EPA-670/2-73-081
September 1973

Environmental Protection Technology Series

Laboratory Study of Self-Sealing Limestone Plugs For Mine Openings

Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

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September 1973

LABORATORY STUDY OF SELF-SEALING LIMESTONE PLUGS FOR MINE OPENINGS

By

RAY G. PENROSE, JR.
IGOR HOLUBEC

Project No. 14010 HKN
Contract No. 68-01-0135
Program Element 1BB040

PROJECT OFFICER

JAMES M. SHAKELFORD
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D. C. 20460

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Prepared for
OFFICE OF RESEARCH AND MONITORING
U.S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C. 20460

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ABSTRACT

Laboratory studies of self-sealing limestone plugs for mine openings were conducted to determine the optimum limestone material for such a treatment and sealant technique.

Conducting a thorough study of the performance of such plugs required pilot plant operations utilizing synthetic solutions representative of anticipated acid mine waters, aggregate additives to improve plug performance, and several basic types of limestone which were varied in terms of size gradation and placement density. The types of limestone used were selected from results of a previous neutralization study; synthetic mine waters were prepared to EPA formulations for ferric, ferrous, and ferric/ferrous solutions; and percentage admixture of bentonite, flyash and air-cooled blast furnace slag additives were used with the aggregate.

Experimental results indicated that permeability, compressibility and strength of a limestone plug are primarily a function of the particle size distribution and density. Plug performance was most effective with high limestone placement density and smaller gradation of stone. Ferric waters were controlled most effectively. Additive effects were less significant throughout the tests.

Further tests were conducted on the effects of particle size distribution variations and placement density and other additives to cement particles into an effective plug.

This report was submitted in fulfillment of Project No. 14010 HKN, Contract No. 68-01-0135 under the sponsorship of the Environmental Protection Agency.

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SECTION I

CONCLUSIONS

This laboratory investigation of various limestone aggregate plugs has led to the following conclusions:

1. The results of this study indicate that limestone aggregate plugs are a feasible means of sealing underground mines which discharge water containing ferric iron.

2. The 3/8" to dust size of limestone No. 1809 placed at 60% relative density was the most satisfactory natural material tested.

3. High placement densities are essential for satisfactory plug performance.

4. Significant stone volume losses can occur when limestone plugs are exposed to acid mine water flow due to settling of the stone upon being wetted, erosion, and chemical consumption of the stone.

5. Limestone plugs will perform best on ferric mine waters and poorest on ferrous mine waters.

6. The Type A limestone (found in previous tests to neutralize acid mine waters better than Types B and C limestones) had the best overall performance, while the Type C limestone had the poorest performance.

7. The 3/8" to dust grade of stone was the most satisfactory size tested.

8. Bentonite and flyash additives improve water flow and treatment properties of permeable plugs.

9. Bentonite and slag additives decrease stone volume losses.

10. Increasing the fines content of commercially available stone to twice the original amount (as determined by the fraction of material which passes a No. 200 sieve) results in improved performance.

SECTION II

RECOMMENDATIONS

This study has shown that limestone permeable plugs must be constructed of well-graded limestone and must be placed in a dense to very dense state. On the basis of this finding, the following recommendations are made:

1. Further research should be conducted to determine the minimum acceptable placement density.

2. Investigations are needed to establish placement densities which can be achieved in the field with presently available equipment.

3. Future prototype limestone seals should be designed and constructed using earth and rock dam technology.

SECTION III

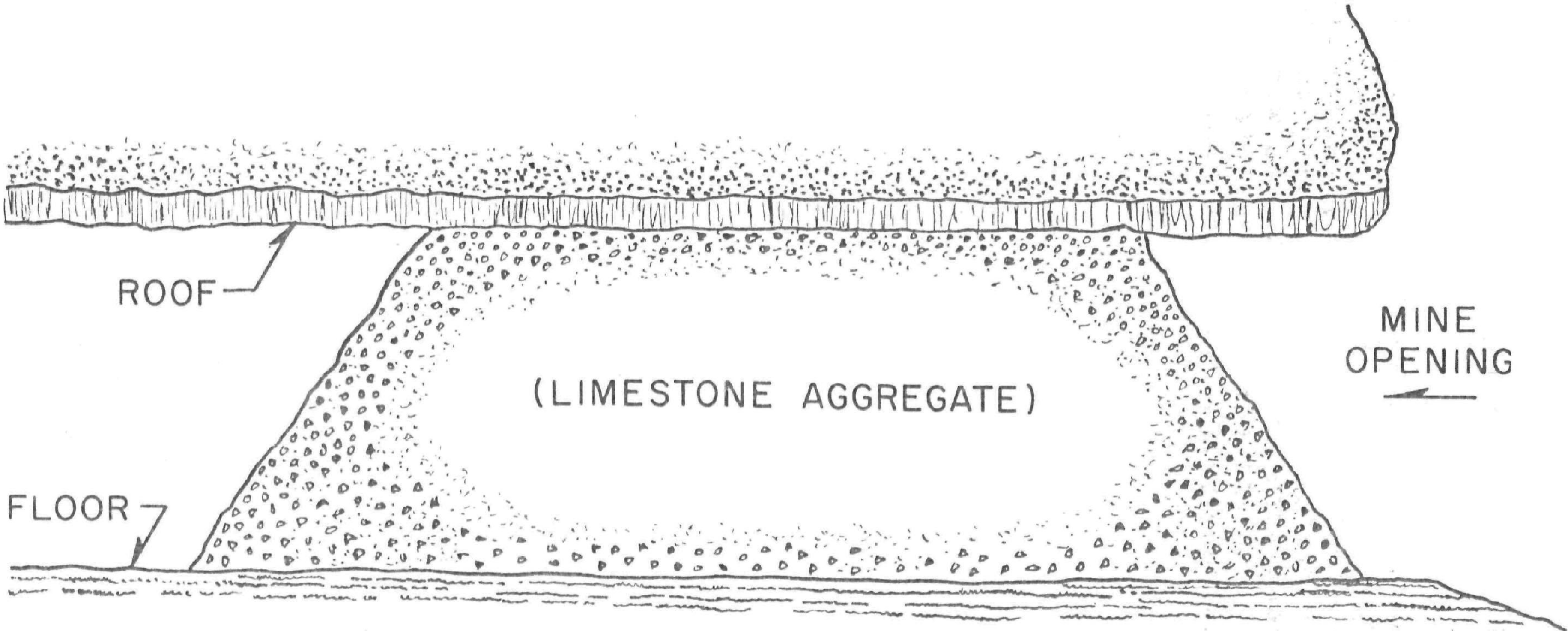
INTRODUCTION

Recent laboratory investigation and field trials have indicated that crushed limestone can be used to seal mine openings which are discharging acid mine drainage. [1] This is accomplished by filling a section of the mine opening with limestone aggregate. An example of this design is shown in Figure 1. Because the aggregate is porous, mine water initially seeps through. But as the water passes through this permeable plug, it is neutralized and filtered. Thus mine water is treated as it passes through the plug. This process gradually seals the plug and eventually eliminates or greatly reduces mine water flow.

Many different types of limestone aggregate could conceivably be used to construct permeable plugs. Research in limestone neutralization of acid mine drainage has shown that limestones can be classified into three groups according to their neutralization behavior. [2] These three groups were called Type A, Type B, and Type C limestones. Beside differing in stone type, limestone aggregates could also have different particle size ranges and different particle size distributions or gradations within a given range. Additives could also be blended with the aggregate to alter its performance as a mine seal.

This study was conducted to investigate the behaviors of various types of limestone aggregate when subjected to mine water percolation. It was intended to determine which type(s) would be most suitable for use in permeable plugs. All three stone types (A, B, and C) were used in the study. Several size ranges of each stone type were tested. The fines content of one size range was varied to determine the effect of particle size distribution. Several additives were also investigated. Since performance might be dependent on the type of mine water, three different synthetic mine waters were used in percolation tests.

All testing was done on a pilot scale in the laboratory. Aggregate samples were placed in square, horizontal tubes to simulate full-scale installations. The resulting model plugs were six inches square and six feet long. Synthetic mine water was supplied to one end of the test vessels and allowed



TYPICAL LIMESTONE MINE SEAL

FIGURE 1

to percolate through the stone. The other end was open and essentially unobstructed, allowing water to discharge freely. Water percolation was allowed to continue without interruption for up to 100 days.

To evaluate the performance of these model plugs, several physical and chemical parameters were observed. Anlyses were made to determine the chemical compositon and particle size distribution of the stone prior to testing. During the test run, flow data and effluent water composition data were recorded. After the test run was concluded, selected plugs were subjected to chemical analysis, grain size analysis, and strength analysis.

SECTION IV

APPARATUS

Equipment was developed to study the effects of mine water percolation on a variety of crushed limestone mine opening plugs on a pilot scale. The equipment simultaneously produced three (3) synthetic mine waters differing only in ferric iron/ferrous iron ratios and supplied each type of water to a battery of up to 24 test vessels at a maximum rate of one (1) GPM per vessel. To insure an adequate supply of test water, the system was sized to continuously produce 25 GPM of each type of water. With this design, a total of 72 tests could be run at one time. A detailed flow diagram of the equipment is presented in Figure A1 in the Appendix.

Tap water and the following technical grade chemicals were used to produce the three (3) test waters:

Manganese sulfate
Magnesium sulfate (epsom salts)
Aluminum sulfate (alum)
Calcium hydroxide (hydrated lime)
Ferric sulfate (ferri-floc)
Ferrous sulfate (copperas)
66° Be sulfuric acid

All the chemicals except sulfuric acid were obtained in 50 or 100 pound bags and stored on pallets. Sulfuric acid was purchased in bulk quantities and stored in a 1500 gallon steel tank.

The dry chemicals were not used directly as received. The sulfate salts were dissolved in tap water to form concentrated solutions and the hydrated lime was suspended in tap water to form a lime slurry.

A tank farm was installed for preparation and storage of these concentrates. Two (2) polyethylene tanks, a main tank and an auxiliary tank, were provided for each of the chemicals. Table 1 lists the tank sizes. All the main tanks were equipped with mixers so that concentrates could be prepared in these tanks. The auxiliary tanks provided additional storage for the chemical concentrates.

Concentrate preparation involved mixing measured volumes of tap water and known weights of dry chemicals in the main tanks. The following recipes were used:

TABLE 1

TANK SIZES

Reagent	Main Tank	Secondary Tank
Manganese Sulfate Solution	55 gal.	55 gal.
Magnesium Sulfate Solution	360 gal.	55 gal.
Aluminum Sulfate Solution	275 gal.	275 gal.
Lime Slurry	500 gal.	55 gal.
Ferrous Sulfate Solution	500 gal.	55 gal.
Ferric Sulfate Solution	500 gal.	55 gal.

10 lbs. manganese sulfate/37 gal. H_2O
1400 lbs. magnesium sulfate/228 gal. H_2O
800 lbs. aluminum sulfate/189 gal. H_2O
400 lbs. hydrated lime/480 gal. H_2O
1200 lbs. ferric sulfate/396 gal. H_2O
1200 lbs. ferrous sulfate/386 gal. H_2O

The water volumes were measured to the nearest 0.1 gallon with a small water meter on the fill line. Since the chemicals were supplied in bags of 50 or 100 pounds, the appropriate number of bags were added. Due to the small amount of manganese sulfate required, it was weighed on a small scale.

Magnesium sulfate, ferric sulfate, and ferrous sulfate solutions were usually fed from the main tank. However, when the main tank was being refilled, solution was fed from the smaller 55 gallon auxiliary tank. The desired tank was selected with a three-way ball valve. This approach prevented an interruption of synthetic mine water production while new concentrate was being made. After the main tank was refilled, normal operation was restored. The auxiliary tank was then refilled with solution from the main tank by a portable 25 GPM transfer pump.

Aluminum sulfate and manganese sulfate solutions were fed from only the auxiliary tank. Because aluminum sulfate dissolved slowly, its auxiliary tank was required to be as large as the main tank. The manganese sulfate tanks were both 55 gallon tanks since this was the smallest practical size. To simplify piping, these solutions were prepared in the main tanks and transferred to the auxiliary tanks for use.

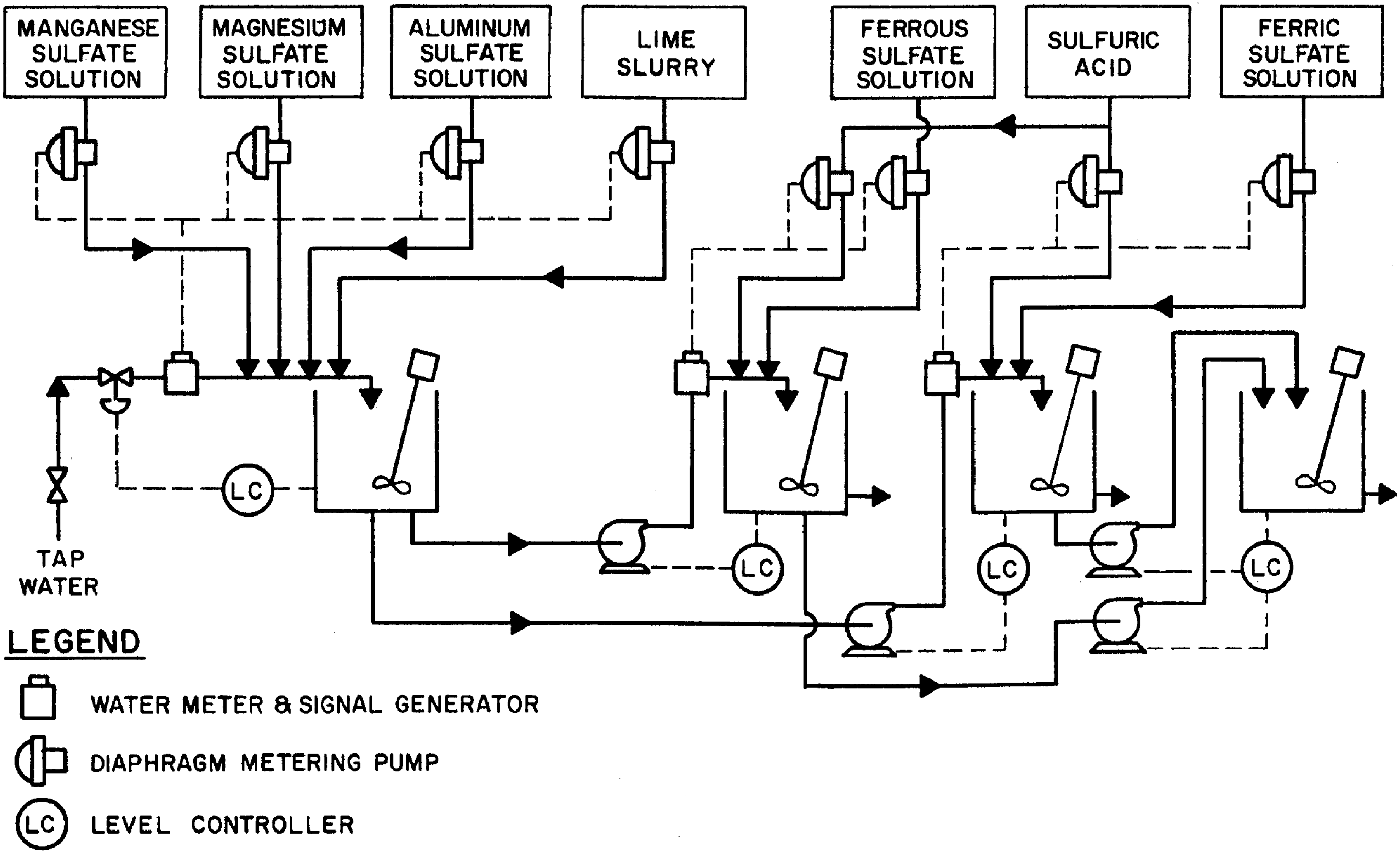
A blending system, shown in Figure 2, was used to produce the three (3) synthetic waters from tap water and the chemical concentrates. Operation was automatic except for refilling the concentrate tanks as required. When operating continuously, the system could produce 25 GPM of each test water.

