ANDERSON - SOUTH PIERSON
SPEARFISH FORMATION
INJECTION WATER TREATMENT STUDY

Prepared for

Anderson Exploration Ltd.

Prepared by

Hycal Energy Research Laboratories Ltd.

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SUMMARY

SUMMARY

Study Objective

At the request of Larry Sopko and Luis Remuldez of Anderson Exploration Limited (Anderson) and Saad Ibrahim of Petro Management Group, Hycal Energy Research Laboratories Ltd. conducted an injection water treatment study using reservoir material and fluids from the Spearfish Formation in the South Pierson area. This study was initiated to optimize the water injection efficiency at the injection plant. The objective of this study was to evaluate a chemical flocculent as a additive to the injection water to improve the filter efficiency at the water injection plant. Particle size analyses and flow tests were conducted to verify the effectiveness of the flocculent and the injectivity of the fluid.

Conclusions

The following conclusions are provided to enhance understanding of the laboratory data and to offer additional insight relative to Hycal's experience with laboratory and field processes. They represent our interpretation as to possible mechanisms and physical phenomena that may be occurring within the laboratory models that have been studied; however, these laboratory experiments are microscale representations of the field scenario and macroscale phenomena may override behaviour exhibited in the laboratory. A more thorough development of these conclusions is presented in the "Discussion" section.

1. An anionic partially hydrolyzed polyacrylamide (PHPA) was provided by Brine Add Fluids (Calgary) for evaluation as a flocculent for the suspended fines in the injection water.

2. Particle size analyses of injection source waters indicated that there was a shift in particle sizes with the addition of the PHPA. The PHPA was successful in flocculating suspended fines together such that the average particle size was much larger with the PHPA addition.

3. A critical filtration test was conducted to evaluate the injectivity of the treated injection water. The injection water was treated with the PHPA and filtered to 2.0 microns. The results indicated fairly good initial injectivity but declined rapidly with increasing flow volume and velocity.

4. In terms of field application, the PHPA should increase the effectiveness of the coarse filters allowing longer service life before replacement. However, as the flow test results indicated, the filtration limit must be finer than 2 microns to be effective. Also the flow velocity must be minimized in order to avoid fines migration problems. Both of these issues were investigated in earlier phases of this project.

DISCUSSION

DISCUSSION

The Spearfish Formation in the South Pierson field has been a difficult zone for water injection. Field production data indicate that the injection rate is behind in voidage replacement at a ratio of nearly 1 to 2. Previous studies have identified that the formation is quite sensitive to injection rates and that extensive filtration (down to 1.0 micron) is required. Horizontal injector wells are in the plans in order to increase the injection volumes. The increased surface area of a horizontal well will also allow increased volume without increasing the flow velocities at the near wellbore area. However, injection water filtration requirement remains a difficult issue. Current injection plant facilities requires frequent filter replacements and on-site personnel supervision.

Particle Size Analysis with PHPA Flocculent

One of the avenues to increase filtration efficiency is the use of a flocculent that could potentially agglomerate the suspended fines in the injection water such that a larger fraction of the particles are filtered out with filters of larger than 1.0 microns. There are other avenues to increase the effectiveness of the filtration process; however, this study centres on the effectiveness of a chemical flocculent.

An anionic PHPA (partially hydrolyzed polyacrylamide) was supplied by Brine Add Fluids of Calgary for testing. The anionic type PHPA (as opposed to cationic) was selected based on the assumption that the majority of the suspended fines are reservoir fines (silt and clay material). Particle size analyses were conducted on field samples of the "Source Well" water and "Produced Treater" water before any filtration. Both of these waters were then treated with the anionic PHPA and the particle sizes were remeasured at 0.5 hour, 1 hour and 2 hours after the addition of the PHPA. The particle size analyses with the addition of the PHPA indicated a definite "shift" of the particle size distribution towards larger particle sizes. The untreated "produced treater" water exhibited a particle size distribution of 1 microns or less. After 0.5 hour of the addition of the PHPA, particle sizes of 30 microns to 125 microns were immediately detected. After 2 hours of the addition of the PHPA, a large percentage of particles were detected in the 350 microns range. These results are shown in Tables 2 to 5.

The results from the "source well" water were not as immediate. The untreated water sample exhibited particle sizes of up to 125 microns. After the addition of the PHPA, the early particle size data at 0.5 hour and 1 hour exhibited a minor increase in particle size distribution. After 2 hours, a more significant shift indicated a high percentage of particles in the >250 microns size. With the current field practice, the available settling time would be upwards of 8 hours. Assuming the trend of the data is continuous, there should be sufficient time for the PHPA to take effect. The results of the particle size analyses for the "source well" water are shown in Tables 6 to 9.

Core #16, Fines Migration Test with Treated Injection Water

A test core plug with an air permeability of 5.02 mD and 14.2% porosity was obtained from Well 14-9-2-29 W1M to represent the reservoir matrix. The sample was prepared initially with 100% formation brine saturation and an absolute permeability to formation brine was measured at 3.0 mD and used as a baseline value. It should be noted that the brine and subsequent injection water were filtered to only 2.0 microns. Although the recommendation for field filtration was down to 1.0 microns, this lab test was conducted with a 2.0 micron filter due to the unavailability of a 1.0 micron within the time frame of this study and also with the hope that, if the 2.0 micron filter was successful in maintaining the injectivity in our lab test, it would mean significant reduction in maintenance requirements in the field.

Once the injection fluid was switched from the formation brine to the injection water treated with the PHPA, the pressure drop began fluctuating. Our observation is that the PHPA did not disperse readily in the injection water, causing some "slugging" effects in the injection stream. As the injection rates were increased, the slugging effect diminished (may also be a function of time, although the PHPA had been added a day before the injection began in our laboratory). However, the effective permeability of the injection water decreased significantly from the beginning of the switch over to the treated injection water. Since the injection water was only filtered to 2.0 microns, this could be a cumulative effect from the build up of the suspended fines and not so much an effect of the injection rate.

In conclusion, the filtration limit for this formation is very demanding and will not tolerate less than optimal sizes. The effectiveness of the PHPA was not conclusively demonstrated with this core flow test. Field trails involving larger injection volumes and close monitoring of the filter conditions will validate the effectiveness of the PHPA. As noted in our flow test, the dispersion of the PHPA was not instantaneous and a "baffle" was recommended by Brine Add Chemicals to improve the dispersion of the PHPA in the settling tanks. A schematic diagram of the proposed injection tank layout is included in Appendix A.

PROCEDURES & EQUIPMENT

PROCEDURES AND EQUIPMENT

Core and Fluid Handling and Preparation

Field samples of the "source well" water, "produced/treater" water and the co-mingled injection water were supplied by Anderson for particle size analysis and to act as the displacing fluid for the core flow test. The anionic PHPA (partially hydrolized polyacrylamide) was supplied by Brine Add Fluids in an "emulsified" form. This emulsion was diluted with water to achieve a 1% "pre-blended" solution. The concentration for treatment of the injection water is usually between 10 to 100 ppm of this pre-blended solution in the injection water. The concentration used in this study was at the median level of 55 ppm. The MSDS (material safety data sheets) are provided in Appendix B.

Small diameter (1.5 inch) core plugs were available from the 14-9-2-29 W1M well to represent the Spearfish Formation in the South Pierson field. The samples were subjected to a special cleaning process using methanol and chloroform in an effort to remove hydrocarbons that may be in the pore spaces. Routine air permeability and helium expansion porosity tests were conducted on the selected samples to verify reservoir quality prior to testing.

Core #HY16 - Critical Flow Rate Test

The core material was initially in a 100% brine-saturated state prior to testing and specified reservoir conditions of temperature and net overburden confining stress were utilized to obtain representative state core for the displacement series. The following fines migration procedure was used to determine the propensity for migration of pore space particulate in a high shear environment.

Test Procedure

The core material to be tested was mounted using the equipment outlined in the "Description of Equipment" section. Core samples were subjected to a net overburden stress of 20000 kPag. The laboratory net overburden stress was corrected using Poisson's ratio to account for the tri-axial stress condition exerted on the sample in the core holder. This ensures that field stress load conditions are simulated to yield representative rock compression and realistic absolute permeability values. The following procedure was utilized to obtain the experimental results for the study.

