire concentrate batch was fed to the filter. At the end of the testing the slurry make-up tank was practically clear in most cases. Analytical evaluation was conducted on the make-up tank at the end of the test if it did not appear clear.

Several cycles were run in test 1 and 2. The concentrate feed was prepared so that the entire amount of solids for the test was mixed in the concentrate tank. Feed was added to the slurry make-up tank at the predetermined feed rate. The concentrate pump was shut off after the desired amount of concentrate was fed to the filter.. Typically this was about 10 minutes before the end of the test.

The filter was then isolated and the housing was pressurized and backwashed thru a 3" butterfly valve into a covered (vented) 55 gallon drum. The backwash was transferred into a Nalgene tank and the liquid volume was recorded. The feed slurry was then mixed with Lutz pump and a sample of the backwash was taken. The backwash was then transferred into another 55 gallon drum for disposal.

7.6.1 Material Balance Summary

Discussion of the Results:
Table #5 lists the Material Balance data for all tests. The % solids of the blowdown is a calculated number based on the fact that we know that we backwashed all of the solids from the filter. Visual examination of the elements,housing and blowdown tank at the end of the testing indicates that there were no solids held up anywhere in the filter.

Analytical evaluation of the % solids of the backwash samples are slightly lower than expected. The numbers are suspect due to the sampling technique used and the relatively rapid settling of the solids during transfer from the blowdown tank.

Material Balance

Battelle LSM Pilot Test WO# 34972

Test #	Thruput Total Gal. (Actual)	Thruput Gal/ft2	Filtrate Flowrate gpm/ft2	Precoat grams	Fe grams	Fe(OH3) grams	Zeolite grams	DE grams	Total LBS Dry	Vol Gal	Blowdown % solids measured	Blowdown % Solids calculate	LBS Wet	LBS Dry	Solids Recovery %
1-1	338	15.6	0.18	983	631	249.245	8287	0	21.0	27.5	9.8	9.0	232.6	20.93	99.8
1-2	370	17.1	0.21	983	631	249.245	8287	0	21.0	27	9.8	9.1	228.3	20.78	99.0
2-1	362	16.8	0.21	983	631	249.245	6914	0	18.0	22.5	10.9	10.1	177.4	17.92	99.8
3-1	353	16.3	0.19	983	631	249.245	5542	0	14.9	28	5.7	6.3	236.8	14.92	99.9
4-1	382	17.7	0.2	983	631	249.245	5542	0	14.9	24	5.8	6.5	227.0	14.76	98.8
5-1	365	16.9	0.23	983	631	249.245	4171	0	11.9	32	5.6	4.3	271.0	11.65	97.8
5-2	367	17.0	0.21	983	631	249.245	4171	0	11.9	24	5.6	5.3	223.0	11.82	99.2
5-3	362	16.8	0.21	983	631	249.245	4171	0	11.9	24	-	5.8	202.4	11.74	98.6
5-4	365	16.9	0.21	983	631	249.245	4171	0	11.9	27	-	5.3	224.6	11.90	99.9
5-5	362	16.8	0.19	983	631	249.245	4171	0	11.9	24	5.1	5.7	206	11.74	98.6
6-1	365	16.9	0.21	983	631	249.245	4171	1372	14.9	26	-	6.7	222	14.87	99.6
6-2	362	16.8	0.25	983	631	249.245	4171	1372	14.9	23	5.5	7.6	196	14.90	99.7
6-3	390	18.1	0.24	983	631	249.245	4171	1372	14.9	24	-	7.3	205	14.97	100.2

* % Solids determined using calculated Blowdown Solids % number

Table #5

7.6.2 Analytical Results

The following Table is a summary of the analytical results evaluated during testing:

Test #	Total PPM*	Concentrate Slurry PPM*	Make-up Slurry PPM Start	Make-up Slurry PPM End	Backwash Slurry PPM	%	Filtrate Stream PPM
1-1	6221	251058	2185	-	98036	9.8	0.23
2-1	5221	210705	3157	642	10899	10.9	0.48
3-1	4221	170352	4227	387	56944	5.7	0.114
4-1	4221	170352	4278	837	58089	5.8	0.121
5-1	3221	130058	3501	381	56139	5.6	0.117
5-5	3221	130058	3974	355	50963	5.1	0.062
6-2	5221	210705	2122	1704	54701	5.5	0.36

* Calculated based on Fe(OH3) Concentration
Includes Zeolite and DE Bodyfeed (Excludes Precoat)

Table # 6

8 Disc Test Results

8.1 Summary of the Disc Test Results

The objective of the disc testing was to determine the initial conditions for the pilot scale Hypulse LSM testing.