Tap water and four concentrates (manganese sulfate, magnesium sulfate, aluminum sulfate, and lime) were first blended in a 200 gallon polyethylene mixing tank, forming an iron free base stock. The concentrates were added in proportion to the amount of water added. Separate addition of these concentrates allowed individual adjustment of manganese, magnesium, aluminum, and calcium concentrations in the synthetic waters. The common base stock assured uniformity in all three (3) test waters.

The rate of reagent addition was placed by a water meter and signal generator. A model FV Niagara Industrial Meter equipped with a model CM impulse transmitter was used. This device generated a short electrical impulse for each two (2) gallons of water passing through the meter. This signal controlled four (4) diaphragm metering pumps which injected the concentrates.

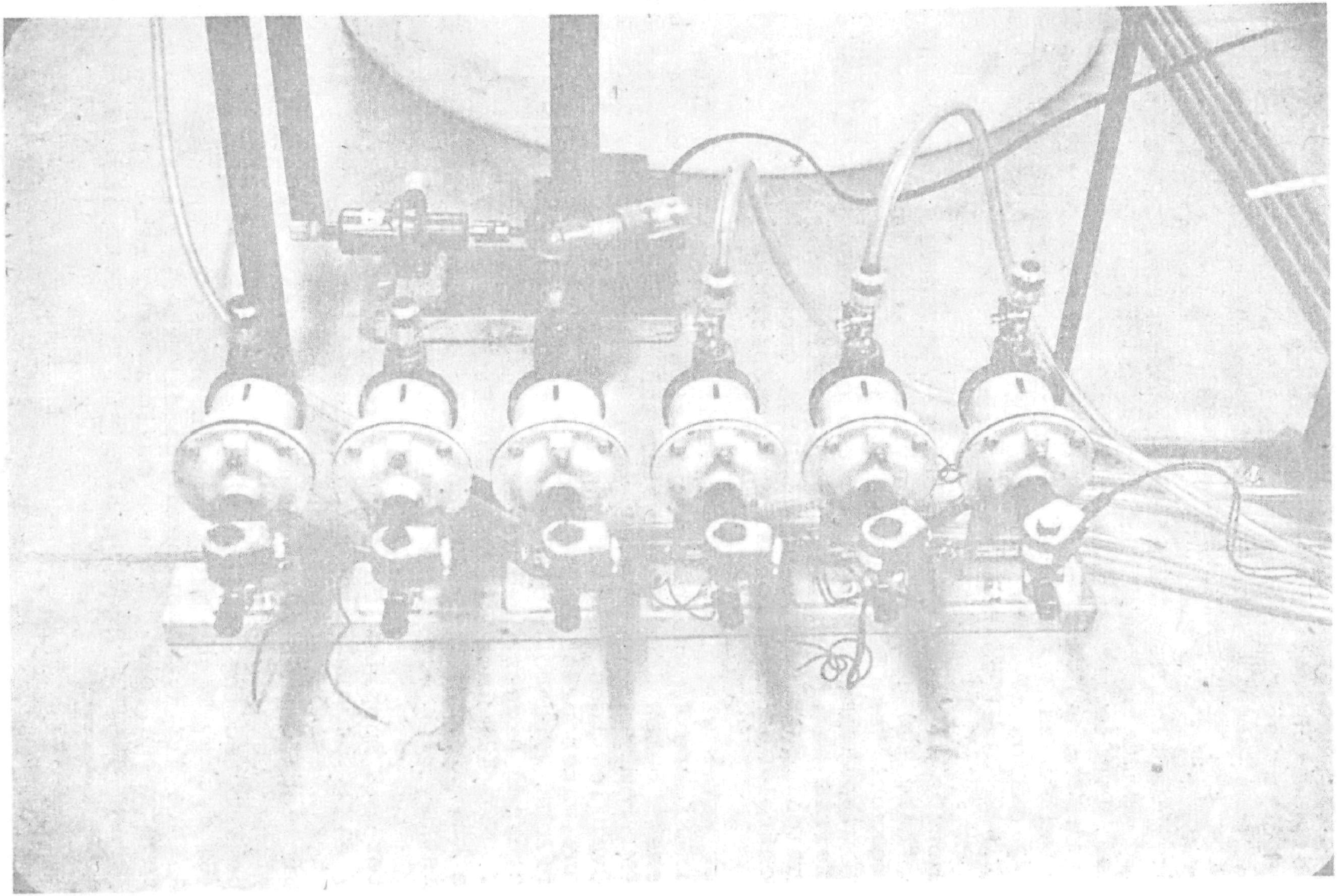
Model 1261 air-driven BIF Chem-O-Feeder metering pumps, shown in Figure 3, were used. The electrical signal opened a three-way solenoid valve, admitting compressed air to the back of the pump's impulse diaphragm. This caused a discharge stroke of the pump. The length of the stroke could be manually adjusted to vary the volume of the discharge. When the electrical signal terminated, the solenoid valve vented the air in the pump's impulse chamber, resetting the pump. With this system, a pre-set volume of concentrate was injected for every two (2) gallons of tap water.

A hi-lo level control was used on the 200 gallon primary tank containing the base stock. When the liquid level dropped below a pre-determined height, the control system opened a control valve on the tap water line. Water flowed into the tank at about 76 GPM, refilling the tank with base stock. After the tank was refilled to a pre-determined height, the control system closed the control valve. Thus the liquid level in the tank was always within pre-set limits. This type of on-off control was used rather than porportional control so that the flow rate of tap water would always be within the range of the water meter.



TEST WATER PREPARATION SYSTEM

FIGURE 2



METERING PUMPS

FIGURE 3

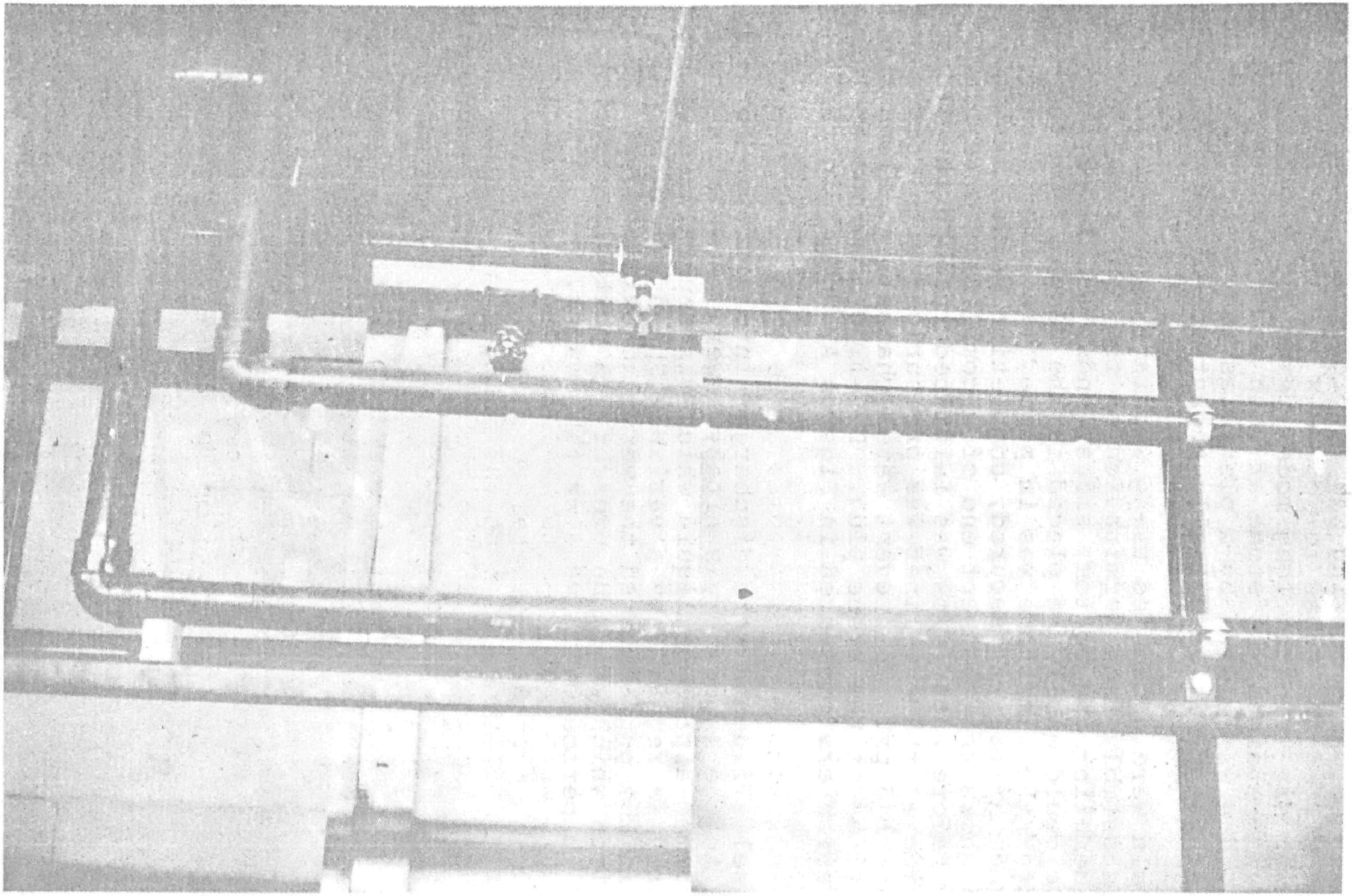
The common base stock was then pumped to each of two (2) 100 gallon polyethylene mixing tanks at the rate of about 38 GPM. Sulfuric acid from the 1500 gallons storage tank was injected into each line. Ferrous sulfate solution was injected into one (1) to form a ferrous test water, while ferric sulfate solution was injected into the other to form a ferric test water. These two (2) waters were identical except for the iron oxidation state.

As before, combination water meters and signal generators were used to control metering pumps which injected the reagents. Due to the smaller flow rates, Model DV Niagara Industrial Meters equipped with Model CM Impulse Transmitters were used. The transmiters generated an impulse for every gallon of water passing through the meters. Again, hi-lo level controls were used.

Equal amounts of ferric and ferrous test waters were blended in a third 100 gallon polyethylene mixing tank to form ferric/ferrous test water. Two (2) Model P25-P2-15N Jabsco positive displacement pumps mounted on a common shaft pumped the ferric and ferrous waters into this third tank at the identical rates of about 13 GPM. Once again, hi-lo level control was used for automatic operation.

Each test water was pumped to a manifold assembly, illustrated in Figure 4, which supplied a battery of up to 24 test vessels below it. Test water was pumped at the rate of 25 GPM from its mixing tank into the upper supply manifold. Overflow tees at each end of the manifold maintained a constant water pressure of about 15" in the manifold. The overflows were connected to the lower return manifold which returned excess feed water to the mixing tank by gravity. Two (2) inch PVC pipe and fittings were used to minimize head loss. Each 25 foot long assembly was mounted on a unistrut rack above the test vessesl.

Test water was supplied from this assembly to a 3/4" diameter by six foot high standpipe attached to the inlet end of each test vessel. A constant one (1) GPM flow was delivered to each standpipe through a calibrated length of polyethylene tubing. An overflow tee at the top of each standpipe limited the head on the test vessel to a maximum of six (6) feet. Test water flow in excess of what was required at a six (6) foot head was diverted by the tee to the return manifold. Thus a maximum feed rate of one (1) GPM and a maximum head of six (6) feet were independently provided.



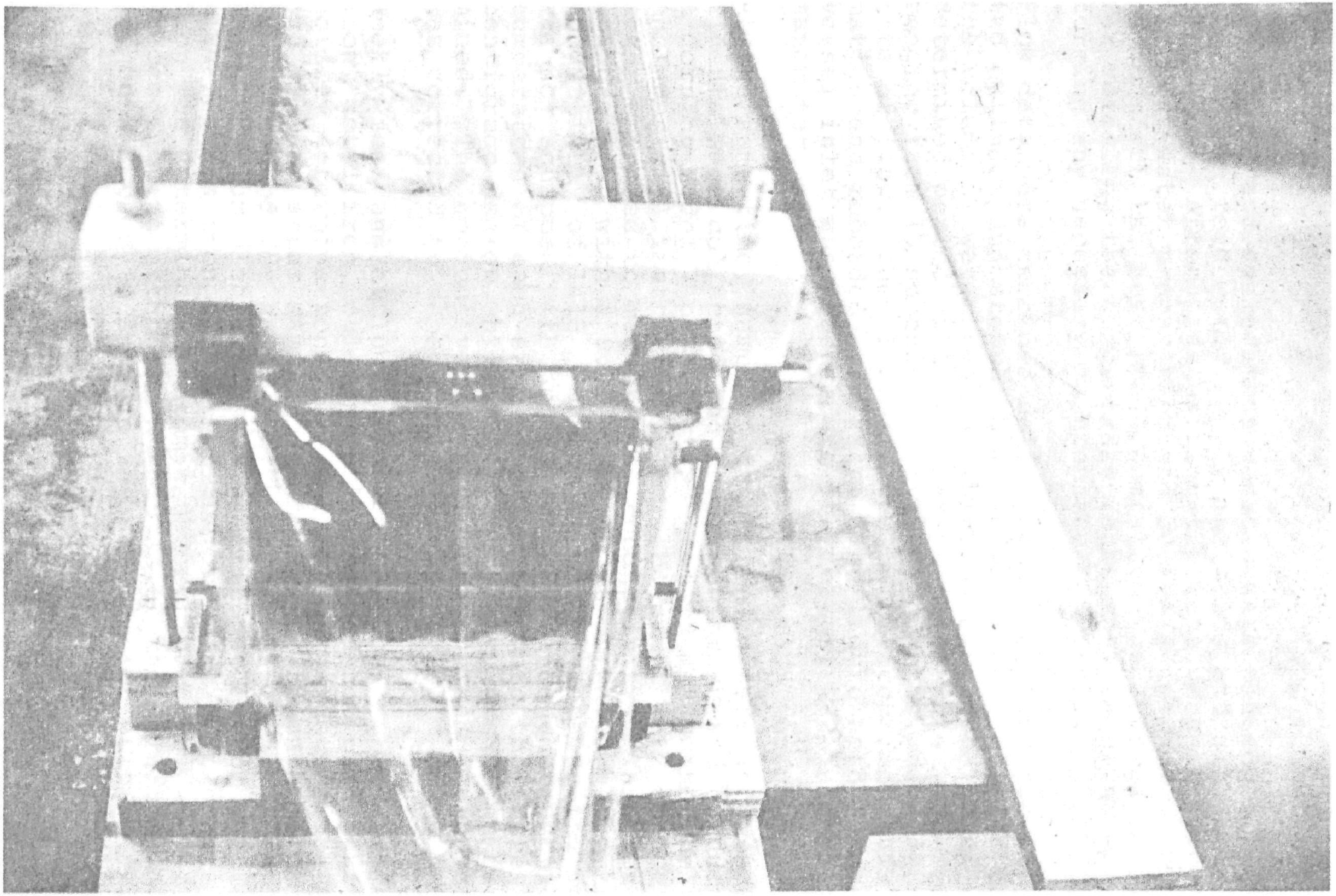
MANIFOLD ASSEMBLY

FIGURE 4

The test vessels containing the crushed limestone were assembled square plexiglas tubes lined with a PVC film sleeve. Use of these clear materials allowed the stone to be observed while testing was in progress. Crushed limestone filled the tubes to form six (6) inch by six (6) inch by six (6) feet long model permeable plugs. PVC screens retained the stone at both ends of the vessel. The inlet end was closed by a plexiglas end plate, while the effluent end was essentially unobstructed.