1. Core material is pressure-saturated with filtered formation water and mounted using specified conditions.

2. Displace filtered formation water through the core at a low constant rate to avoid the potential for fines mobilization. Measure delta pressure across core to calculate the initial absolute baseline permeability to brine.

3. With a stable pressure gradient established in the core, displacement is switched to test injection water "on the fly" to eliminate pressure shock experienced by the core.

4. The test injection fluid is displaced through the core at the constant rate and delta pressure is measured as a function of cumulative pore volumes of injection to determine the potential for matrix impairment resulting from injection fluid exposure.

5. Repeat Step 4 at incrementally increasing injection rates (i.e. reducing the rate to the base rate velocity for each permeability measurement) to facilitate the development of a plot indicating the permeability versus rate relationship.

Description of General Displacement Test Equipment

Equipment that is used in conventional displacement experiments is common to most core flow evaluation techniques. A detailed schematic of the specific apparatus configuration is provided in Figure 1. General descriptions of the laboratory equipment utilized for these tests appear in the following paragraphs.

Conventional Core Flow Heads

The portions of the core holder directly adjacent to the injection and production ends of the core are equipped with radial distribution plates to ensure that fluid flow is uniformly distributed into and out of the core sample. These heads are used for experiments which involve fluids that are prefiltered to remove large suspended solids which could entrain in the flow ports. All wetted surfaces of the flow equipment use conventional 316 SS.

Pressure Measurement

Pressure differential is monitored using Validyne pressure transducers. The transducers are mounted directly across the core and measure the pressure differential between the injection and production ends. The pressure transducers have ranges of sensitivity ranging from 0 to 14 and 0 to 26000 kPa and is rated as accurate to 0.01% of the full scale value. The appropriate transducer size is selected based upon the expected permeability and associated range of accompanying differential pressures for a given core sample. The signal from the pressure transducer appears on a multi-channel digital Validyne terminal from which the test operator records pressure readings during the displacement processes. The signal can also be downloaded to a computerized continuing data acquisition system for long-term runs.

Temperature Control

The core holder and associated injection fluids are contained in a temperature controlled air bath to simulate reservoir temperature. The oven contains a circulating air system to eliminate internal temperature gradients and can control at temperatures from 20 to 200°C with a rated accuracy of ±1 °C.

Fluid Displacement

A highly accurate positive displacement pump is used to inject fluids into the core. The pump can inject fluids at rates from 0.6 to 8200 cm^3/hr and at pressures of up to 68.9 MPa, with an accuracy of ± 0.01 cm^3. The pump is filled with distilled water that displaces hydrocarbon fluid, test fluid or immiscible buffer fluid which in turn displaces test fluid into the core relative to the specific application. The experimental system has been designed to minimize dead volumes and to ensure that the entire system is at pressure equilibrium prior to any fluid change. Backpressure on the system (for full reservoir condition tests) is controlled using a 316 SS controlling backpressure regulator rated accurate to 0.5% of the setpoint value. This regulator allows for the smooth production of fluids from the system at any required flowrate and setpoint pressure.

TABLES

TABLE 1
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
TOTAL SUSPENDED SOLIDS ANALYSIS

Fluid Type / Source	Date of Sample	Total Suspended Solids	Units
Source Well Water	Sept 13, 2000	34	mg / liter
Produced/Treater Water	Sept 13, 2000	16	mg / liter
Co-mingled Water	Sept 13, 2000	27	mg / liter

TABLE 2
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
PARTICLE SIZE ANALYSIS

SAMPLE PARAMETERS		Bin Size microns	Incr. Fraction	Cuml. Fraction
Field:	SOUTH PIERSON	0.69	0.036	0.036
Well Location:	S. Pierson Injection Plant	0.97	0.053	0.089
Fluid Source	Produced/Treater Water	1.4	0.100	0.189
Sample Condition:	Original Untreated Sample	1.9	0.070	0.259
		2.7	0.026	0.285
		3.9	0.153	0.438
STATISTICAL DATA		5.5	0.206	0.644
Median Particle Size, µm:	6.14	7.8	0.162	0.806
Mean Particle Size, µm:	4.99	11	0.194	1.000
		15	0.000	1.000
		22	0.000	1.000
PARTICLE SIZE CATEGORY		31	0.000	1.000
1000 - 2000 microns:	Very Coarse Sand	44	0.000	1.000
500 - 1000 microns:	Coase Sand	62	0.000	1.000
250 - 500 microns:	Medium Sand	88	0.000	1.000
125 - 250 microns:	Fine Sand	125	0.000	1.000
62 - 125 microns:	Very Fine Sand	175	0.000	1.000
Less than 62 microns:	Silt & Clay	250	0.000	1.000
		350	0.000	1.000
		500	0.000	1.000

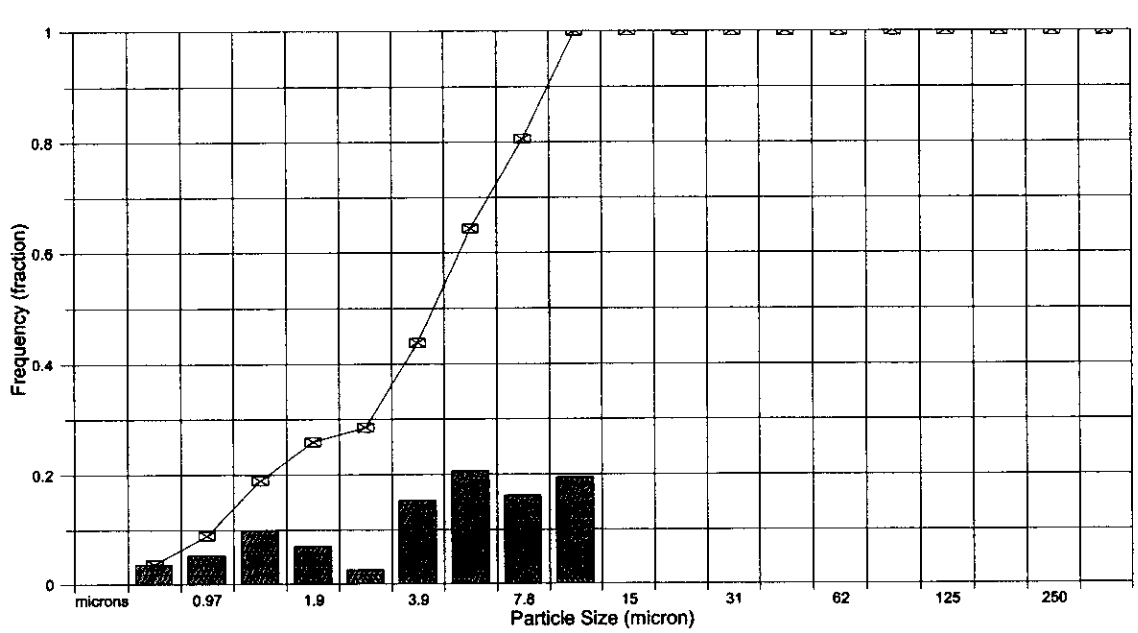


TABLE 3
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
PARTICLE SIZE ANALYSIS

		Bin Size microns	Incr. Fraction	Cuml. Fraction
SAMPLE PARAMETERS				
Field:	SOUTH PIERSON	0.69	0.031	0.031
Well Location:	S. Pierson Injection Plant	0.97	0.047	0.078
Fluid Source	Produced/Treater Water	1.4	0.094	0.172
Sample Condition:	½ Hour after PHPA Addition	1.9	0.080	0.252
	PHPA Concentration = 0.55%	2.7	0.111	0.363
		3.9	0.142	0.505
STATISTICAL DATA		5.5	0.080	0.585
Median Particle Size, µm:	5.34	7.8	0.087	0.672
Mean Particle Size, µm:	7.38	11	0.116	0.788
		15	0.000	0.788
		22	0.000	0.788
PARTICLE SIZE CATEGORY		31	0.060	0.848
1000 - 2000 microns:	Very Coarse Sand	44	0.034	0.882
500 - 1000 microns:	Coase Sand	62	0.002	0.884
250 - 500 microns:	Medium Sand	88	0.069	0.953
125 - 250 microns:	Fine Sand	125	0.047	1.000
62 - 125 microns:	Very Fine Sand	175	0.000	1.000
Less than 62 microns:	Silt & Clay	250	0.000	1.000
		350	0.000	1.000
		500	0.000	1.000