Disc feasibility tests were performed using 180 PPM Fe(OH)3 concentration with Ground Zeolite (IE-96) concentrations of 3.04, 4.04, 5.04, and 6.04 grams/liter at a pH of 9 and 12. The effect of a filteraid addition to the feed (bodyfeed) was not evaluated in the disc test program. See Summary Table #7 for the complete disc test results.

The filter was precoated using 0.1#/ft2 Manville Celite filteraid. Precoat flowrate was 1.0 gpm/ft2.
The feed slurry was moved to the disc at a flowrate of 0.2 gpm/ft2. Testing was terminated once the pressure drop reached 45 PSI. Thruput data was slightly less than 16.19 gal/ft2 in most cases. Thruput opimization was not evaluated in this test program.

Testing demonstrated that the minimum amout of Zeolite (3.04 g/l) could be used and performance was satisfactory. Improved performance was expected using the Hypulse LSM (Multimode) configuration. Tests were conducted with feed at pH 9 as the disc test results inicated that the pressure drop was slightly lower.

Pilot scale tests were conducted using various Zeolite solids load to the filter. Testing was to be conducted with solution pH of 9. Repeat cycle testing was conducted using the minimum amount of Zeolite. The effect of a DE bodyfeed was evaluated in the pilot scale tests.

Table #7

Test #	Previous Disc Testing Zeolite IE-95 October 1989 4	8	Disc Testing Zeolite IE-96 Ground October 1990 1	2-1	2-2	3-1	3-2	4	5	6
Precoat 0.1#/ft2 Celite	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Feed Sample	180 PPM	180 PPM	180 PPM	180 PPM	180 PPM	180 PPM	180 PPM	180 PPM	180 PPM	180 PPM
Grams of $FeCl_3$	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Grams of $FeCl_3$/L	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Grams of $CdCl_2$	-	-	-	-	-	-	-	-	-	-
Liters of Water	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Neutralize with NaOH to a pH of :	12	12	12	12	12	12	12	12	9	9
Grams of Zeolite	7.6	7.6	7.6	10.1	10.1	12.6	12.6	15.1	15.1	12.6
Grams of Zeolite/L	3.04	3.04	3.04	4.04	4.04	5.04	5.04	6.04	6.04	5.04
Grams of DE as Bodyfeed	7.6	-	-	-	-	-	-	-	-	-
2 Micron Disc #	1	1	New	Same	Same	Same	Same	Same	Same	Same
Cycle Time Minutes	64	33	60	35.5	39	42	40	58	59	79
Filtrate Volume cc's	1900	660	1340	860	1010	1130	1080	1510	1600	2000
Thruput Gal/ft2	16.19	5.62	11.42	7.33	8.61	9.63	9.2	12.87	13.63	17.04
Average Flux Gpm/ft2	0.25	0.17	0.19	0.21	0.22	0.23	0.23	0.222	0.231	0.216
Terminal Pressure PSI	20	40	45	45	46.5	47	46	47	25	41.5
Cake Thickness Inches	0.265	0.087	-	0.08	0.13	0.115	0.085	0.11	0.19	0.17
Backwash Slurry Wt. grams	37.47	16.63	223	21.34	22.1	22	21.6	18.63	24.98	23.67
Dewater PSI	40	40	-	45	45	45	45	45	25	45
Backwash PSI	60	60	65	65	65	65	65	65	45	65
Filtrate Turbidity Range NTU"S	0.23-0.4	-	0.2-3.3	.31-.82	.33-1.5	.27-1.7	.4-1.1	.12-.47	.11-1.2	.07-.92
Composite Filtrate Turbidity NTU'S	0.26	0.65	3.2	1.7	1	1.1	0.86	0.68	0.32	0.19
Composite Filtrate Quality PPM TSS	2.27	1.62	-	-	-	-	-	-	-	-
Clean Flow Data % Recovery						97.7	-	-	-	89.7

8.2 Equipment Evaluated

Disc feasibility tests were performed using the Mott 70 MM disc test filter and 2.0 micron porous media.(.031 ft2 area) The equipment arrangement is described in figure 3. Tests were run with solution temperatures of 110-130 F.