The vessels were assembled using separate pieces to facilitate disassembly upon termination of the test run. By first assembling the bottom, sides, ends, and liner, limestone could easily be placed in the vessel from the top. After the limestone was in place, the liner was sealed and the top was secured, completing vessel assembly. Figure 5 shows the effluent end of a completely assembled vessel. Before water flow was initiated through the stone, the outside of the PVC liner was pressurized with compressed air at about 5 psig to prevent water channelling along the top and sides of the stone plug. Detailed drawings of the vessel design are presented in Figures A2 and A3 in the Appendix.

Test vessel effluents were discharged into a trench for disposal to the laboratory sanitary sewer. A weir in the trench formed a pond of liquid which was neutralized with lime slurry as required by a variable speed pump. An air sparger in the pond aerated the water to oxidize any ferrous iron which might be present. A portable pH meter was used to periodically monitor this water.



ASSEMBLED TEST VESSEL (EFFLUENT END)

FIGURE 5

SECTION V

PROCEDURE

The filled and sealed test vessels were placed on a test rack beneath the feed water supply manifolds and all piping was connected. After pressurizing the test vessels with air, the test water preparation and delivery systems were turned on to start the test run. Operation was automatic except for refilling the concentrate tanks when required and performing any necessary maintenance or repair.

Flow data were recorded daily during the test run. A graduated cylinder and stopwatch were used to collect and measure the volume of water passing through each vessel over a predetermined period of time. Various time intervals were used, ranging from 15 seconds to five (5) minutes, depending on the rate of flow. The flow rate was calculated from this information and recorded as ml/min. The liquid head at each vessel inlet was measured to the nearest 1/2 inch with a manometer.

At the same time, samples of the feed waters and vessel effluents were collected and analyzed for pH and conductivity. A Corning Model 7 pH Meter was used to determine the pH. An Industrial Instruments, Inc., Model RC 16B2 conductivity meter was used to measure the conductivity. This meter was standardized with a 0.01 M KCl solution which has a known conductivity of 1413 MHO/cm at 25°C. Because the meter was not equipped with automatic temperance compensation, the temperature of each sample was measured to the nearest centigrade degree while the conductivity was being determined. The conductivity measured at the sample temperature was corrected to an equivalent value at 25°C.

Weekly feed and effluent samples were collected for ferrous iron, total iron, calcium, sulfate, and hot phenolphthalein acidity determinations. Ferrous iron was determined within one (1) day after sampling using the o-Phenanthroline colorimetric method for samples with less than 10 mg/l iron and the potassium dichromate titrametric method for samples with ferrous iron concentrations of 10 mg/l or more. Total iron was determined by atomic absorption or by one of the preceeding two methods. Either AA or the EDTA titrametric method was used to analyze the samples for calcium. Sulfate concentrations were determined gravimetrically. Hot pht. acidity was determined by titrating with a standard sodium hydroxide solution and reported in mg/l as calcium carbonate. One (1) set of samples was also analyzed for manganese using the ammonium persulfate colorimetric method.

After terminating the test, the vessels were opened by removing the plexiglas top and any volume decrease of each limestone plug was determined. A wood block was placed across the vessel perpendicular to the direction of flow. The distance between the bottom of the block and the stone surface was measured to the nearest 1/8" with a ruler and subtracted from 6" (the height of the vessel sides) to give the stone height. This was done at distances of 0'6", 1'6", 2'6", 3'6", 4'6", and 5'6" from the inlet end. In addition, the average width of the stone plug was estimated. This data was used to calculate the stone volume loss as a percentage of the initial 1.5 $ft.^3$ volume.

SECTION VI

DISCUSSION

This study was conducted in two sequential laboratory cycles, Lab Cycle I and Lab Cycle II. In Lab Cycle I, a total of 72 limestone specimens were tested. Six size ranges of each of three different limestones were tested on ferric, ferrous and ferric/ferrous synthetic mine waters. In addition, three additives were investigated. The results of these tests were used to select promising materials to be tested in Lab Cycle II.

Lab Cycle I

Selection of the three limestones used in Lab Cycle I was based on a previous limestone neutralization study [2] which showed that limestones could be classified into three groups, called Types A, B, and C limestones. Type A limestones were the most effective in neutralizing acid mine drainage, while Type C limestones were the least effective. One limestone from each group was selected for this study. Limestone No. 1809 (Type A), limestone No. 1355 (Type B) and limestone No. 1337 (Type C) were used. These stones were obtained from Winfield Lime and Stone Company, Elkins Limestone Company, and Mineral Pigments and Metals Company, respectively.

The following six size fractions of each stone type were tested on each of the three waters:

1" to dust (called 1 x 0)
1" to 50 mesh (called 1 x 50M)
1/2" to dust (called 1/2 x 0)
1/2" to 50 mesh (called 1/2 x 50M)
1/4" to dust (called 1/4 x 0)
1/8" to dust (called 1/8 x 0)

All six size fractions were prepared by screening a blend of equal weights of three commercially available grades of crushed limestone. A blend was used rather than one standard grade because no single grade contained the entire range of one inch particles to dust. The commercial grades used to produce the blends of each stone type are listed in Table 2.

TABLE 2

LIMESTONE GRADES USED IN LAB CYCLE I

STONE TYPE	ASSIGNED NUMBER	SUPPLIER	GRADES USED
A	1809	Winfield Lime and Stone Company, Inc. West Winfield, Pa.	Pa. No. 1, 1B, 2*
B	1355	Elkins Limestone Company Elkins, West Virginia	AASHO No. 10, 8, 67**
C	1337	Mineral Pigments and Metals Charles Pfizer Gibsonburg, Ohio	1) Primary screening (3/8" to dust) 2) Road stone (3/4" to 3/8") 3) Rotary kiln feed (1-1/2" by 1/2")

* Pa. - Pennsylvania Department of Highways Designation

** AASHO - American Association of State Highway Officials Designation

In addition to these 18 specimens (6 sizes of 3 stone types), three different additives were investigated. Limestone mixtures containing 5% bentonite, 10% flyash, and 10% air-cooled blast furnace slag were tested on all three synthetic waters. These additives were blended with both 1 x 0 and 1/2 x 0 size fractions of limestone No. 1809 (Type A stone). Thus a total of six specimens containing additives were tested on each water.

Chemical compositions of the 1/4 x 0 sizes of all three stone types were determined before testing. The results of these determinations are listed in Table 3. Due to an oversight, Al_2O_3, Fe_2O_3, and S analyses were not performed on limestones No. 1355 and No. 1337. However, analyses had been performed on limestone samples from the same two sources in a previous study.[2] Al_2O_3 and Fe_2O_3 values from that study were included in Table 3 for completeness.

Reported values from these two independent analyses are compared in Table 4. This comparison shows that the two analyses were in reasonable agreement. Furthermore, the agreement is closer for limestones No. 1355 and No. 1337 than for limestone No. 1809. It is expected that Al_2O_3 and Fe_2O_3 values would have followed the same pattern of agreement.

Complete particle size analyses were performed on representative samples of all 24 different stone specimens before testing. These data are given in Tables A4 through A6 in the Appendix. Grain size distributions are presented in Figures 6 through 13. These curves show a considerable particle size variation in the 1/8 x 0 and 1/4 x 0 size fractions of all three limestones. They also show that limestone No. 1337 consistently contained considerably more fines than the other two stone types. Both the 1/2 x 50M and 1 x 50M sizes of the three stone types had similar particle size distributions.

Three test vessels were loosely filled with each of the 24 different limestone aggregate specimens for a total of 72 test vessels. The three sets of 24 specimens were tested on ferric, ferric/ferrous, and ferrous synthetic mine waters. For identification purposes, the test vessels were assigned test vessel numbers as listed in Tables A1, A2, and A3 in the Appendix.

TABLE 3

ANALYSIS OF LIMESTONES TESTED IN LAB CYCLE I

(REPORTED AS WEIGHT % OF IGNITED SAMPLE)

	STONE #1809	STONE #1355	STONE #1337
Loss on ignition	36.93	33.8	46.00
SiO_2	15.4	23.9	1.82
Al_2O_3	3.9	5.75*	0.15*
CaO	71.9	62.3	54.3
MgO	0.59	1.65	39.1
Fe_2O_3	2.86	2.48*	0.25*
S	0.29		

* Data taken from previous study

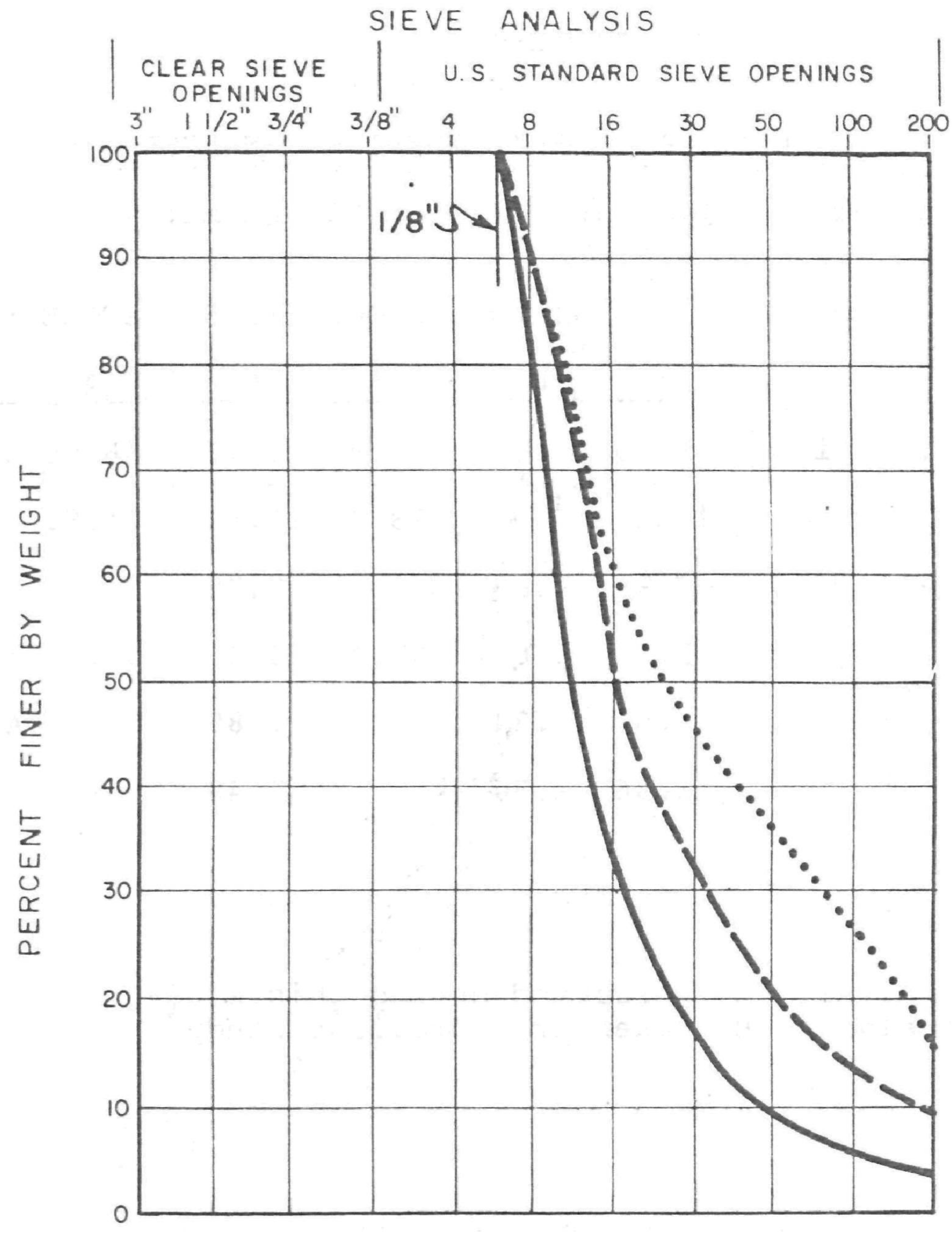
TABLE 4

COMPARISON OF INDEPENDENT LIMESTONE ANALYSES

(REPORTED AS WEIGHT % OF IGNITED SAMPLE)

	STONE #1809		STONE #1355		STONE #1337	
	A	B	A	B	A	B
Loss on ignition	36.93	41.5	33.8	33.3	46.00	47.5
SiO_2	15.4	5.90	23.9	27.5	1.82	0.78
Al_2O_3	3.9	1.99		5.75		0.15
CaO	71.9	88.0	62.3	60.0	54.3	53.0
MgO	0.59	1.34	1.65	1.85	39.1	45.0
Fe_2O_3	2.86	1.50		2.48		0.25

NOTE: Analysis "A" performed during this study
Analysis "B" taken from previous study[2]

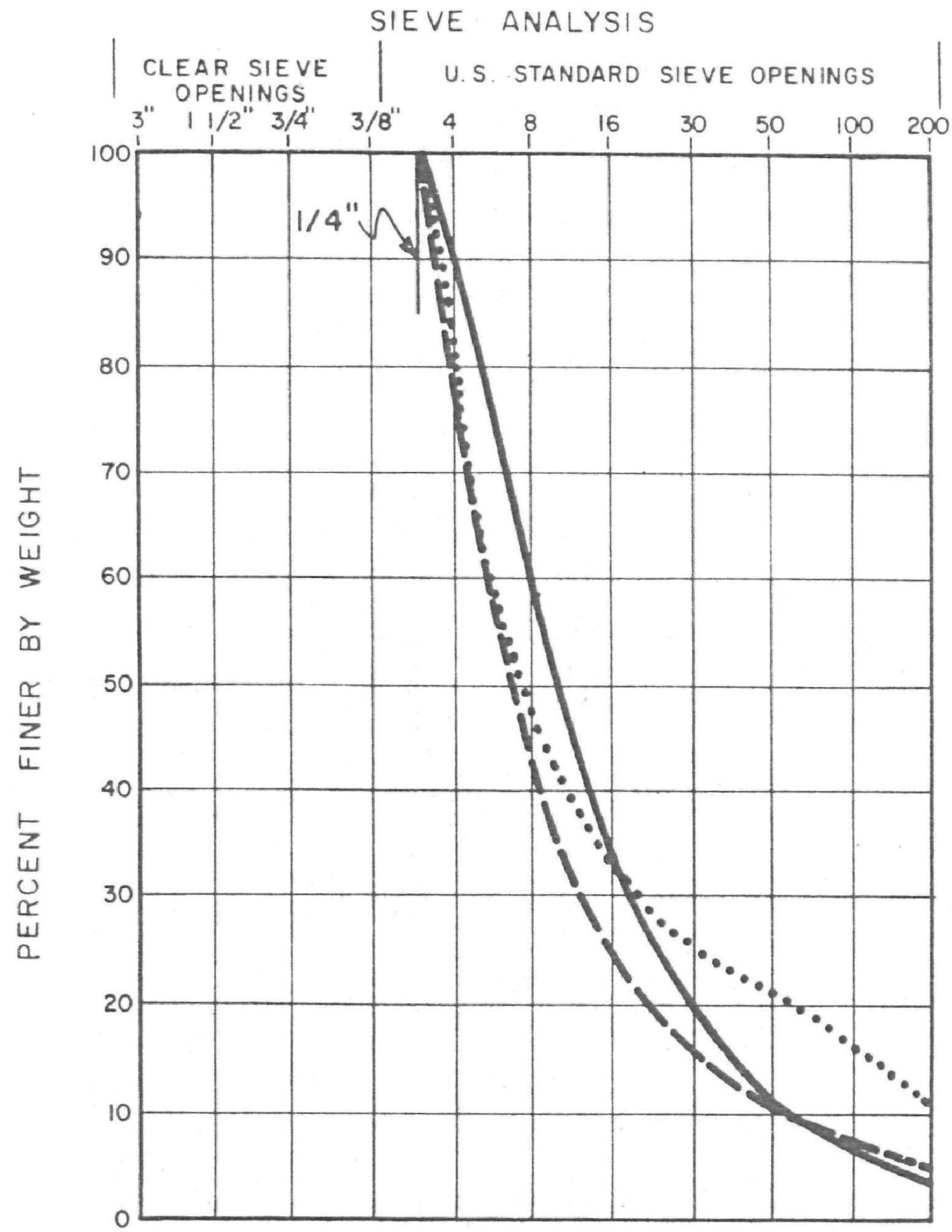


COBBLES	GRAVEL		SAND		
	COARSE	FINE	COARSE	MEDIUM	FINE

	LIMESTONE DESCRIPTION		
	MATERIAL	STONE SIZE	PERCENT PASSING NO. 200 SIEVE.
———	1809	1/8 X 0	3.9
– – –	1355	1/8 X 0	8.5
········	1337	1/8 X 0	16.1