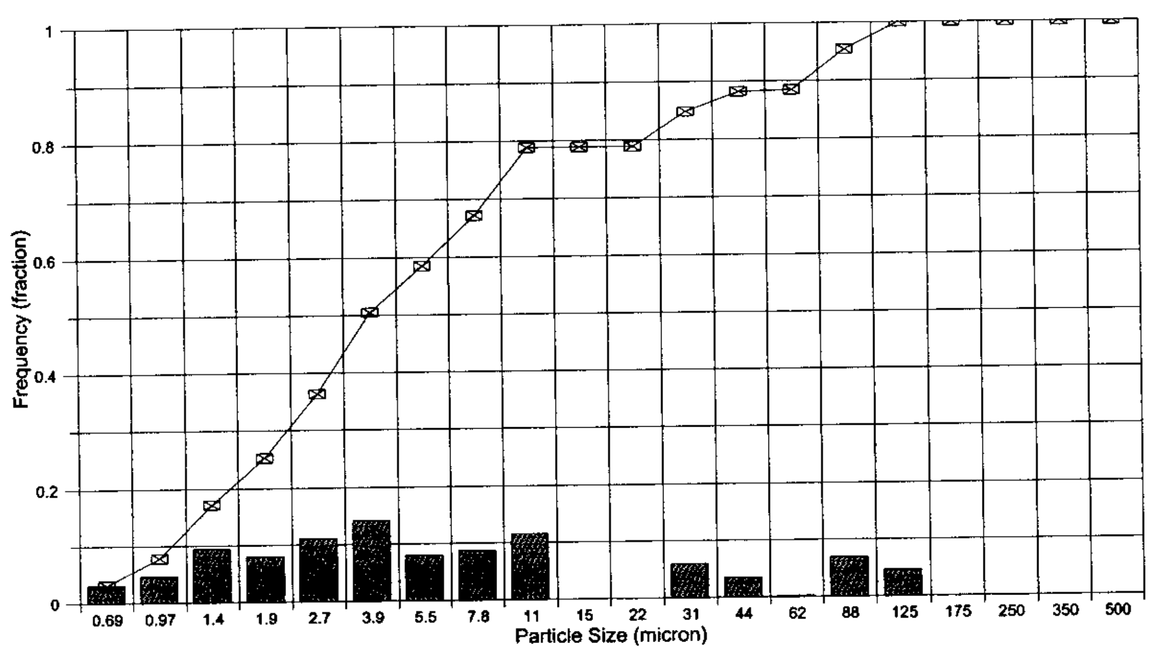


TABLE 4
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
PARTICLE SIZE ANALYSIS

SAMPLE PARAMETERS		Bin Size microns	Incr. Fraction	Cuml. Fraction
Field:	SOUTH PIERSON	0.69	0.025	0.025
Well Location:	S. Pierson Injection Plant	0.97	0.035	0.060
Fluid Source	Produced/Treater Water	1.4	0.056	0.116
Sample Condition:	1.0 Hour after PHPA Addition	1.9	0.040	0.156
	PHPA Concentration = 0.55%	2.7	0.068	0.224
		3.9	0.087	0.311
STATISTICAL DATA		5.5	0.052	0.363
Median Particle Size, µm:	101.5	7.8	0.054	0.417
Mean Particle Size, µm:	47.6	11	0.062	0.479
		15	0.000	0.479
		22	0.000	0.479
PARTICLE SIZE CATEGORY		31	0.000	0.479
1000 - 2000 microns:	Very Coarse Sand	44	0.000	0.479
500 - 1000 microns:	Coase Sand	62	0.000	0.479
250 - 500 microns:	Medium Sand	88	0.069	0.548
125 - 250 microns:	Fine Sand	125	0.045	0.593
62 - 125 microns:	Very Fine Sand	175	0.017	0.610
Less than 62 microns:	Silt & Clay	250	0.151	0.761
		350	0.239	1.000
		500	0.000	1.000

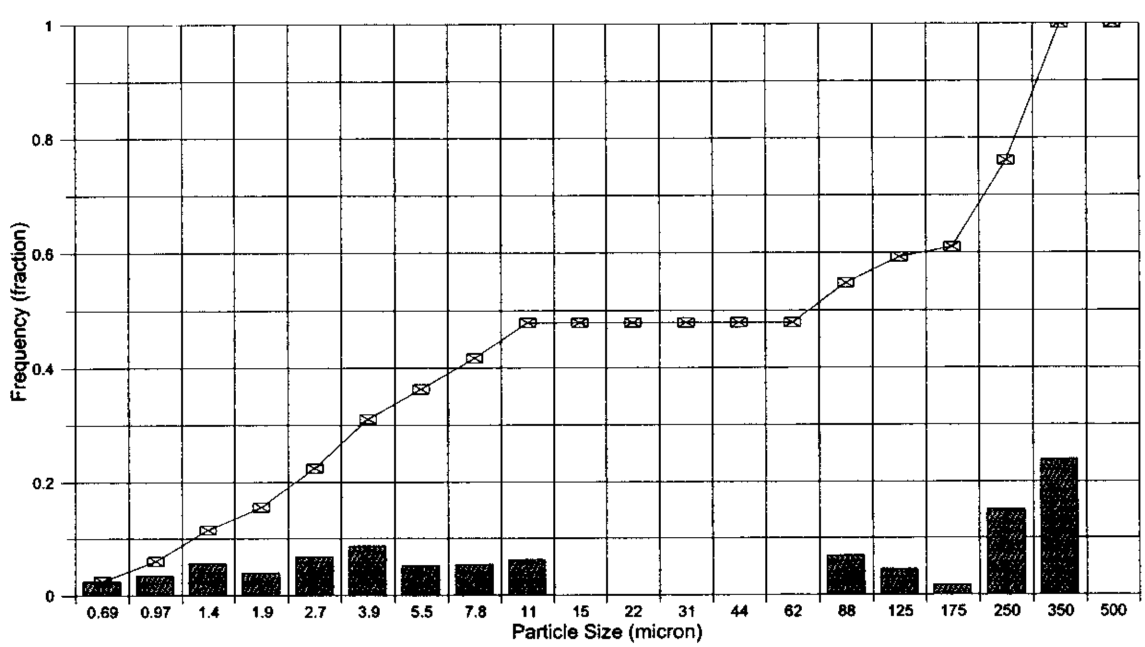


TABLE 5
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
PARTICLE SIZE ANALYSIS

SAMPLE PARAMETERS		Bin Size microns	Incr. Fraction	Cuml. Fraction
Field:	SOUTH PIERSON	0.69	0.020	0.020
Well Location:	S. Pierson Injection Plant	0.97	0.025	0.045
Fluid Source	Produced/Treater Water	1.4	0.031	0.076
Sample Condition:	2.0 Hour after PHPA Addition	1.9	0.014	0.090
	PHPA Concentration = 0.55%	2.7	0.039	0.129
		3.9	0.052	0.181
STATISTICAL DATA		5.5	0.028	0.209
Median Particle Size, µm:	392.7	7.8	0.029	0.238
Mean Particle Size, µm:	94.4	11	0.030	0.268
		15	0.000	0.268
		22	0.000	0.268
PARTICLE SIZE CATEGORY		31	0.000	0.268
1000 - 2000 microns:	Very Coarse Sand	44	0.000	0.268
500 - 1000 microns:	Coase Sand	62	0.000	0.268
250 - 500 microns:	Medium Sand	88	0.056	0.324
125 - 250 microns:	Fine Sand	125	0.031	0.355
62 - 125 microns:	Very Fine Sand	175	0.044	0.399
Less than 62 microns:	Silt & Clay	250	0.000	0.399
		350	0.601	1.000
		500	0.000	1.000