Variables recorded during testing were flowrate, pressure drop, pH, temperature, cycle time, volumetric thruput, backwash slurry weight, and filtrate turbidity.

Filtrate turbidity was determined using a Hach Turbidimeter. Analytical data was not performed in the disc test phase of the testing.

8.2.1 Test Procedure

1.) Prepare feed per customers instructions.

2.) Once-thru precoat at 1 gpm/ft2 using 0.1#/ft2 precoat solids loading.

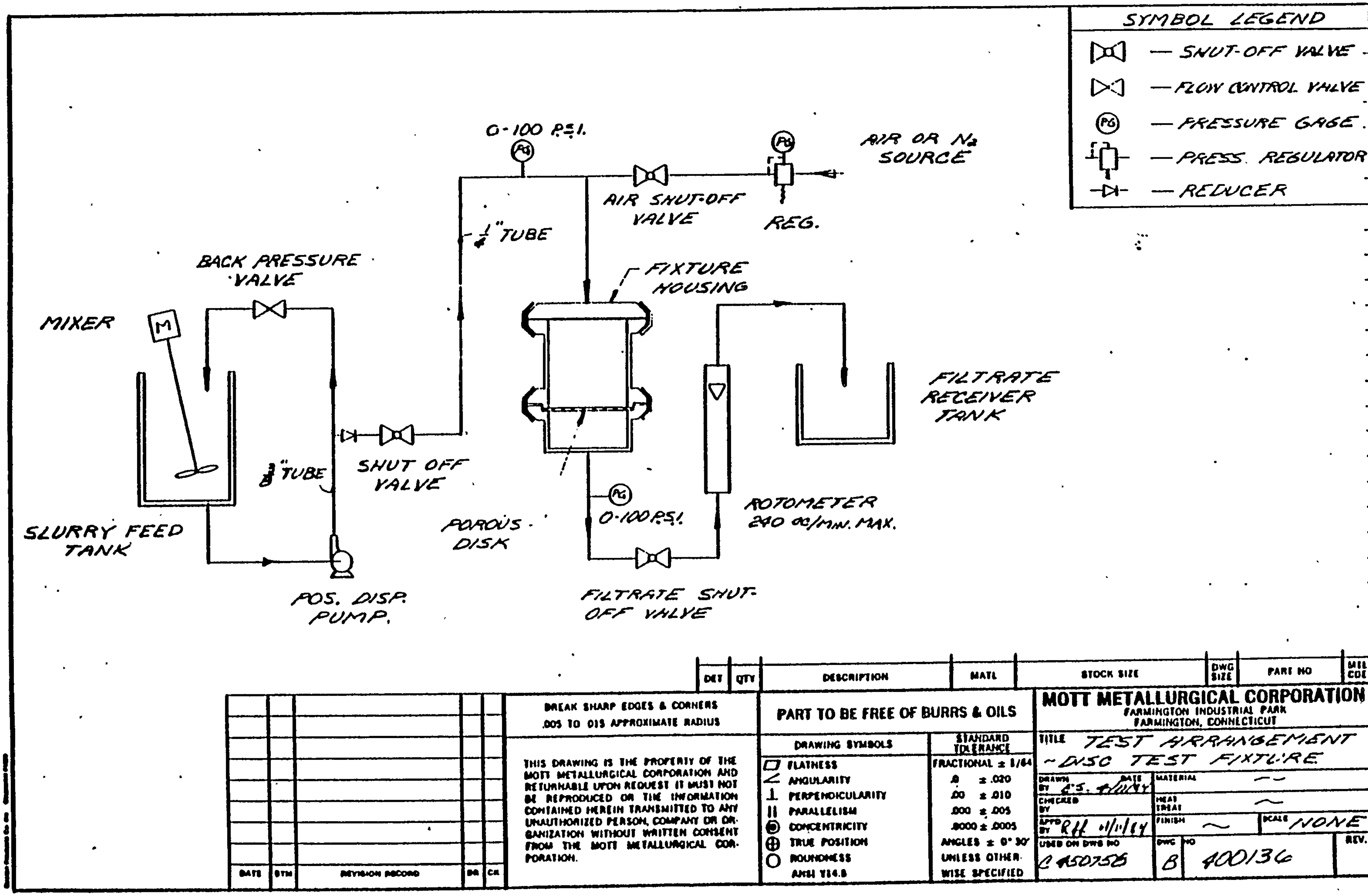
3.) Start feed and pump at 0.2 gpm/ft2 flowrate to the filter and collect filtrate. Record filtrate turbidity.