INITIAL GRAIN SIZE CURVES
1/8 x 0 STONES

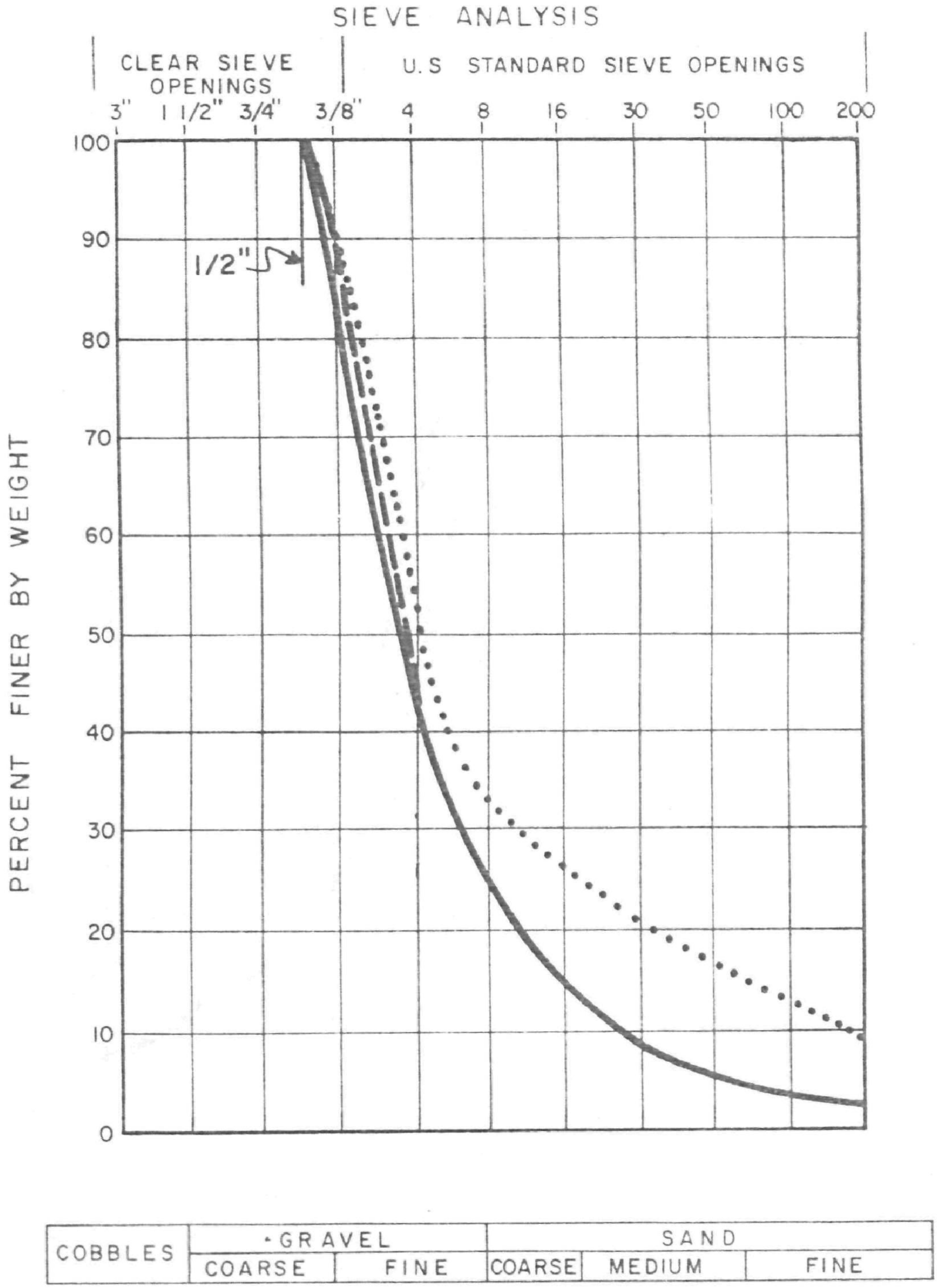
FIGURE 6



COBBLES	GRAVEL		SAND		
	COARSE	FINE	COARSE	MEDIUM	FINE

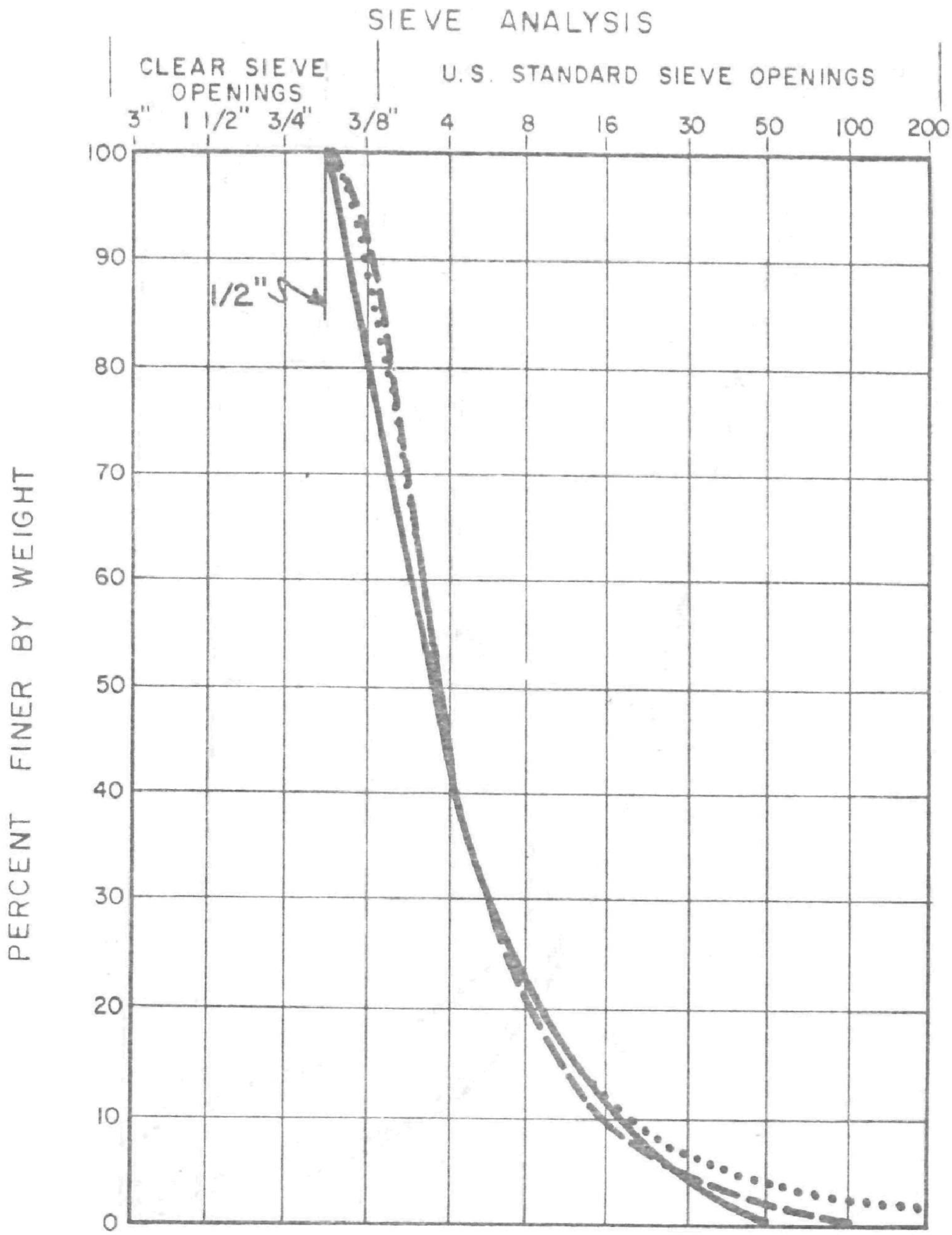
LIMESTONE DESCRIPTION		
MATERIAL	STONE SIZE	PERCENT PASSING NO. 200 SIEVE.
1809	1/4 X 0	3.9
1355	1/4 X 0	5.6
1377	1/4X 0	10.8

INITIAL GRAIN SIZE CURVES
1/8 X 0 STONES
FIGURE 7



LIMESTONE DESCRIPTION		
MATERIAL	STONE SIZE	PERCENT PASSING NO. 200 SIEVE.
1809	1/2 X 0	1.9
1355	1/2 X 0	2.1
1337	1/2 X 0	8.8

INITIAL GRAIN SIZE CURVES
1/2 X O STONES
FIGURE 8

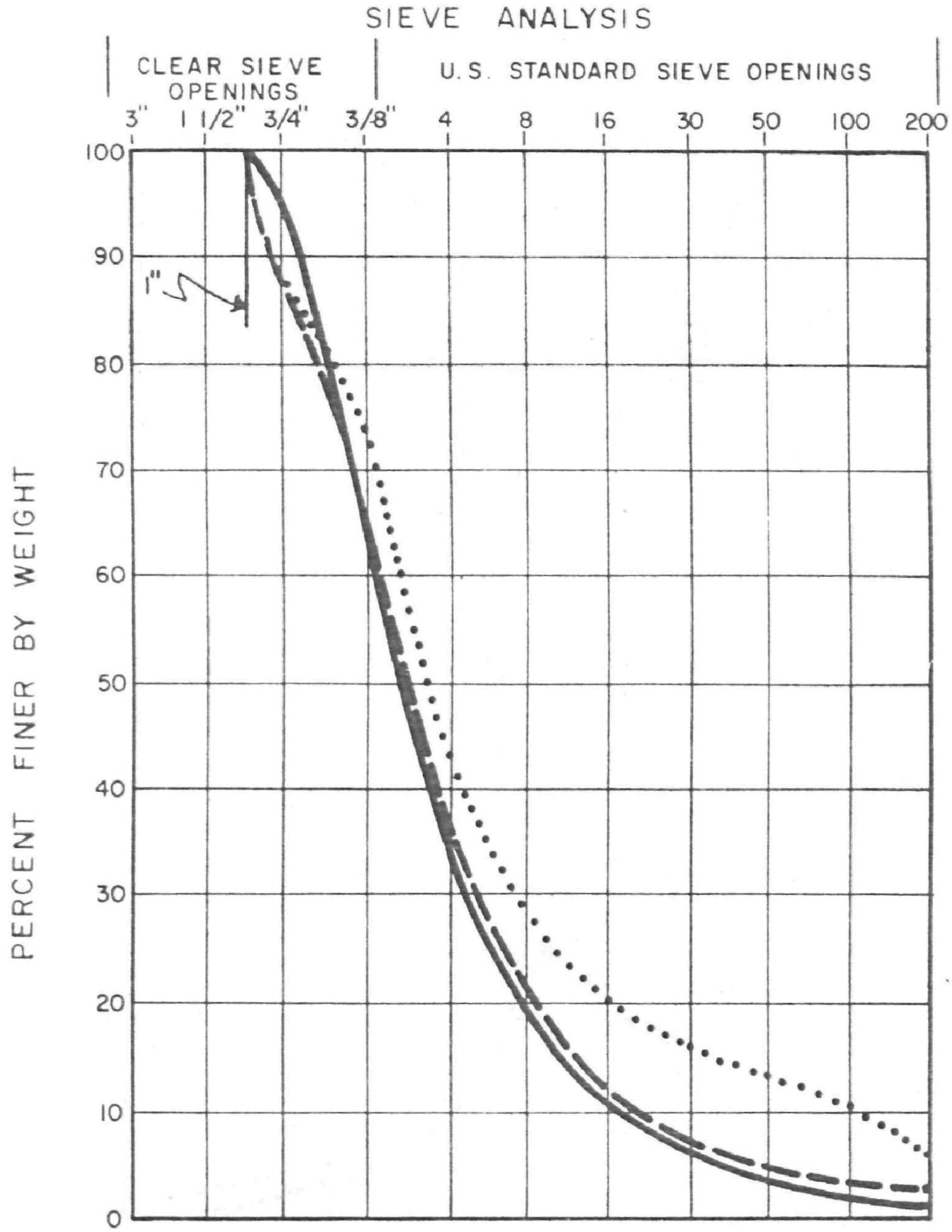


COBBLES	GRAVEL		SAND		
	COARSE	FINE	COARSE	MEDIUM	FINE

LIMESTONE DESCRIPTION		
MATERIAL	STONE SIZE	PERCENT PASSING NO. 200 SIEVE.
1809	1/2 X 50	0.1
1355	1/2 X 50	0.4
1337	1/2 X 50	2.6

INITIAL GRAIN SIZE CURVES
1/2 X 50 STONES

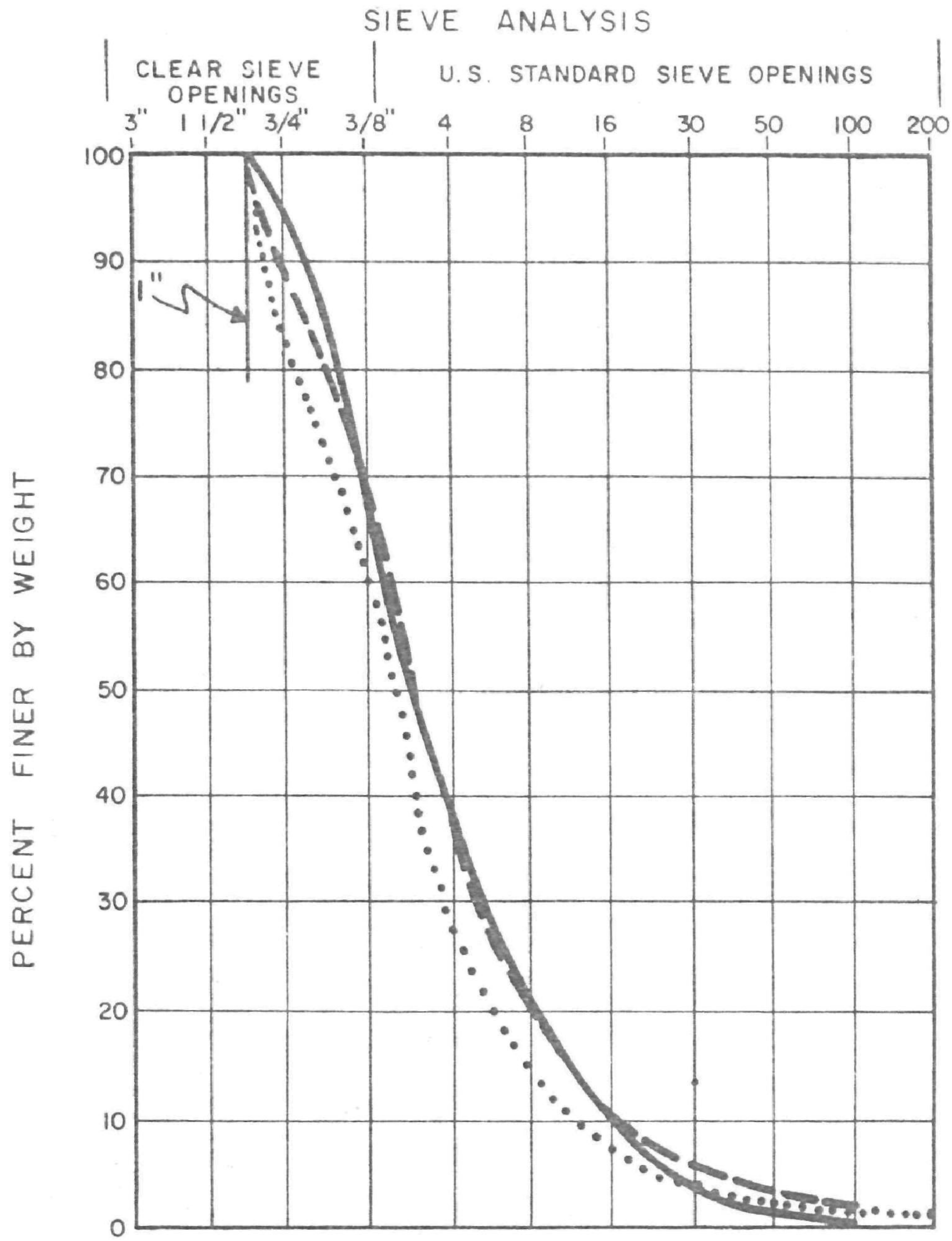
FIGURE 9



COBBLES	GRAVEL		SAND		
	COARSE	FINE	COARSE	MEDIUM	FINE

	LIMESTONE DESCRIPTION		
	MATERIAL	STONE SIZE	PERCENT PASSING NO. 200 SIEVE.
(solid line)	1809	1 X O	1.2
(dashed line)	1355	1 X O	1.9
(dotted line)	1337	1 X O	6.9