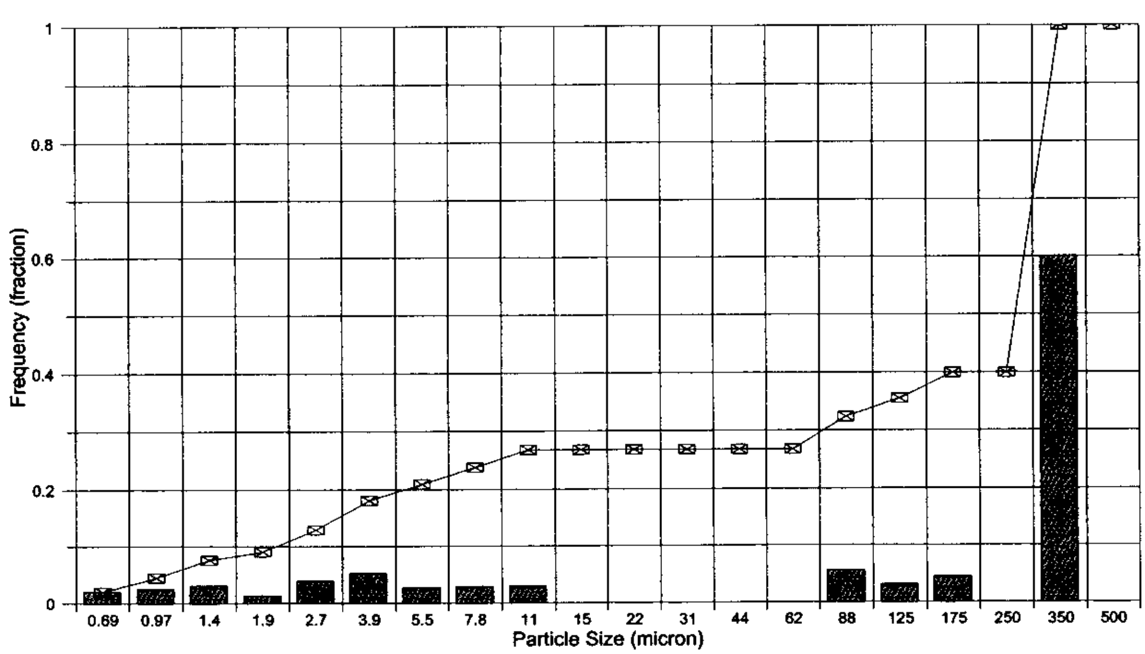


TABLE 6
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
PARTICLE SIZE ANALYSIS

SAMPLE PARAMETERS		Bin Size microns	Incr. Fraction	Cuml. Fraction
Field:	SOUTH PIERSON	0.69	0.038	0.038
Well Location:	S. Pierson Injection Plant	0.97	0.061	0.099
Fluid Source	Source Well Water	1.4	0.146	0.245
Sample Condition:	Original Untreated Sample	1.9	0.148	0.393
		2.7	0.154	0.547
		3.9	0.115	0.662
STATISTICAL DATA		5.5	0.041	0.703
Median Particle Size, µm:	3.41	7.8	0.064	0.767
Mean Particle Size, µm:	4.2	11	0.093	0.860
		15	0.007	0.867
		22	0.000	0.867
PARTICLE SIZE CATEGORY		31	0.039	0.906
1000 - 2000 microns:	Very Coarse Sand	44	0.039	0.945
500 - 1000 microns:	Coase Sand	62	0.012	0.957
250 - 500 microns:	Medium Sand	88	0.008	0.965
125 - 250 microns:	Fine Sand	125	0.035	1.000
62 - 125 microns:	Very Fine Sand	175	0.000	1.000
Less than 62 microns:	Silt & Clay	250	0.000	1.000
		350	0.000	1.000
		500	0.000	1.000

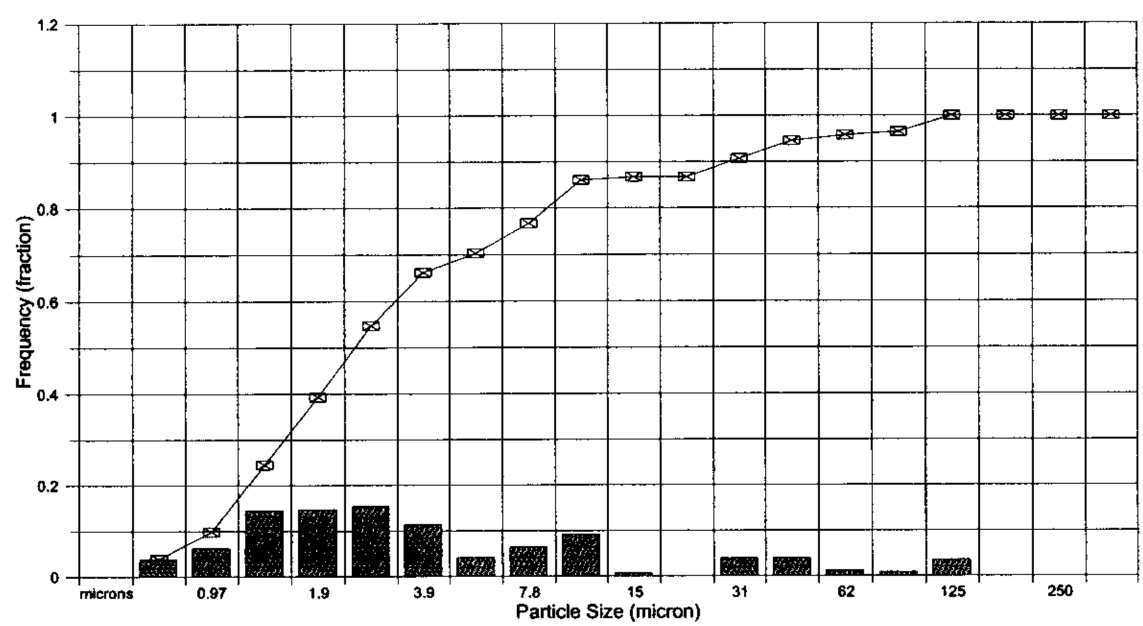


TABLE 7
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
PARTICLE SIZE ANALYSIS

SAMPLE PARAMETERS		Bin Size microns	Incr. Fraction	Cuml. Fraction
Field:	SOUTH PIERSON	0.69	0.035	0.035
Well Location:	S. Pierson Injection Plant	0.97	0.056	0.091
Fluid Source	Source Well Water	1.4	0.127	0.218
Sample Condition:	½ Hour after PHPA Addition	1.9	0.143	0.361
	PHPA Concentration = 0.55%	2.7	0.143	0.504
		3.9	0.100	0.604
STATISTICAL DATA		5.5	0.063	0.667
Median Particle Size, µm:	3.78	7.8	0.056	0.723
Mean Particle Size, µm:	6.73	11	0.061	0.784
		15	0.014	0.798
		22	0.000	0.798
PARTICLE SIZE CATEGORY		31	0.031	0.829
1000 - 2000 microns:	Very Coarse Sand	44	0.035	0.864
500 - 1000 microns:	Coase Sand	62	0.041	0.905
250 - 500 microns:	Medium Sand	88	0.055	0.960
125 - 250 microns:	Fine Sand	125	0.040	1.000
62 - 125 microns:	Very Fine Sand	175	0.000	1.000
Less than 62 microns:	Silt & Clay	250	0.000	1.000
		350	0.000	1.000
		500	0.000	1.000