4.) Run at 0.2 gpm/ft2 until a maxamum of 45 PSI delta P is reached or the entire volume of feed (1.9 liters) is filtered.

5.) Dewater the cake at the terminal delta P to evaluate cake characteristics.

6.) Invert the housing, pressurize and backwash at 20 PSI above the terminal pressure drop.

7.) Reorient the housing, inspect the disc for solids release, reassemble and resume the next cycle.


SYMBOL LEGEND
— SHUT-OFF VALVE
— FLOW CONTROL VALVE
— PRESSURE GAGE
— PRESS. REGULATOR
— REDUCER
0-100 P.S.I.
AIR OR N2 SOURCE
AIR SHUT-OFF VALVE
REG.
1/4" TUBE
BACK PRESSURE VALVE
FIXTURE HOUSING
MIXER
M
FILTRATE RECEIVER TANK
3/8" TUBE
SHUT OFF VALVE
SLURRY FEED TANK
POROUS DISK
0-100 P.S.I.
ROTOMETER
240 cc/min. MAX.
POS. DISP. PUMP.
FILTRATE SHUT-OFF VALVE
DET
QTY
DESCRIPTION
MATL
STOCK SIZE
DWG SIZE
PART NO
MTL CDE
BREAK SHARP EDGES & CORNERS .005 TO .015 APPROXIMATE RADIUS
PART TO BE FREE OF BURRS & OILS
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CONCENTRICITY
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ROUNDNESS
ANSI Y14.5
STANDARD TOLERANCE
FRACTIONAL ± 1/64
.0 ± .020
.00 ± .010
.000 ± .005
.0000 ± .0005
ANGLES ± 0° 30'
UNLESS OTHERWISE SPECIFIED
DRAWN BY
DATE
MATERIAL
CHECKED BY
HEAT TREAT
APPD BY
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SCALE NONE
USED ON DWG NO
C 450756
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400136
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REVISION RECORD
DR
CK

Figure 3

APPENDIX B

PERMISSION TO USE MOTT'S DRAWINGS B400249 AND B400151

MOTT METALLURGICAL CORPORATION

FARMINGTON INDUSTRIAL PARK, FARMINGTON CONN 06032
FAX: 203-674-1489 TELEX: 99374 PHONE 203-677-7311

January 10, 1990

Mr. John Calhoun
BATTELLE, P.N.L.
P.O. Box 999
Richland, WA 99352

Ref: P.O. 081618-A-A3

Dear Mr. Calhoun:

Regarding your request to publish data contained in our Laboratory Test Report #2, issued 12-1-89, Mott Metallurgical Corporation hereby grants permission to publish such data as Battelle finds necessary with the stipulation Mott Metallurgical be referenced as the source of such data. This includes drawings B400249 and Figure 1, Dwg. B400151 which contain restrictive clauses.

We do NOT grant permission to publish in the public domain Figures 13, Drawing B2214123 Rev. F, and Drawing B400248. These figures and drawings should be treated as confidential between Mott and its customers. For purposes of this job, Battelle, Fluor and Westinghouse Hanford are considered customers.

Mott Metallurgical requests the opportunity to review any documents or reports prepared for publication from our Test Report #2.

You are reminded that the Mott HyPulse LSM filter is protected by U.S. Patent No. 4552669 and Canada Patent 1218022. Any mention of the LSM should contain a statement to that effect.

Sincerely Yours,

Ron S. Sekellick
Manager, Applications Development

Approved By:

John C. Washburn
Executive Vice President

RSS:sae

Controlled Porosity For Precision Products

RECEIVED
JAN 16 1990
SUBCONTRACTS