INITIAL GRAIN SIZE CURVES
1 X O STONES
FIGURE 10

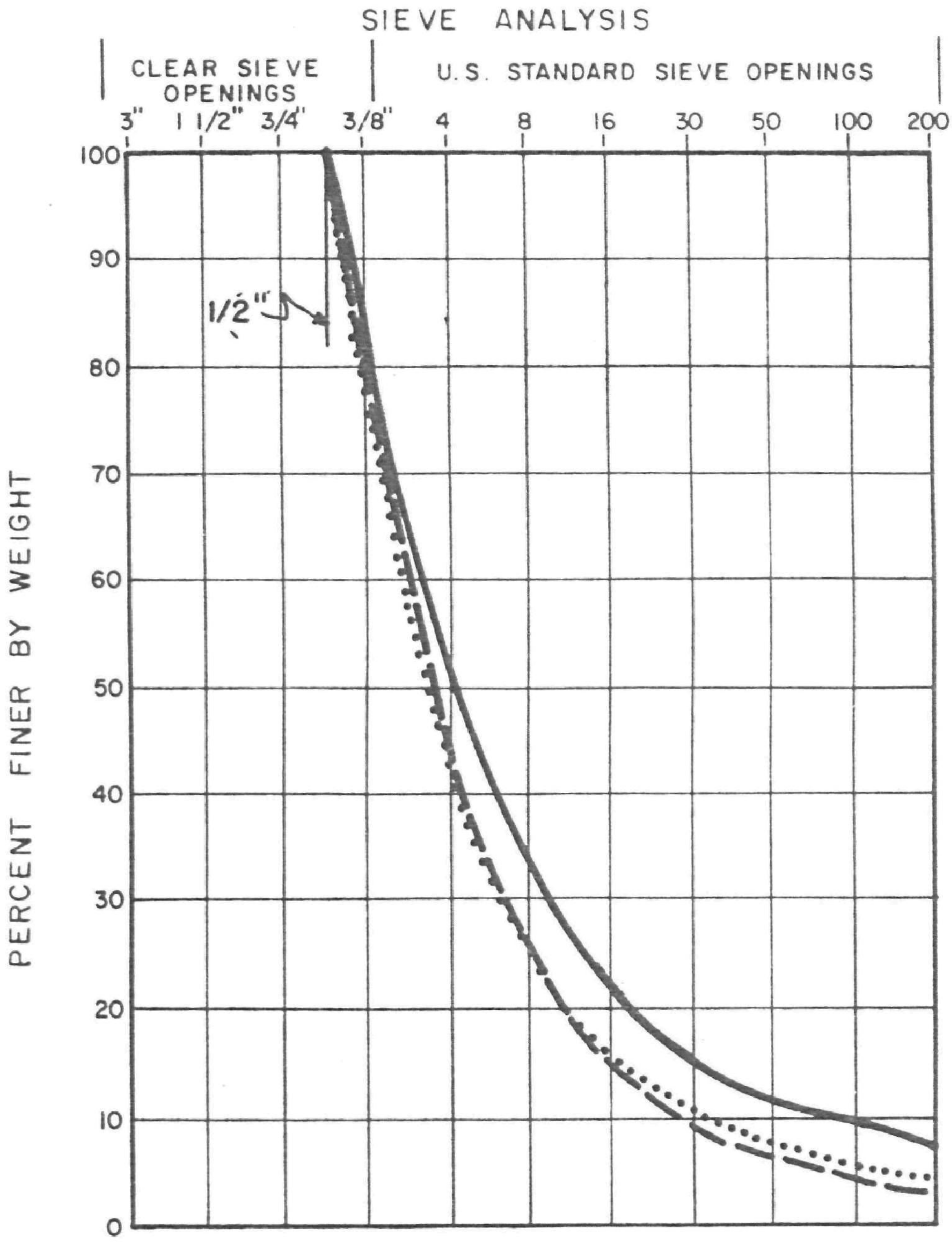


COBBLES	GRAVEL		SAND		
	COARSE	FINE	COARSE	MEDIUM	FINE

LIMESTONE DESCRIPTION		
MATERIAL	**STONE SIZE**	PERCENT PASSING NO. 200 SIEVE.
1809	1 X 50	0.1
1355	1 X 50	1.3
1337	1 X 50	1.2

INITIAL GRAIN SIZE CURVES
1 X 50 STONES

FIGURE 11

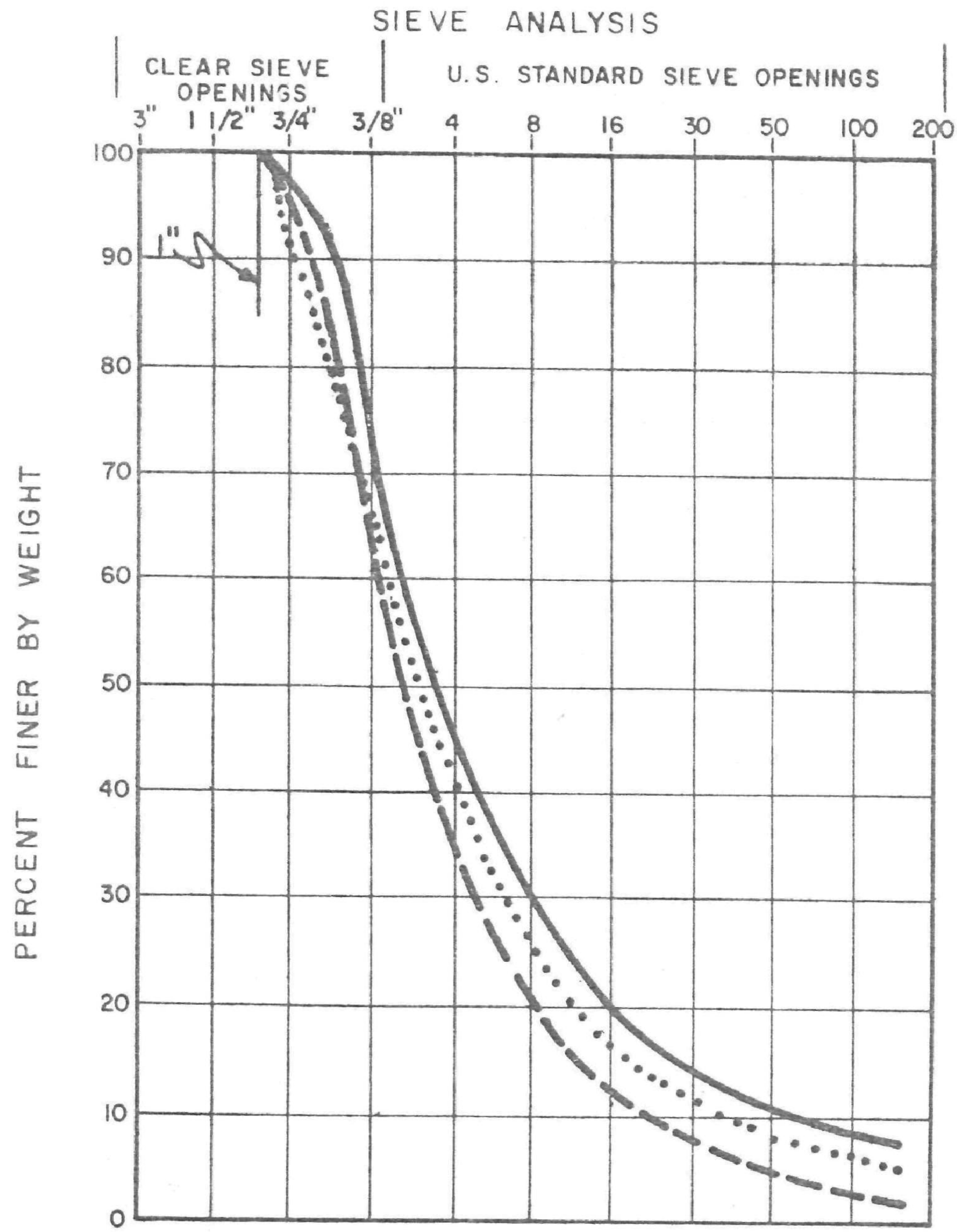


COBBLES	GRAVEL		SAND		
	COARSE	FINE	COARSE	MEDIUM	FINE

LIMESTONE DESCRIPTION				
	MATERIAL	STONE SIZE	PERCENT PASSING NO. 200 SIEVE.	ADDITIVE
———	1809	1/2 X 0	7.4	10% FLYASH
— — —	1809	1/2 X 0	2.3	10% SLAG
········	1809	1/2 X 0	4.0	5% BENTONITE

INITIAL GRAIN SIZE CURVES
1/2 X 0 STONES CONTAINING ADDITIVES

FIGURE 12



COBBLES	GRAVEL		SAND		
	COARSE	FINE	COARSE	MEDIUM	FINE

	LIMESTONE DESCRIPTION			
	MATERIAL	STONE SIZE	PERCENT PASSING NO. 200 SIEVE.	ADDITIVE
———	1809	1X0	7.5	10% FLYASH
— — —	1809	1X0	1.4	10% SLAG
•••••••	1809	1X0	5.2	5% BENTONITE

INITIAL GRAIN SIZE CURVES
1x0 STONES CONTAINING ADDITIVES

FIGURE 13

Start-up for the ferrous, ferric, and ferric/ferrous batteries were staggered over three days. The inlet heads on all the 1/8 x 0 and 1/4 x 0 sizes quickly rose to the maximum six feet. Initial heads on the coarser stones were as low as six inches. Flow data was recorded daily beginning 24 hours after start-up. The flow rates after one day of testing, referred to as initial flow rates, ranged from 15 ml/min to the maximum 1 GPM (3785 ml/min). A view of testing in progress is presented in Figure 14.

The flow rate of water through a permeable material is given by the relation:

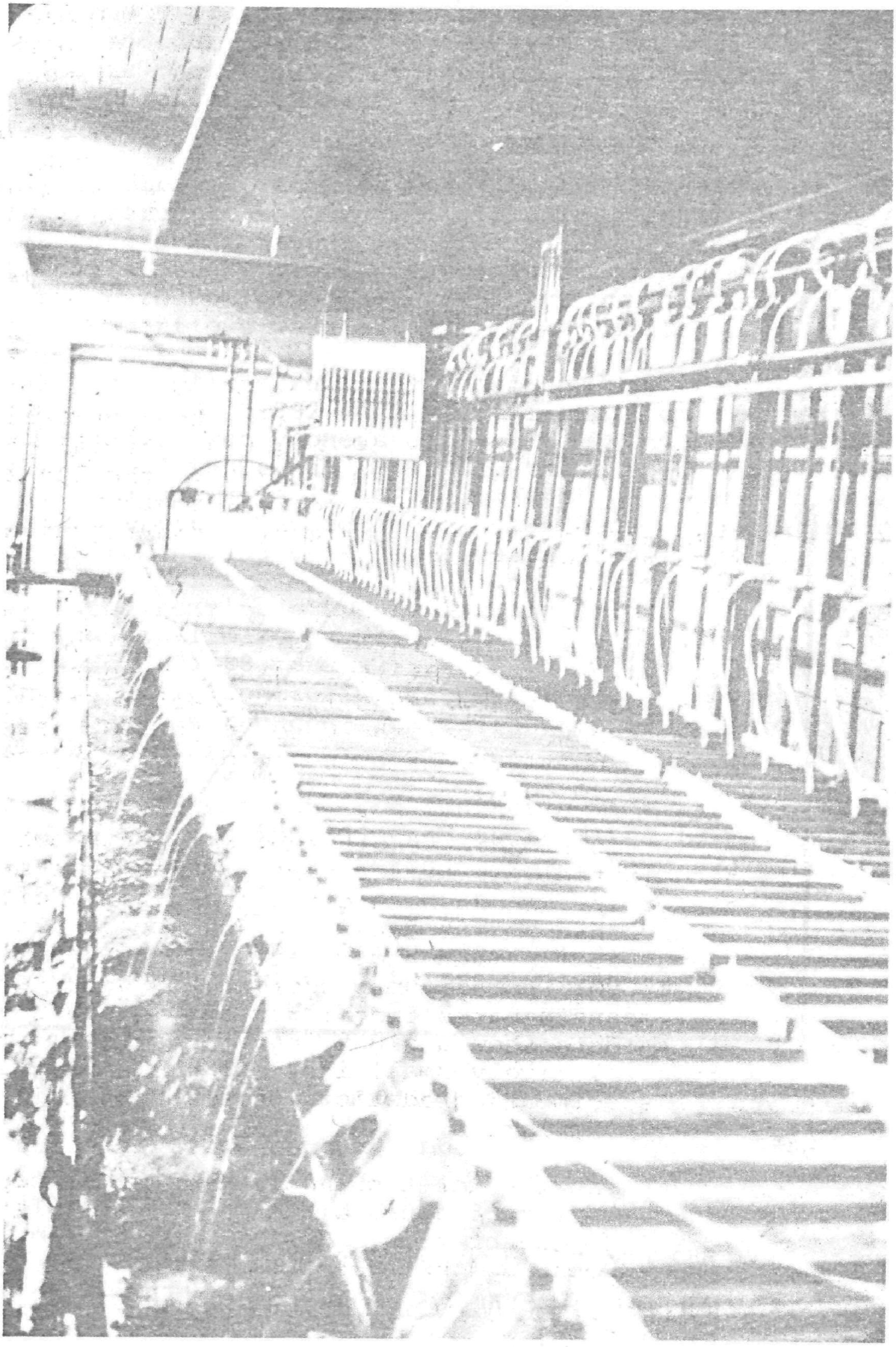
$$Q = k(hA/L)$$

In this equation, Q is the flow rate, k is the permeability coefficient, h is the head loss through the material, A is the cross sectional area of flow, and L is the length of the flow path. The permeability coefficient, k, is a function of the particle shape, grain size distribution, and density of the material.

In well-graded materials with no particle sizes missing, the fraction of the material passing a No. 200 sieve has a great influence on the permeability. Small increases of fines greatly decrease the permeability of well-graded gravels. Granular materials with 10 to 20 percent passing the No. 200 sieve and placed at a medium density or greater are relatively impermeable.