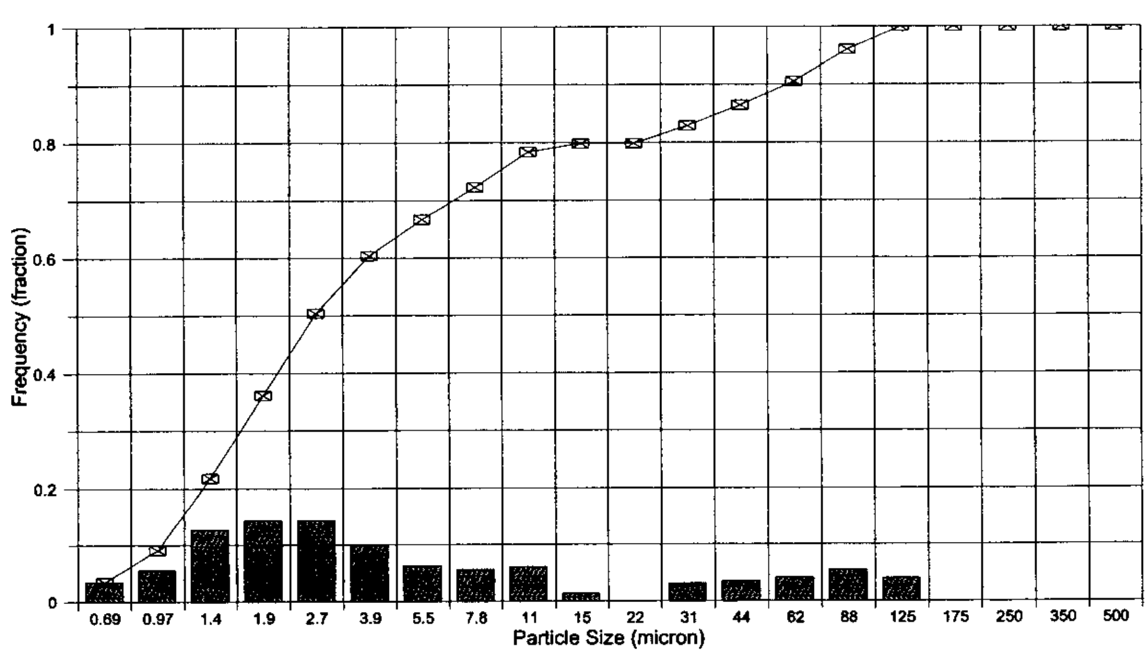


TABLE 8
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
PARTICLE SIZE ANALYSIS

SAMPLE PARAMETERS		Bin Size microns	Incr. Fraction	Cuml. Fraction
Field:	SOUTH PIERSON	0.69	0.040	0.040
Well Location:	S. Pierson Injection Plant	0.97	0.063	0.103
Fluid Source	Source Well Water	1.4	0.138	0.241
Sample Condition:	1.0 Hour after PHPA Addition	1.9	0.143	0.384
	PHPA Concentration = 0.55%	2.7	0.138	0.522
		3.9	0.096	0.618
STATISTICAL DATA		5.5	0.038	0.656
Median Particle Size, µm:	3.56	7.8	0.052	0.708
Mean Particle Size, µm:	6.58	11	0.073	0.781
		15	0.000	0.781
		22	0.000	0.781
PARTICLE SIZE CATEGORY		31	0.043	0.824
1000 - 2000 microns:	Very Coarse Sand	44	0.038	0.862
500 - 1000 microns:	Coase Sand	62	0.025	0.887
250 - 500 microns:	Medium Sand	88	0.070	0.957
125 - 250 microns:	Fine Sand	125	0.043	1.000
62 - 125 microns:	Very Fine Sand	175	0.000	1.000
Less than 62 microns:	Silt & Clay	250	0.000	1.000
		350	0.000	1.000
		500	0.000	1.000

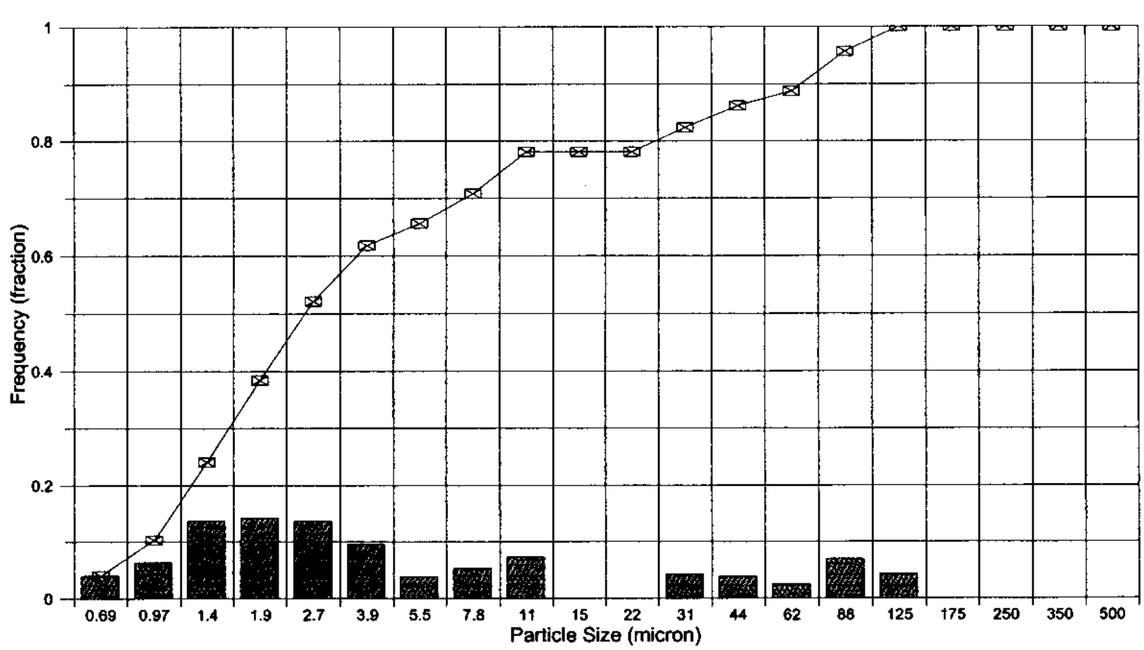


TABLE 9
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
PARTICLE SIZE ANALYSIS

SAMPLE PARAMETERS		**Bin Size microns**	**Incr. Fraction**	**Cuml. Fraction**
Field:	SOUTH PIERSON	0.69	0.040	0.040
Well Location:	S. Pierson Injection Plant	0.97	0.056	0.096
Fluid Source	Source Well Water	1.4	0.100	0.196
Sample Condition:	2.0 Hour after PHPA Addition	1.9	0.072	0.268
	PHPA Concentration = 0.55%	2.7	0.085	0.353
		3.9	0.063	0.416
STATISTICAL DATA		5.5	0.000	0.416
Median Particle Size, µm:	98.1	7.8	0.000	0.416
Mean Particle Size, µm:	36.9	11	0.000	0.416
		15	0.000	0.416
		22	0.000	0.416
PARTICLE SIZE CATEGORY		31	0.039	0.455
1000 - 2000 microns:	Very Coarse Sand	44	0.014	0.469
500 - 1000 microns:	Coase Sand	62	0.010	0.479
250 - 500 microns:	Medium Sand	88	0.079	0.558
125 - 250 microns:	Fine Sand	125	0.048	0.606
62 - 125 microns:	Very Fine Sand	175	0.041	0.647
Less than 62 microns:	Silt & Clay	250	0.329	0.976
		350	0.023	0.999
		500	0.000	0.999