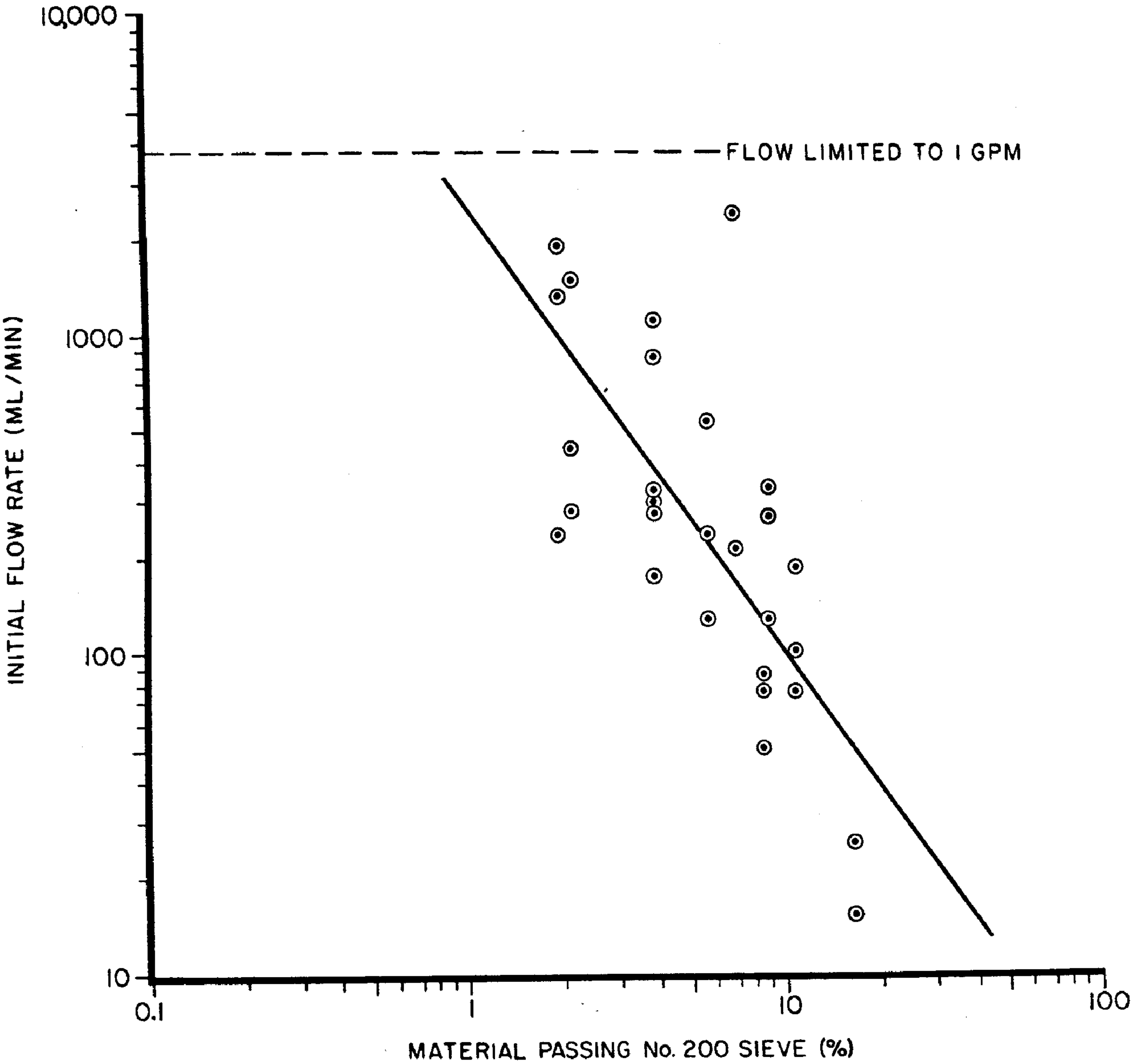
Measured initial flows exhibited this effect, as shown in Figure 15 where initial flow rates were plotted against fines content for specimens which did not contain additives. Test vessels which had not attained a 6 foot head were not plotted, since their flow rates were artifically restricted to the maximum 1 GPM. Logarithmic coordinates were used so that a least means squares linear regression could be performed. These data show a significant decrease in permeability with a relatively small increase of fines, indicating that the specimens' gradations were responsible for initial flow behaviors.

Gas pockets formed in the inlet chambers of several test vessels during the first 24 hours of testing, possibly due to air leakage or CO_2 generation. Sharp edges of the plexiglas vessels could possible have torn the PVC liners,



LAB CYCLE I TESTING

FIGURE 14



LAB CYCLE I LIMESTONE SPECIMENS
INITIAL FLOW VS. FINES CONTENT

FIGURE 15

allowing the pressurizing air to leak into the vessels. However, the 9 mil liners were relatively tough and care was exercised during vessel assembly. A more likely explanation is that CO_2 was accumulated as limestone, which is mainly calcium carbonate, neutralized the acid test water.

During the first 3 weeks of testing, the flow rate of test water delivered to each vessel standpipe decreased from the design 1 GPM to about 1/2 GPM. This was due to feed pump impeller wear. Test vessels which maintained a six foot head were not affected by this condition, since the standpipe overflows were diverting excess flow.

After 20 days of testing, the specimens with flows in excess of 0.5 GPM (1892 ml/min) at a six foot head were discontinued. Twenty-one specimens fell into this category and are listed in Table 5. All of these specimens had a 1/2" or 1" upper size limit and most of them had a 50 mesh lower size limit. The remaining specimens were continued for an additional 33 days for a total of 53 days of testing.

Three of the remaining specimens, the 1/8 x 0, 1/4 x 0, and 1 x 0 sizes of limestone No. 1355 on ferric/ferrous water (Vessels No. 37, 38, and 42), were tested for a total of 101 days. Daily monitoring was continued during the last 48 days, but was reduced from seven days per week to five, Monday through Friday.

Throughout the test run, the synthetic mine water compositions were checked and adjusted as required to maintain consistent values. The average compositions are presented in Table 6.

Flow and effluent composition data for all 72 test vessels are presented in Tables A7 through A78 in the Appendix. This data includes the following parameters:

Inlet head (in.)
Flow rate (ml/min)
pH
Specific conductance (mho)
Ferrous iron (mg/l)
Total iron (mg/l)
Calcium (mg/l)
Sulfate (mg/l)
Hot pht. acidity (mg/l as $CaCO_3$)

TABLE 5

SPECIMENS DISCONTINUED AFTER 20 DAYS

FERRIC TEST WATER

Vessel No. 9 - Stone #1809, 1/2 x 50 m
Vessel No. 11 - Stone #1809, 1 x 50 m
Vessel No. 12 - Stone #1809, 1 x 0
Vessel No. 15 - Stone #1355, 1/2 x 50 m
Vessel No. 17 - Stone #1355, 1 x 50 m
Vessel No. 22 - Stone #1337, 1/2 x 50 m
Vessel No. 23 - Stone #1337, 1 x 50 m

FERRIC/FERROUS TEST WATER

Vessel No. 36 - Stone #1809, 1 x 0
Vessel No. 40 - Stone #1355, 1/2 x 50 m
Vessel No. 41 - Stone #1355, 1 x 50 m
Vessel No. 45 - Stone #1337, 1/2 x 50 m
Vessel No. 47 - Stone #1337, 1 x 50 m

FERROUS TEST WATER

Vessel No. 50 - Stone #1809, 1 x 0 (10% slag)
Vessel No. 52 - Stone #1809, 1 x 0 (10% bentonite)
Vessel No. 57 - Stone #1809, 1/2 x 50 m
Vessel No. 60 - Stone #1809, 1 x 0
Vessel No. 65 - Stone #1355, 1 x 50 m
Vessel No. 69 - Stone #1337, 1/2 x 50 m
Vessel No. 70 - Stone #1337, 1/2 x 0
Vessel No. 71 - Stone #1337, 1 x 50 m
Vessel No. 72 - Stone #1337, 1 x 0

TABLE 6

SYNTHETIC ACID MINE WATERS

AVERAGE COMPOSITION

	FERRIC WATER	FERRIC/FERROUS WATER	FERROUS WATER
pH	2.5	2.6	2.5
Sp. conductance	2700	2700	2850
Hot pht acidity	743	894	874
Calcium	81	78	75
Magnesium	28	22	23
Manganese	5.3	5.8	5.0
Aluminum	16	16	18
Total iron	205	209	198
Ferrous iron	10	106	197
Ferric iron	195	103	1
Sulfate	1055	1030	1122

The inlet head and flow rate through the stone are directly proportional according to:

$$Q = \frac{kA}{L} h$$

For a material with a given permeability (k), cross-sectional area (A), and length (L), the ratio of flow rate to head is a constant (kA/L). This principle can be used to adjust measured flow rates at measured heads to equivalent flow rates at a six foot head. When this is done, it can be seen that most of the specimens reduced the equivalent flow rate of water over the test period.

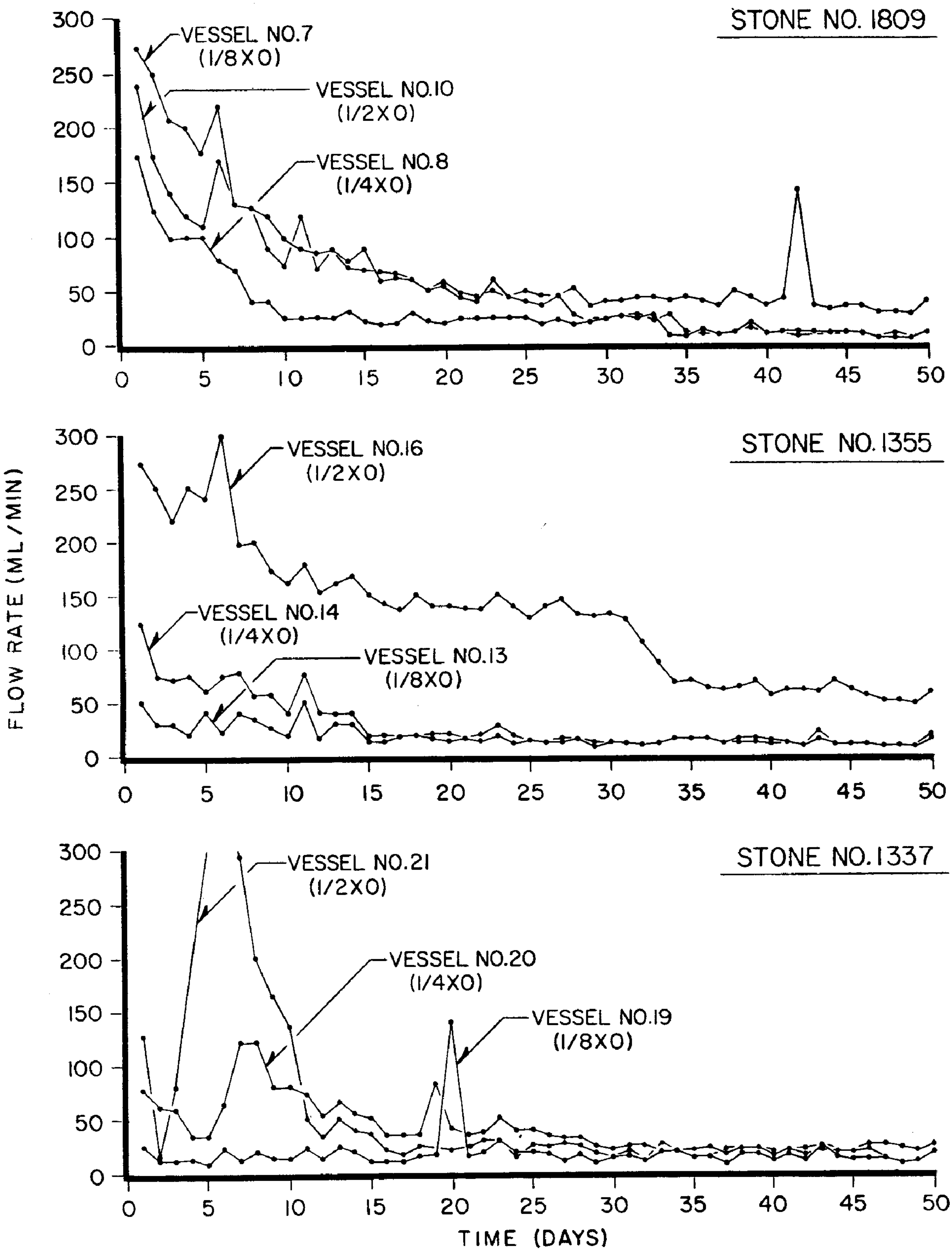
Flow histories of the limestone specimens with flow rates of 300 ml/min or less are presented in Figures 16, 17, and 18. Flow rate adjustment was not necessary, since the inlet heads on these vessels were six feet. These plots shows the measured flow rates vs time.

Test water type had a significant effect on flow behavior. Although all flow histories showed a considerable fluctuation, this fluctuation was least severe for specimens on ferric water and most severe for specimens on ferrous water. Ferric water specimens generally had the lowest flow rates, while ferrous water specimens had the highest.

Flow behavior was also shown to be dependent on stone type. Initial flow rates were highest for stone No. 1809 (Type A) and lowest for stone No. 1337 (Type C). As previously discussed, this was due to the initial fines content of the aggregate. For example, the 1/8 x 0 size of stone No. 1337 contained over four times as much fines as the same size of limestone No. 1809.

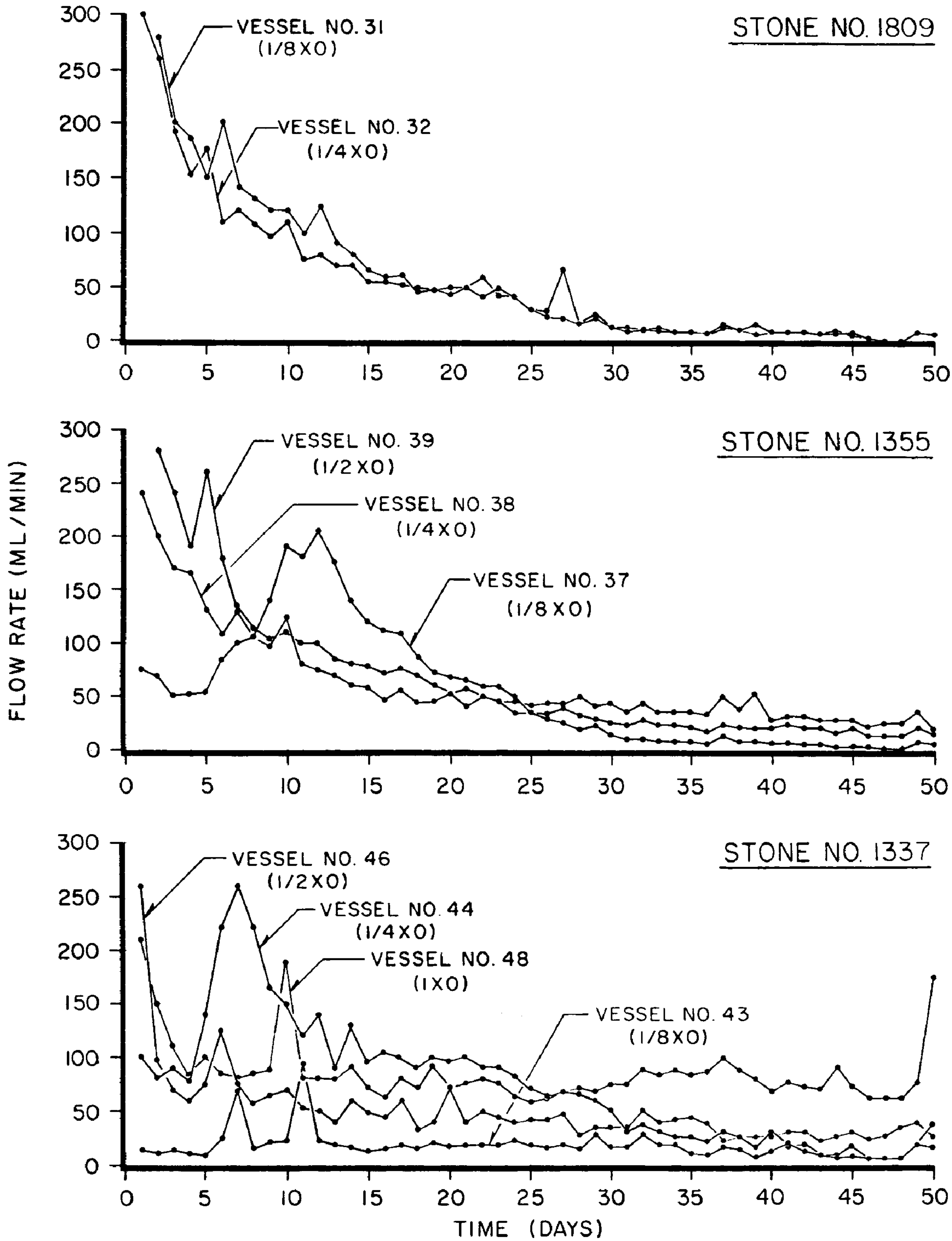
During the test run, however, stone No. 1809 exhibited the greatest reduction of flow, while stone No. 1337 exhibited the smallest reduction. As a result, flow rates after 50 days of testing for stone No. 1809 specimens tested on ferric or ferric/ferrous water were generally lower than for corresponding stone No. 1337 specimens.