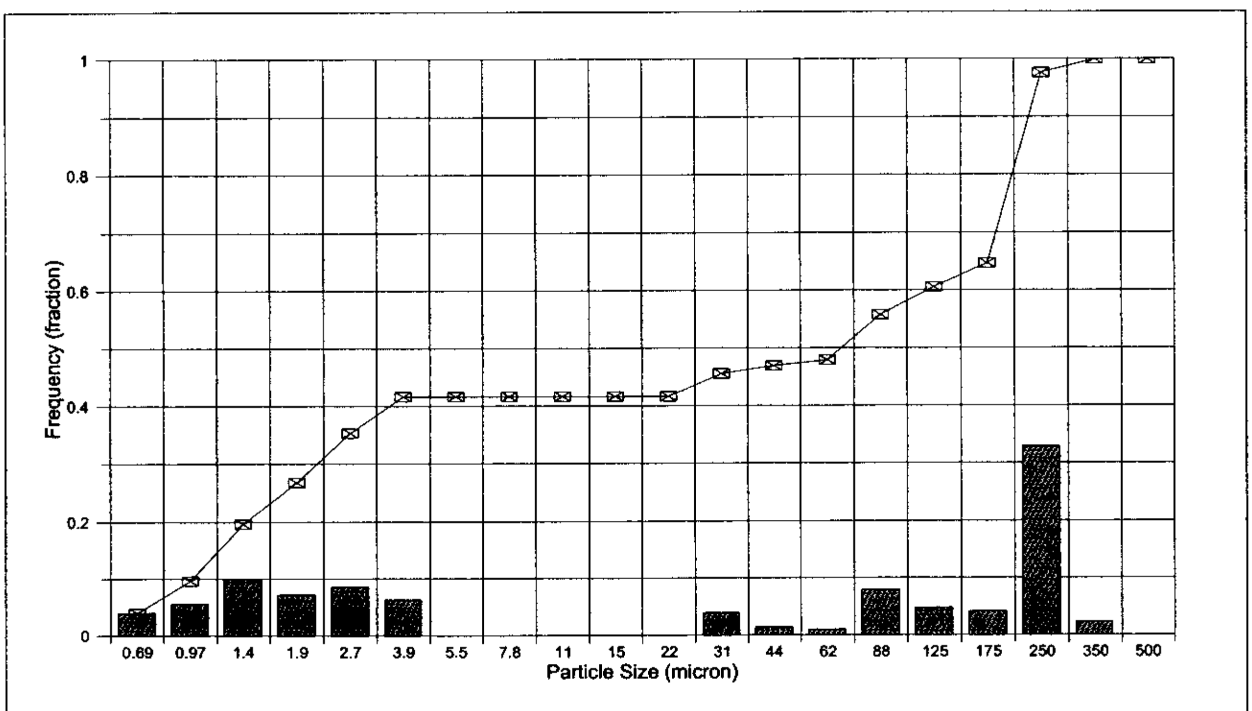


TABLE 10
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
CORE #HY16 - CRITICAL FLOW RATE TEST
WITH TREATED INJECTION WATER

Core and Test Parameters			
Formation	South Pierson	Well I.D.	14-9-002-29 W1M
Core Number	HY16	Core Depth (m)	1023.77
Length (cm)	4.17	Diameter (cm)	3.79
Effective Flow Area (cm^2)	11.28	Bulk Volume (cm^3)	46.96
Porosity (fraction)	0.142	Pore Volume (cm^3)	6.67
Routine Air Permeability (mD)	5.02	Absolute Brine Permeability (mD)	3.038
Test Temperature (°C)	Ambient	Initial Water Saturation (%)	100
Back Pressure (kPag)	2750	Net Overburden Pressure (kPag)	20000

Test Summary				
Fluid Type/ Flow Rate	**Equivalent Field Injection Rates**		**Effective Permeability**	
	Vertical Well* (m^3/day)	**Horizontal Well** (m^3/day)**	**mD**	**% of Baseline**
Formation Brine Baseline	0.16	25.6	3.038	Baseline
Treated Water @ 1 cc/hr	0.16	25.6	1.917	63.1
Treated Water @ 3 cc/hr	0.5	76.7	1.621	53.4
Treated Water @ 8 cc/hr	1.3	204.0	0.483	15.9
Treated Water @ 16 cc/hr	2.6	409.0	0.089	2.9
Treated Water @ 32 cc/hr	5.2	818.0	0.062	2.1
Treated Water @ 64 cc/hr	10.4	1636.0	0.092	3.0

* For vertical well applications, the conversion is based on 4.0 meters of completed depth, perforation density of 13 jspm, perforation diameter of 2.5 cm and perforation depth of 30 cm.

** For horizontal well applications, the conversion is based on 600 meters of open horizontal leg and a hole diameter of 10.2 cm.

TABLE 11
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
CORE #HY16 - CRITICAL FLOW RATE WITH TREATED INJECTION WATER
PERMEABILITY SUMMARY

Field	South Pierson	Air Permeability (mD)	5.02
Formation	Spearfish	Porosity (%)	14.20
Sample I.D.	HY16	Pore Volume (cc)	6.67

Test Fluid	Injection Volume		Permeability (mD)
	Cumulative (cc)	Cumulative (PV)	
Formation Brine Baseline	54.4	8.2	3.017
Formation Brine Baseline	61.1	9.2	3.102
Formation Brine Baseline	95.4	14.3	3.038
Treated Water @ 1 cc/hr	107.3	16.1	3.504
Treated Water @ 1 cc/hr	117.7	17.7	1.314
Treated Water @ 1 cc/hr	131.2	19.7	5.102
Treated Water @ 1 cc/hr	139.2	20.9	1.591
Treated Water @ 1 cc/hr	162.4	24.4	1.285
Treated Water @ 1 cc/hr	190.6	28.6	1.917
Treated Water @ 3 cc/hr	201.0	30.2	2.001
Treated Water @ 3 cc/hr	212.2	31.8	1.611
Treated Water @ 3 cc/hr	225.4	33.8	0.831
Treated Water @ 3 cc/hr	237.2	35.6	0.434
Treated Water @ 3 cc/hr	253.6	38.0	1.621
Treated Water @ 8 cc/hr	271.0	40.7	0.550
Treated Water @ 8 cc/hr	289.0	43.4	0.330
Treated Water @ 8 cc/hr	306.0	45.9	0.241
Treated Water @ 8 cc/hr	326.6	49.0	0.200
Treated Water @ 8 cc/hr	356.6	53.5	0.148
Treated Water @ 8 cc/hr	365.5	54.8	0.483
Treated Water @ 16 cc/hr	386.3	58.0	0.160
Treated Water @ 16 cc/hr	412.4	61.9	0.142
Treated Water @ 16 cc/hr	438.0	65.7	0.127
Treated Water @ 16 cc/hr	478.4	71.8	0.107
Treated Water @ 16 cc/hr	509.4	76.4	0.094
Treated Water @ 16 cc/hr	517.8	77.7	0.060
Treated Water @ 16 cc/hr	529.6	79.4	0.089
Treated Water @ 32 cc/hr	539.0	80.9	0.117
Treated Water @ 32 cc/hr	566.4	85.0	0.109
Treated Water @ 32 cc/hr	590.4	88.6	0.104
Treated Water @ 32 cc/hr	616.4	92.5	0.093
Treated Water @ 32 cc/hr	627.1	94.1	0.037
Treated Water @ 32 cc/hr	630.3	94.6	0.062
Treated Water @ 64 cc/hr	646.8	97.0	0.166
Treated Water @ 64 cc/hr	665.4	99.8	0.172
Treated Water @ 64 cc/hr	678.4	101.8	0.169
Treated Water @ 64 cc/hr	706.4	106.0	0.163
Treated Water @ 64 cc/hr	728.4	109.3	0.156
Treated Water @ 64 cc/hr	737.4	110.6	0.092

FIGURES

FIGURE 1
ANDERSON - SOUTH PIERSON
INJECTION WATER TREATMENT STUDY
FINES MIGRATION & SENSITIVITY APPARATUS

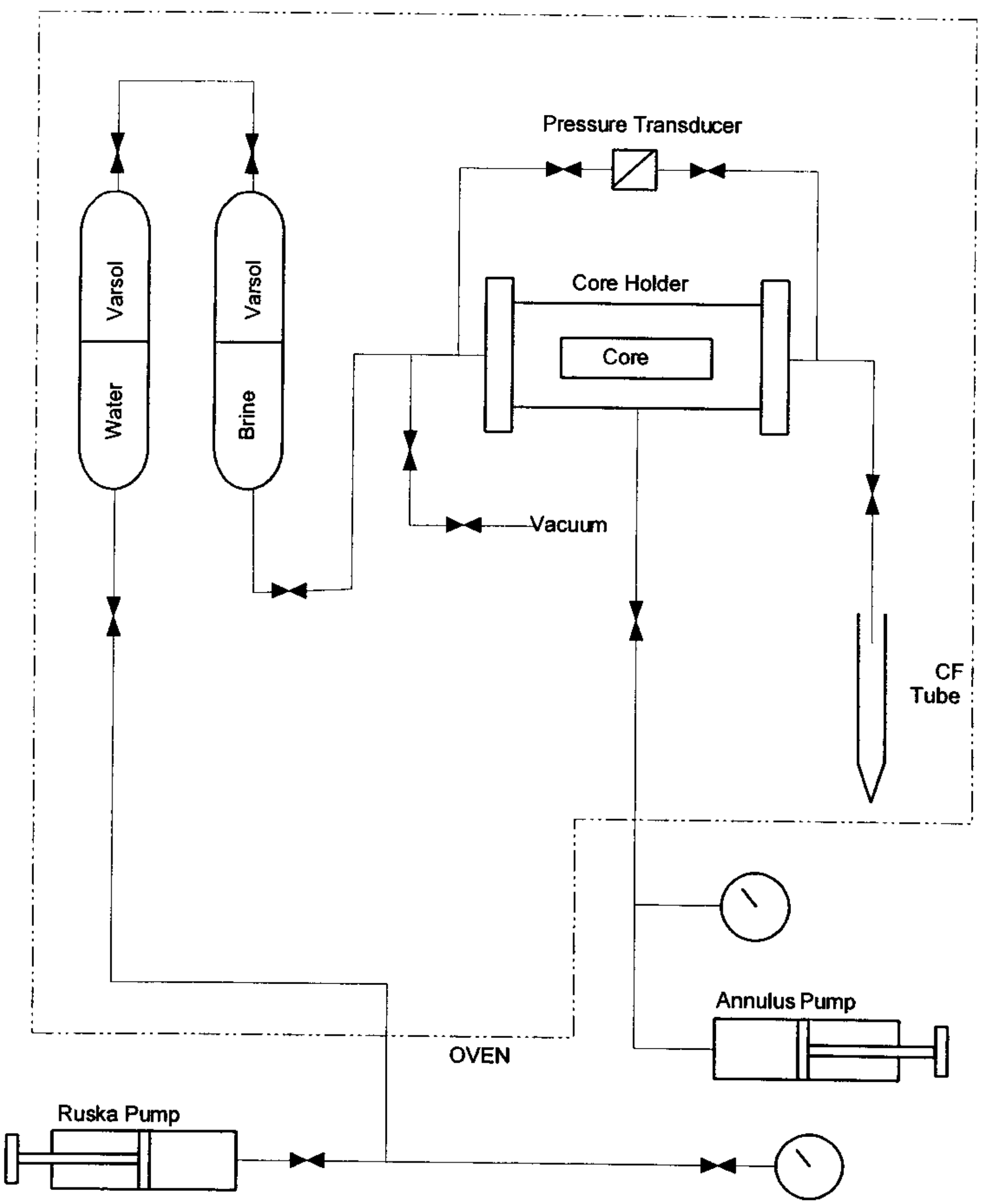
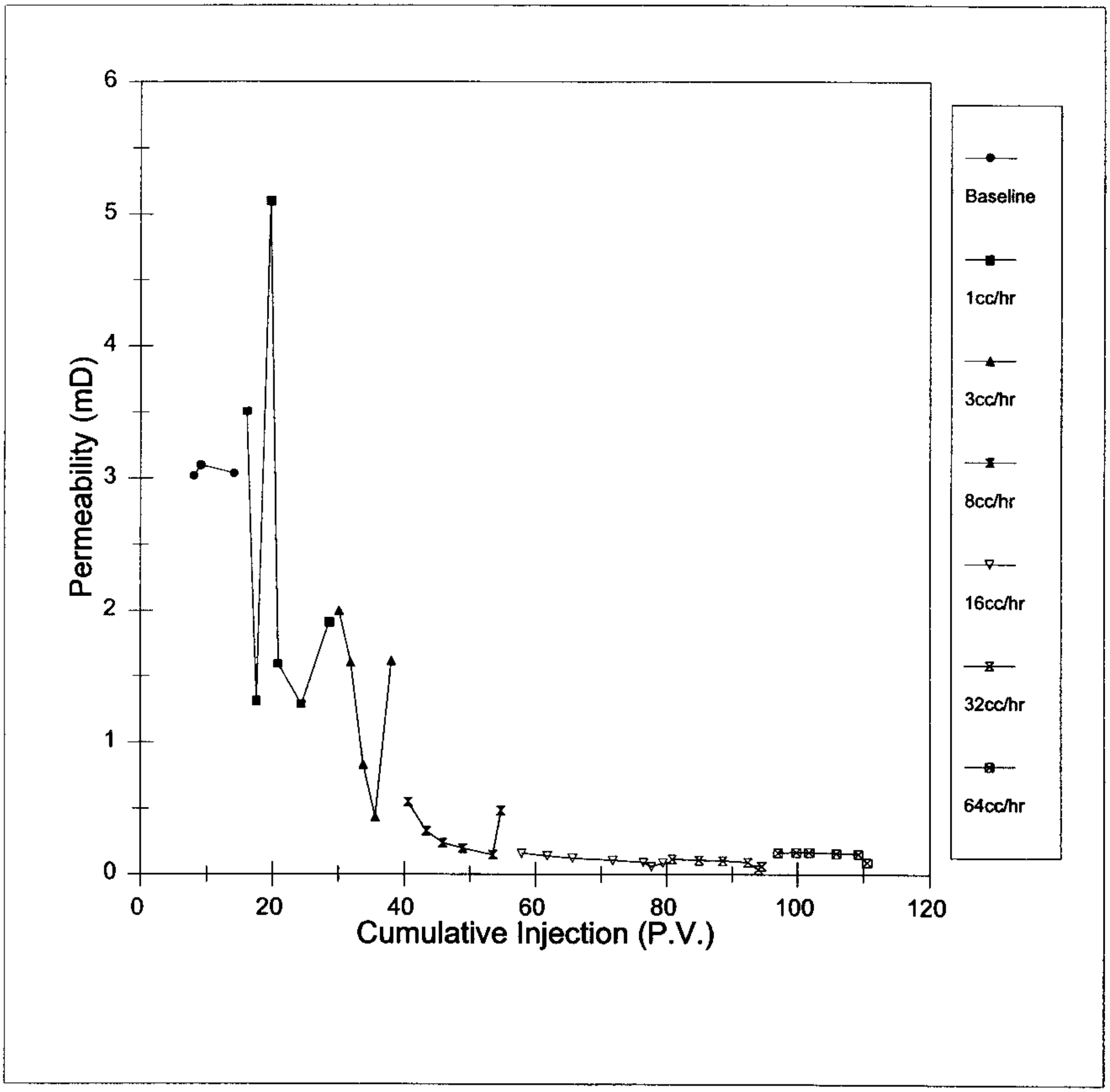


FIGURE 2
ANDERSON - SOUTH PIERSON
FORMATION DAMAGE STUDY
CORE # HY16 - CRITICAL FLOW RATE TEST with TREATED INJECTION WATER
PERMEABILITY PROFILE

Field :	SOUTH PIERSON	Air Permeability (mD):	5.02
Formation :	Spearfish	Porosity (%) :	14.20
Sample I.D. :	HY16	Pore Vol. (cc) :	6.67