The lowest recorded flows occurred with the 1/8 x 0 and 1/4 x 0 sizes, while the highest recorded flows occurred with the 1/2 x 50M and 1 x 50M sizes. All the 1/8 x 0 sizes and all but one (Vessel No. 56) of the 1/4 x 0 sizes maintained flows less than 300 ml/min. Flow histories for these two sizes were similar, although the 1/8 x 0



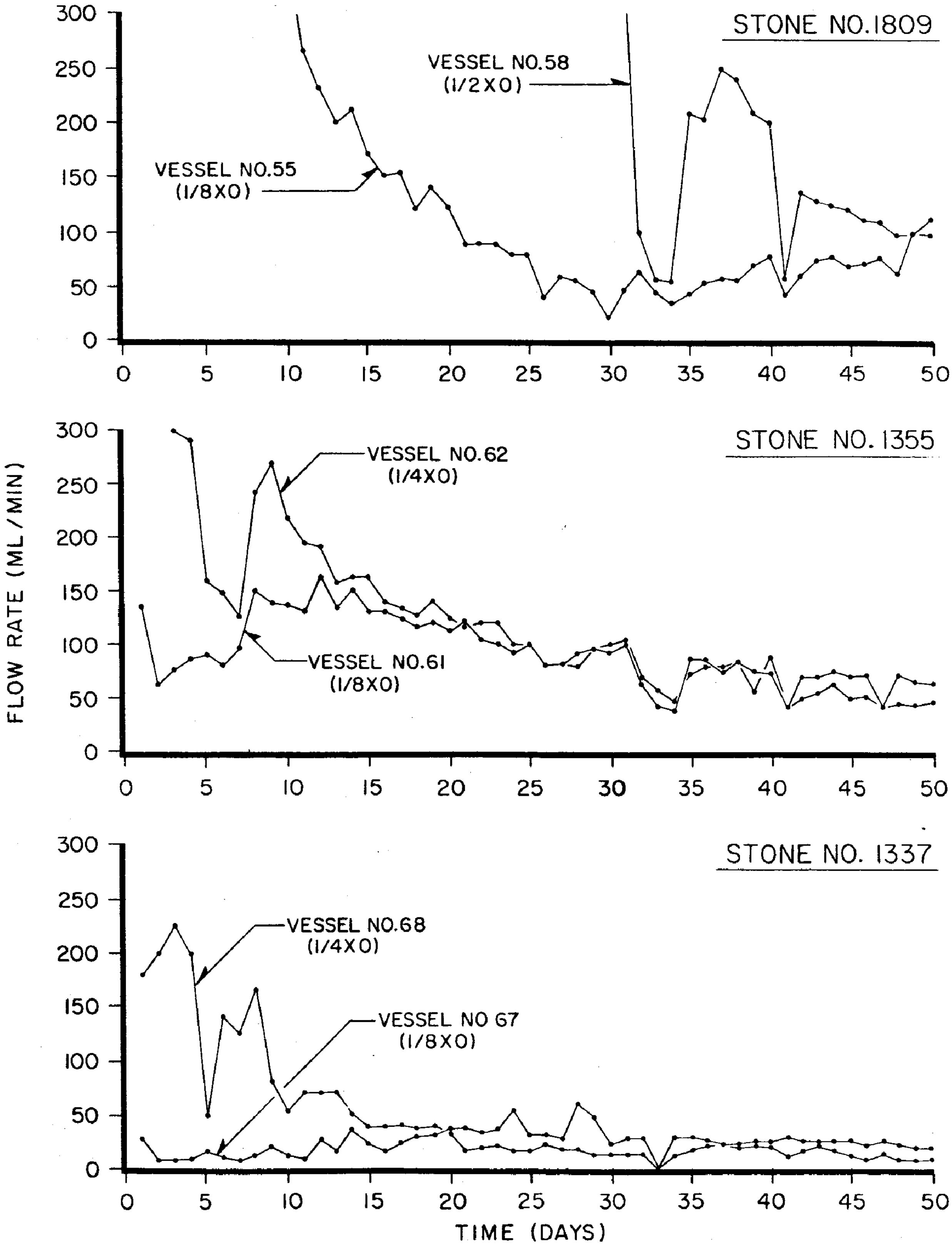
FERRIC WATER-SPECIMEN FLOW HISTORIES

FIGURE 16



FERRIC/FERROUS WATER-SPECIMEN FLOW HISTORIES

FIGURE 17



FERROUS WATER-SPECIMEN FLOW HISTORIES

FIGURE 18

size generally exhibited lower initial flow rates. Flow histories for the 1/2 x 0 sizes tested on ferric or ferric/ ferrous water were slightly greater than those for the 1/8 x 0 and 1/4 x 0 sizes. As previously discussed, most of the 1/2 x 50M and 1 x 50M sizes were discontinued after 20 days of testing due to their high flow rates.

Specimens which had lower flow rates neutralized mine water through the stone more effectively than those with high flow rates. Also, the pH of the effluents from the specimens tended to increase slightly throughout the tests as the observed flow rates decreased. These results were expected, since the neutralization reaction is relatively slow when limestone is used, and slower flow rates provided increased detention time. The effluents typically had pH values of 6 or 7 for those specimens having flows less than 300 ml/min.

Chemical compositions of the effluents were also pretty much as expected. Ferric iron concentrations in the neutralized effluents were typically less than 20 mg/l (a 90% removal of iron) and were often less than 0.03 mg/l. Ferrous iron was also removed in many cases, but not as completely as ferric iron. Calcium concentrations were significantly higher in this neutralized effluents. Due to the neutralization reaction and erosion. Sulfate concentrations were essentially unchanged.

These results show that iron is precipitated and trapped within the stone, but that calcium sulfate is not. The superior flow behaviors which were observed for specimens tested on ferric water indicate that the precipitated iron had a significant effect on the permeabilities of the specimens, since ferric iron was removed more effectively than ferrous iron.

Flyash and bentonite additives were shown to improve the performances of 1/2 x 0 and 1 x 0 stone sizes. Use of these additives, particularly flyash, provided lower flow rates and more effective mine water treatment. Performance of specimens containing these additives were comparable to performances of the 1/8 x 0 and 1/4 x 0 sizes (without additives) in tests using ferric and ferric/ferrous waters. Both the 1/2 x 0 and 1 x 0 sizes containing flyash were more successful than smaller sizes without additives in ferrous water tests.

After the test runs were completed, the tops of the test vessels were removed and the stone specimens were visually examined. Variable amounts of stone discoloration were observed, as illustrated in Figure 19. All specimens showed some yellowish-brown or red discoloration and a thin crust on the top and sides. The discoloration was largest in the coarser stones and smallest in the stones with large percentages of fines. Although no specimens were rigidly cemented, some small blocks of lightly cemented material within 6" to 12" of the inlet end were observed in the more heavily discolored specimens.

A decrease in stone heights and widths, shown in Figure 20 was also observed. Height decreases ranged from 1/8" to 1", and width decreased ranged from 0" to 1/2". Since the inlet ends of the vessels were most severely affected, it is believed that stone consumption by neutralization reactions was a major cause of these volume losses. Settling of the stone upon wetting, hydraulic erosion, and compression by the pressurizing air could also be responsible.

Average volume losses were determined for each specimen and are listed in Table 7. The reported values are believed to be accurate to within about 3 percentage points. These data show the following trends:

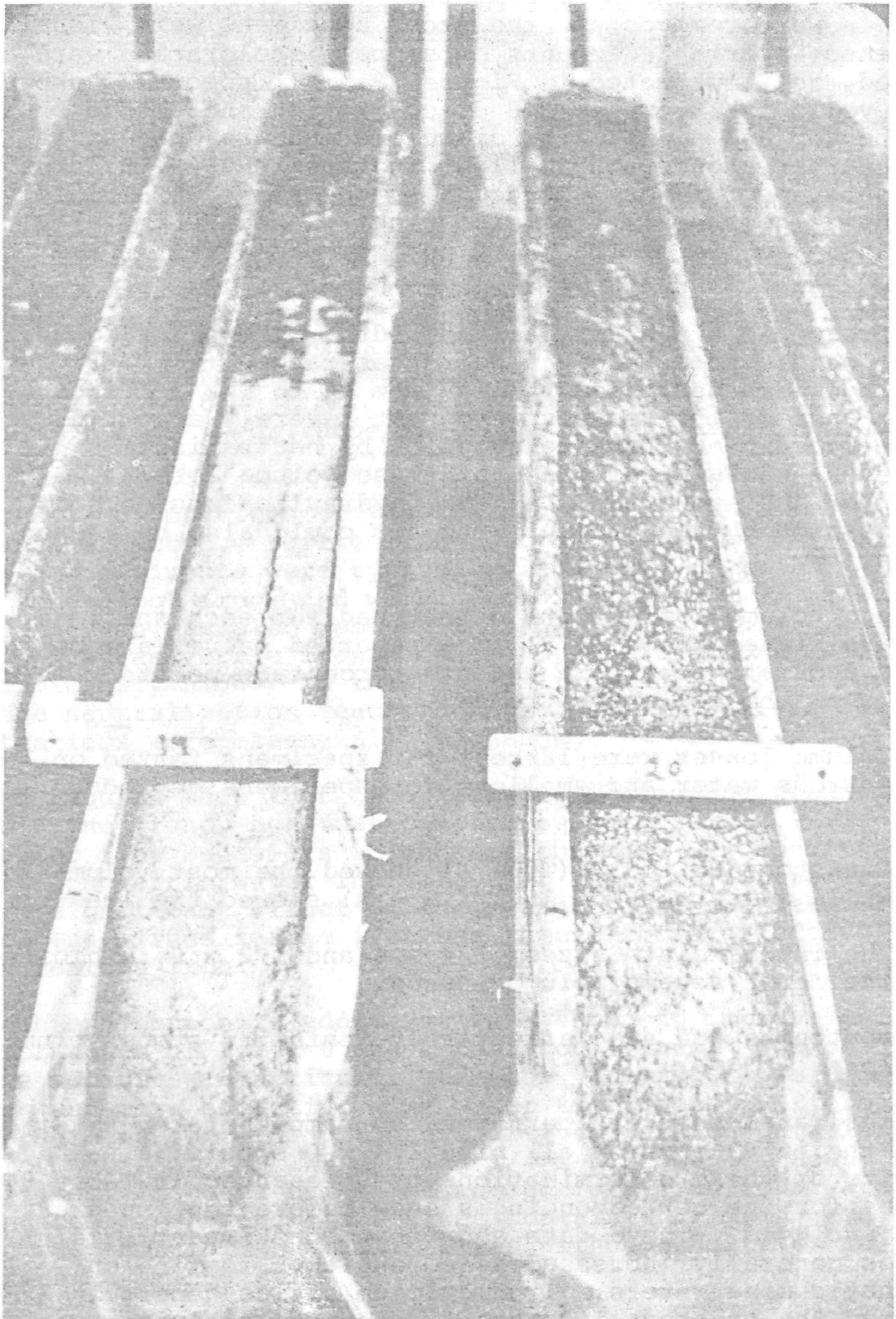
1. Volume losses were largest for specimens tested on ferrous water and smallest for specimens tested on ferric water.

2. Limestone No. 1337 (Type C) showed the most volume loss, while limestone No. 1809 (Type A) showed the least.

3. The intermediate sizes, 1/4 x 0 and 1/2 x 0, exhibited the least severe volume losses.

4. Bentonite and slag effectively inhibited stone volume loss.

Chemical analyses were performed on samples taken six inches from the inlet ends of all nine 1/4 x 0 specimens. The results of these determinations are presented in Table 8. Values for the corresponding stones before testing are also included. These data show that constituent/calcium ratios generally increased as a result of testing on synthetic mine waters. Iron/calcium ratios generally exhibited the greatest increase, indicating that iron was deposited in the first foot of the plug.



LIMESTONE SPECIMENS AFTER TESTING

FIGURE 19

LIMESTONE VOLUME LOSS

FIGURE 20

TABLE 7

STONE VOLUME LOSSES

EXPRESSED AS % OF INITIAL VOLUME

STONE	SAMPLES ON FERRIC WATER	SAMPLES ON FERRIC/FERROUS WATER	SAMPLES ON FERROUS WATER
1809, 1/8 x 0	5	7	12
1809, 1/4 x 0	4	7	10
1809, 1/2 x 0	9	11	38
1809, 1 x 0	6*	9*	18*
1809, 1/2 x 50 m	5*	13	21*
1809, 1 x 50 m	2*	7	36
1809, 1/2 x 0, 10% slag	5	6	6
1809, 1 x 0, 10% slag	6	9	13
1809, 1/2 x 0, 5% bentonite	3	3	8
1809, 1 x 0, 5% bentonite	7	7	14
1809, 1/2 x 0, 10% flyash	14	16	11
1809, 1 x 0, 10% flyash	14	20	12
1355, 1/8 x 0	17	24**	20
1355, 1/4 x 0	6	13**	3
1355, 1/2 x 0	8	15	15
1355, 1 x 0	7	17**	20
1355, 1/2 x 50 m	5*	6*	23
1355, 1 x 50m	6	8*	13*
1337, 1/8 x 0	30	28	19
1337, 1/4 x 0	18	16	11
1337, 1/2 x 0	14	18	
1337, 1 x 0	9	9	20*
1337, 1/2 x 50 m	3*	13*	39*
1337, 1 x 50 m	6*	10*	33*

NOTE: * Specimen discontinued after 20 days of testing
** Specimen discontinued after 101 days of testing
Others discontinued after 53 days of testing

TABLE 8

ANALYSIS OF LIMESTONES TESTED IN LAB CYCLE I

BEFORE AND AFTER TESTING

(REPORTED AS WEIGHT % OF IGNITED SAMPLE)

VESSEL NO.	STONE NO.	TEST WATER	LOSS ON IGNITION	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	S
None	1809	None	36.93	15.4	3.9	71.9	0.59	2.86	0.29
8	1809	Fe^{+3}	35.8	15.3	4.2	67.8	1.20	6.90	0.59
32	1809	Fe^{+3}/Fe^{+2}	5.7	11.1	2.0	45.1	4.03	11.52	0.27
56	1809	Fe^{+2}	29.5	25.0	20.0	49.1	1.23	9.33	0.57
None	1355	None	33.8	23.9	5.75*	62.3	1.65	2.48*	
14	1355	Fe^{+3}	32.2	23.6	6.05	59.4	1.77	4.43	0.60
38	1355	Fe^{+3}/Fe^{+2}	9.3	22.7	3.86	33.6	0.78	17.3	0.86
62	1355	Fe^{+2}	32.0	24.6	5.29	58.1	0.49	4.42	0.59
None	1337	None	46.0	1.82	0.15*	54.3	39.1	0.25*	
20	1337	Fe^{+3}	44.8	1.78	1.45	53.6	38.4	4.14	0.33
44	1337	Fe^{+3}/Fe^{+2}	44.2	5.56	1.61	52.0	40.9	5.12	0.34
68	1337	Fe^{+2}	45.1	1.42	0.73	55.7	40.6	2.06	0.18

* Data taken from previous study[2]

In-place density, particle size distribution, compressibility, and strength parameters were evaluated for eleven of the stone plugs. Densities, compressibilities, and shear strengths were measured on 4" diameter, 6" high cylindrical specimens trimmed from the inlet ends of the stone plugs where the effects of mine water percolation were greatest. A summary of the data is presented in Tables 9 through 14 and Figures 21 through 31 in the text and detailed data are given in the Appendix.