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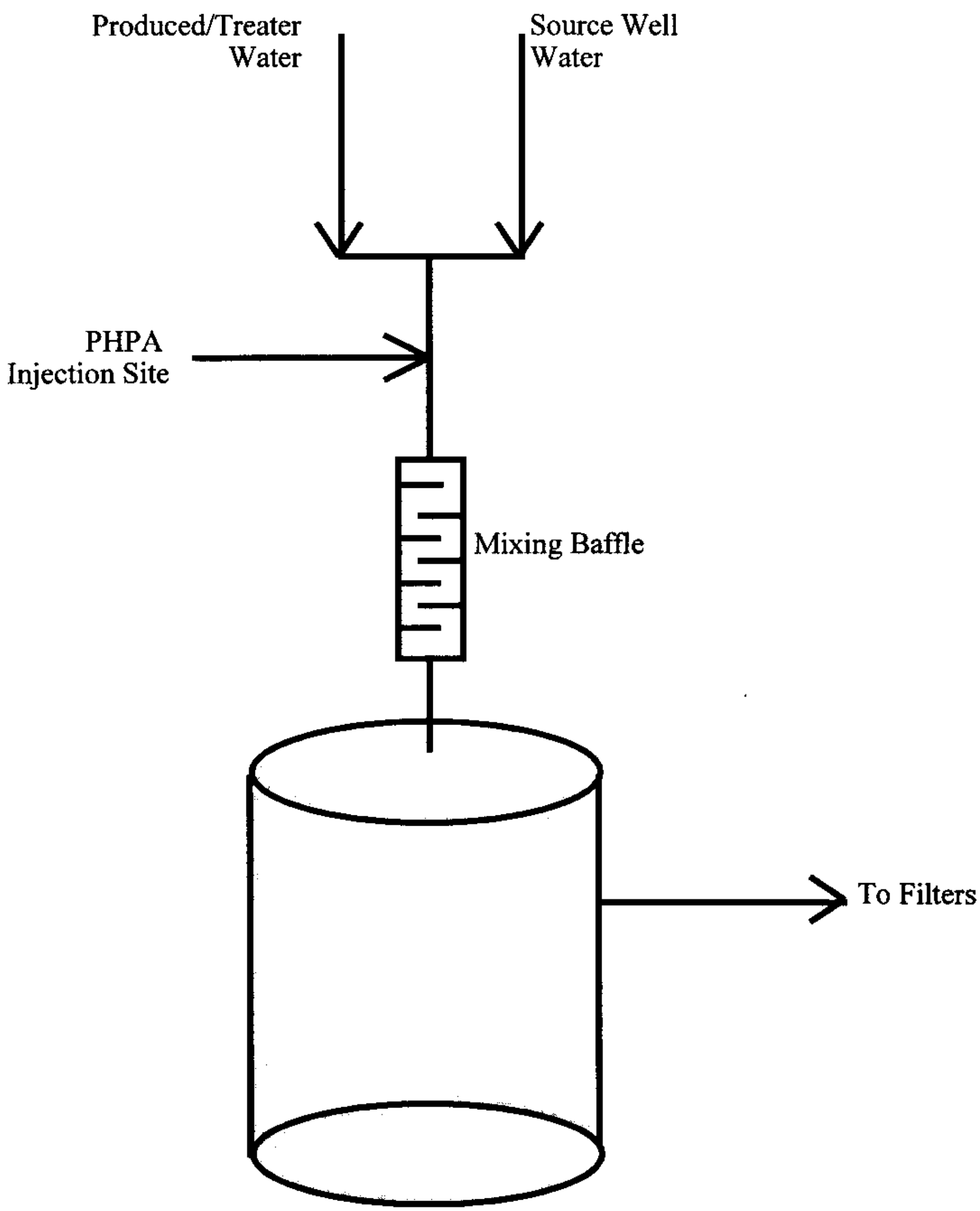
APPENDICES

APPENDIX A

Water Treatment Plant
Proposed PHPA Co-Injection Layout

ANDERSON - SOUTH PIERSON
iNJECTION WATER TREATMENT STUDY
PROPOSED "PHPA" INJECTION BAFFLE



APPENDIX B

Material Safety Data Sheet (MSDS)
for the PHPA Additive
Proposed PHPA Co-Injection Layout

SECTION I: IDENTIFICATION OF PRODUCT

SYNERCHEM INTERNATIONAL, INC.
4333 46th Ave. S.E.
Calgary, Alberta T2B 3N5
EMERGENCY PHONE: 403/279-8545
PRODUCT NAME : SYNERFLOC 73 PRODUCT USE: Drilling Mud Additive
CHEMICAL FAMILY: COPOLYMER OF ACRYLAMIDE WITH SODIUM ACRYLATE

WORK PLACE HAZARDOUS MATERIALS INFORMATION SYSTEM (WHMIS)
WHMIS CLASSIFICATION: Class D-2(B)
WORK PLACE HAZARD : Skin and Eye Irritant

TRANSPORTATION OF DANGEROUS GOODS (TDG)
TDG CLASSIFICATION: Not Dangerous Goods
PACKAGE GROUP: Not Applicable
PRODUCT IDENTIFICATION NUMBER (PIN): Not Applicable

SECTION II: HAZARDOUS INGREDIENTS

Ingredient	Percent	CAS Number	LD_{50} (oral rat)	LD_{50} (dermal rabbit)
Mineral Spirits	30-60	64742-47-8	>5 g/kg	>3 g/kg
Alkyl Phenol Ethoxylate	3-7	68412-54-4	3000 mg/kg	2830 mg/kg

SECTION III: HEALTH HAZARDS

ROUTE OF ENTRY:[XX]SKIN[XX]EYE CONTACT [ ]INHALATION[XX]INGESTION

THRESHOLD LIMIT VALUE : Not Determined

EFFECTS OF EXPOSURE:
INHALATION: Not Available.
SKIN: Contact may cause irritation, redness, swelling, or dermatitis.
EYE: Will cause painful burning or stinging of eyes and lids, watering of eyes, and inflammation of conjunctiva.
INGESTION: May cause nausea and vomiting.
EFFECTS OF CHRONIC EXPOSURE: Skin irritation or dermatitis may occur upon frequent or prolonged contact.

SECTION IV: FIRST AID MEASURES

SKIN CONTACT: Wash exposed area with soap and water. If irritation or abnormalities persist, call a physician.
EYE CONTACT: Immediately flush eyes with water for 15 minutes and call a physician.

INHALATION: Remove to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen. Call a physician.
INGESTION: Do not induce vomiting. If conscious, dilute by giving two glasses of water. Call a physician immediately.

SECTION V: PHYSICAL DATA

APPEARANCE AND ODOR	: liquid emulsion
SPECIFIC GRAVITY	: 1.01
BOILING POINT (°C)	: Not Available
MELTING POINT (°C)	: Not Available
SOLUBILITY IN WATER	: Soluble
pH	: 6.0 - 9.0 (0.6% in D.W.)
PERCENT VOLATILE BY VOLUME	: Not Available
EVAPORATION RATE	: Not Available
VAPOR PRESSURE (mm Hg)	: Not Available
VAPOR DENSITY (Air = 1)	: Not Available

SECTION VI: FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (°C) : >100 °C
FLAMMABLE LIMITS : Not Available
EXTINGUISHING MEDIA : Water Spray, foam, dry chemical, carbon dioxide.
SPECIAL FIRE FIGHTING PROCEDURES : Self-contained respirators required for fire fighting personnel.
UNUSUAL FIRE AND EXPLOSION HAZARDS: Water may cause slipperiness

SECTION VII: REACTIVITY DATA

STABILITY: Stable [XX] Unstable [ ]
INCOMPATIBILITY (CONDITIONS TO AVOID) : Strong oxidizers
HAZARDOUS DECOMPOSITION PRODUCTS : CO_x, smoke on combustion
HAZARDOUS POLYMERIZATION: Will Not Occur [XX] May Occur [ ]

SECTION VIII: PREVENTIVE MEASURES

SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION : Use of chemical cartridge respirators when PEL and
VENTILATION : General mechanical
PROTECTIVE GLOVES : Suggest chemical gloves.
EYE PROTECTION : Suggest goggles
OTHER PROTECTIVE EQUIPMENT (Specify): Suggest rubber apron.

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Avoid ingestion. Practice reasonable caution and personal cleanliness. Avoid skin and eye contact. Store in a cool well ventilated area.

STEPS TO BE TAKEN IN CASE THE MATERIAL IS SPILLED OR RELEASED

(Use appropriate safety equipment.) Small spills, soak up with absorbent material. Large spills, dike to contain spill to prevent water pollution. Recover diked material; return recovered material to plant.

WASTE DISPOSAL METHOD

Absorb spilled material with absorbent compound, incinerate/dispose to conform with local disposal regulations.

SECTION IX: PREPARATION

THE INFORMATION CONTAINED HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE.

DATE ISSUED: October 2000 BY: Product Safety Committee
DATE REVISED: May 21, 1999 PHONE: 403 279 8545