The density of uncemented granular materials has a great influence on the compressibility, permeability, and strength of the stones. The density of granular materials is determined by the specific gravity of the particles, particle shapes, particle size distribution and the particle structure. In a loose state, particle contacts are edge to plane and edge to edge producing a structure which collapses on disturbance. In a dense state, the particle contacts are primarily plane to plane producing a strong and stable structure since the material must expand to be sheared. Loose and dense structures are illustrated in Figure 21.

These states are defined by minimum and maximum densities determined by laboratory tests, and the in-place density of a granular material is related to these limiting densities by a relative density parameter. The relative density is expressed in percent and is obtained from the following equation:

$$DR = \frac{\gamma d_{max} \; (\gamma d - \gamma d_{min})}{\gamma d \; (\gamma d_{max} - \gamma d_{min})} \times 100\%$$

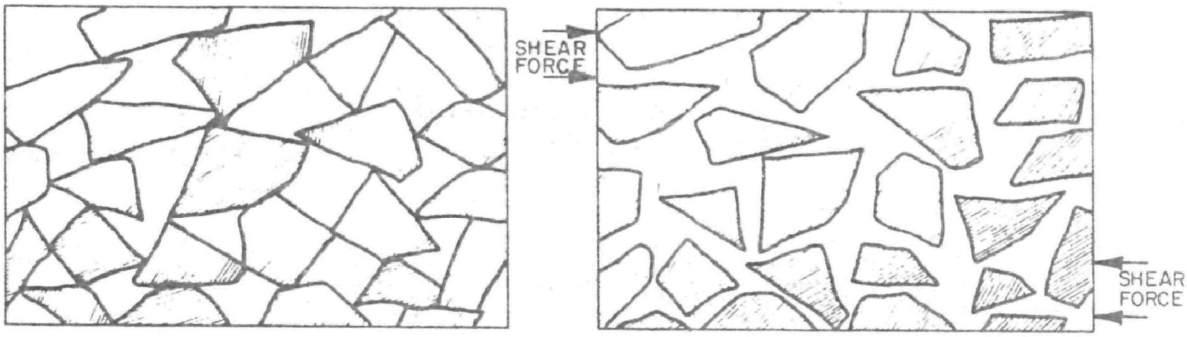
DR = relative density, %

γd = dry density

γd_{max} = maximum dry density

γd_{min} = minimum dry density

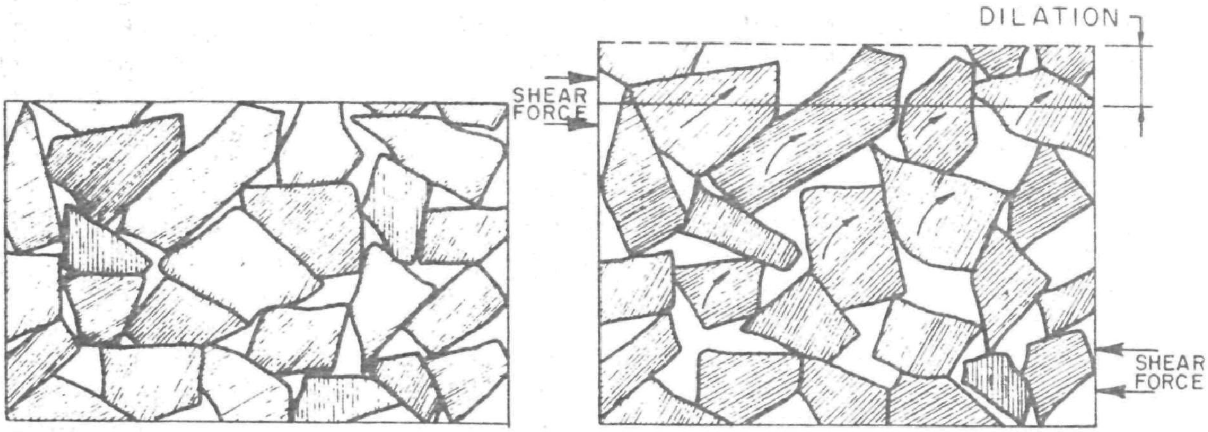
The significance of relative density values may be shown as follows:



AT REST

WHEN SHEARED, STRUCTURE COLLAPSES

VERY LOOSE, D_r = 0%



AT REST

WHEN SHEARED, STRUCTURE DILATES

VERY DENSE, D_r = 100%

NOTE
D_r = RELATIVE DENSITY

PARTICAL STRUCTURES AT
MINIMUM AND MAXIMUM DENSITIES

FIGURE 21

Relative Density (Percent)	Material Description	Type of Structure
0 - 15	Very Loose	Collapsing
15 - 35	Loose	Collapsing
36 - 65	Medium Dense	Intermediate
65 - 85	Dense	Dilating
85 - 100	Very Dense	Dilating

The dry densities of the limestones in the test vessels were evaluated by relative density calculated from minimum and maximum densities shown in Table 9.

It should be noted that since the density affects the physical properties of the stones, the minimum and maximum densities provide a criterion for evaluating of stones with various particle size distributions. The stones with higher densities should have better properties. Assuming the stones were placed with the same compaction effort or at the same relative density, stone No. 1355, 1/8 x 0 size, should have the best permeability, compressibility and strength properties.

The in-place densities of trimmed cylindrical specimens of the limestones subjected to mine water percolation were measured. These densities, relative density, and porosity are presented in Tables 10 and 11. The volume decrease is also shown for completeness of the density discussion. The densities were calculated from the measurements taken on trimmed cylindrical specimens from the test vessels. In the case of Test Vessel 58, undisturbed samples could not be obtained because of the large collapse and irregularity of the stone surface in the test vessel. The three specimens of each material are listed in order of sampling from the influent end with the center of the first specimen located about six inches from the influent, and the centers of the second and third specimens approximately 12 and 18 inches, respectively.

The relative densities of all trimmed specimens show the limestones at the influent end of the vessels to be loose to very loose. In six of the eleven vessels, the final densities are less than the minimum densities obtained by very loose placement of dry material resulting in negative relative densities. These negative densities indicate a large loss of material produced by the erosion of unprotected particle surfaces leaving a particle structure considerably looser and more fragile than can be obtained by physical placement. Therefore, these limestones are very loose, compressible and susceptible to structural collapse.

TABLE 9

MINIMUM AND MAXIMUM
DRY DENSITIES

Material BCR No.	Stone Size	Minimum Dry[a] Density, PCF	Maximum Dry[b] Density, PCF
1809	1/8 x 0	91.8	130.0
1809	1/4 x 0	94.8	130.7
1809	1/2 x 0	83.2	134.8
1355	1/8 x 0	97.5	140.0
1355	1/4 x 0	88.4	136.0
1355	1/2 x 0	78.0	130.0

[a]Minimum by ASTM Method, D-2049

[b]Maximum by Modified Proctor Test, ASTM Method, D-1557

TABLE 10

VOLUME LOSS, DRY DENSITY AND POROSITY OF TRIMMED SPECIMENS (AFTER 50 DAYS OF MINE WATER PERCOLATION, LAB CYCLE I)

Stone No. & TV No.	Stone Size	Volume Loss, %	Dry Density γ_d, PCF	Dry Density Avg. γ_d, PCF	Dry Density DR[a] %	Porosity n, %
	Ferrous Mine Water					
1809	1/2 x 0	38				
58			86.8	86.8	11	47.5
	Ferric Mine Water					
			84.0		4	49.2
1809	1/2 x 0	9	94.3	91.7	30	43.0
10			96.8		37	41.4
	Ferric-Ferrous Mine Water					
			87.5		-17	47.1
1809	1/8 x 0	7	99.4	95.1	-25	40.0
31			98.5		-23	40.4
			94.5		-1	42.8
1809	1/4 x 0	7	91.6	94.2	-13	44.5
32			96.6		7	41.5
			77.2		-20	53.3
1809	1/2 x 0	11	77.8	79.8	-18	53.0
34			84.3		3	49.0
			72.2		-40*	56.4
1355	1/2 x 0	15	81.8	79.5	-4	50.6
39			84.6		4	48.8
			92.0		25*	44.4
1337	1/2 x 0	18	88.4	90.5	15	46.5
46			91.0		23	45.0
			90.0		20*	45.4
1809	1/2 x 50	13	83.2	84.8	0	49.8
33			81.2		-6	50.9

TABLE 11

VOLUME LOSS, DRY DENSITY AND POROSITY OF TRIMMED SPECIMENS
(AFTER 100 DAYS OF MINE WATER PERCOLATION, LAB CYCLE I)

Stone No. & TV No.	Stone Size	Volume Loss %%	Dry Density γ_d, PCF	Dry Density Avg γ_d, PCF	Dry Density DR[a] %	Porosity n, %
	Ferric-Ferrous Mine Water					
			106.8		28.7	35.5
1355	1/8 x 0	24	107.8	107.7	31.4	34.9
37			108.6		33.7	34.4
			100.0		33.1	39.7
1355	1/4 x 0	13	96.0	99.1	22.6	42.0
38			101.2		36.0	38.8
			72.7		-21.9	56.2
1355	1 x 0	17	74.8		-12.9	54.6
42			76.5		-5.9	53.8

Finally, the settlement of the stone surfaces without corresponding increase of relative density from the loose placement density to medium density indicates stone erosion in the vessels.

Particle size analyses of the stones subjected to mine water percolation all showed an increase of fines. This is shown in Table 12 where the percentage of fines passing the No. 200 sieve before and after percolation are given and in Figure 22 where the effect of type of mine water on No. 1809, 1/2 x 0, stone is illustrated. The increase of fines is due to the dissolving of larger limestone particles and the accumulation of precipitates. This increase of fines would plug the voids in the stones and decrease correspondingly the flow of water.

The effect of density on permeability is illustrated in Figure 23 where permeability test results on 3/8 x 0 stone specimens prepared at different densities are presented. These data indicate a significant decrease of permeability with an increase of dry density. Thus, increasing the placement density considerably reduces the flow of water through the stone.

Triaxial tests were conducted on trimmed cylindrical specimens of the limestones to determine their compressibility and strength after mine water percolation. In the triaxial test a cylindrical specimen is enclosed by a rubber membrane, confined by a lateral pressure and sheared by an axial load applied through a piston. The triaxial test apparatus is illustrated in Figure 24.

Two types of tests were conducted in this apparatus. The first was a constant-diameter compression test in which the diameter was kept constant by continually increasing the lateral confining pressure during axial loading of the specimen as illustrated schematically in Figure 25. The need to increase the confining pressure was sensed by a lateral gage mounted at mid-height of the cylinder. During the compression test the axial deformation, axial load and confining pressure were recorded and the axial strain, axial and confining stress and the ratio between the vertical and horizontal pressures calculated.

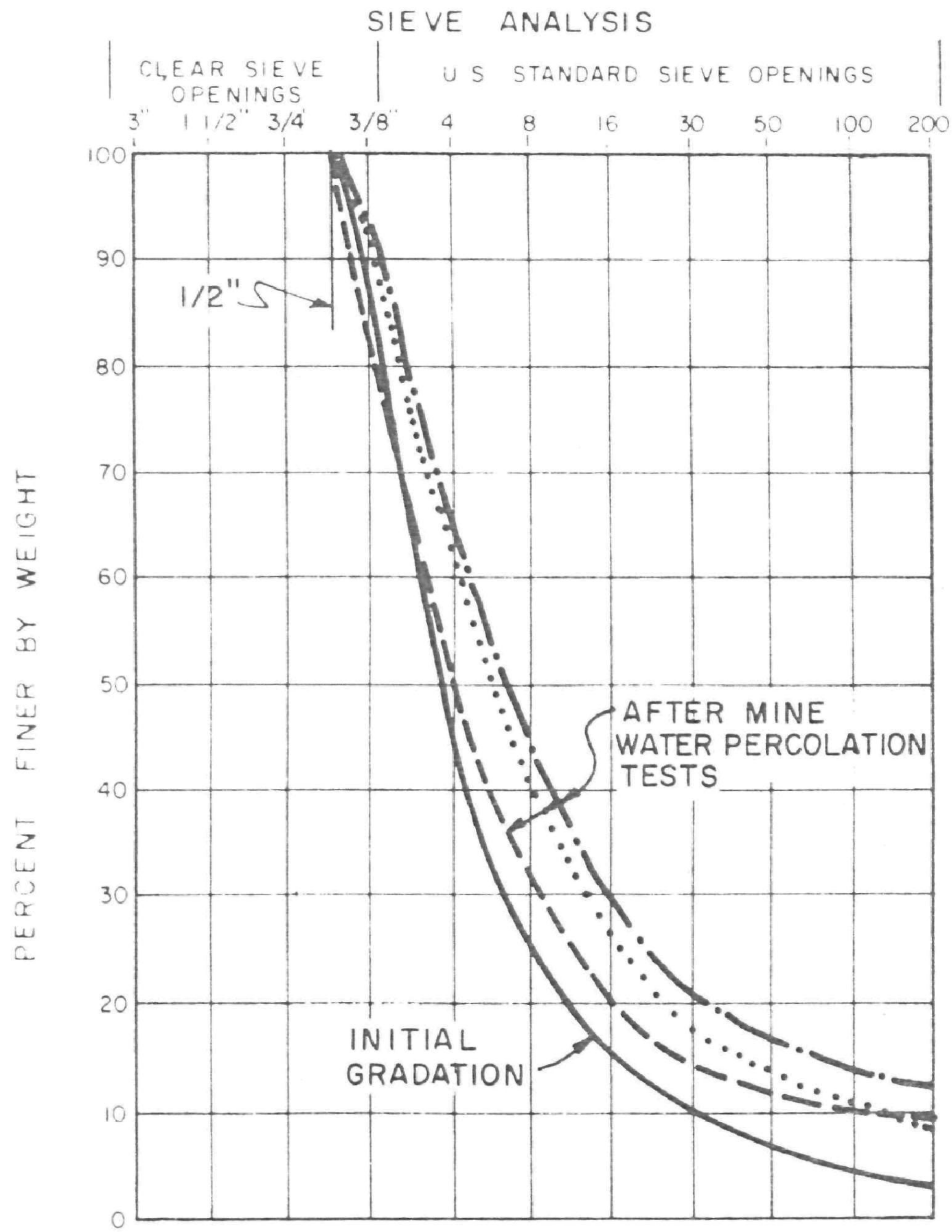
The second type of test was a shear strength test conducted at a constant confining pressure, illustrated in Figure 26. This type of test was necessary because the limestones after being subjected to the mine water percolation were found to

TABLE 12

INCREASE OF FINES DUE TO
MINE WATER PERCOLATION

Test Vessel	Stone Size	Type of Water	Sample Description	Percent of Material Passing No. 200 Sieve Before	After
Lab Cycle I - 50 Days Percolation - Stone No. 1809					
31	1/8 x 0	F/F		3.9	5.8
32	1/4 x 0	F/F	Placed	3.9	4.5
34	1/2 x 0	F/F	In	1.9	8.5
10	1/2 x 0	Ferric	Loose	1.9	10.7
38	1/2 x 0	Ferrous	State	1.9	7.9
Lab Cycle I - 100 Days Percolation - Stone No. 1335					
37	1/8 x 0	F/F	Placed	8.5	13.7
38	1/4 x 0	F/F	In Loose	5.6	7.1
42	1 x 0	F/F	State	1.9	9.4

F/F = Ferric-Ferrous

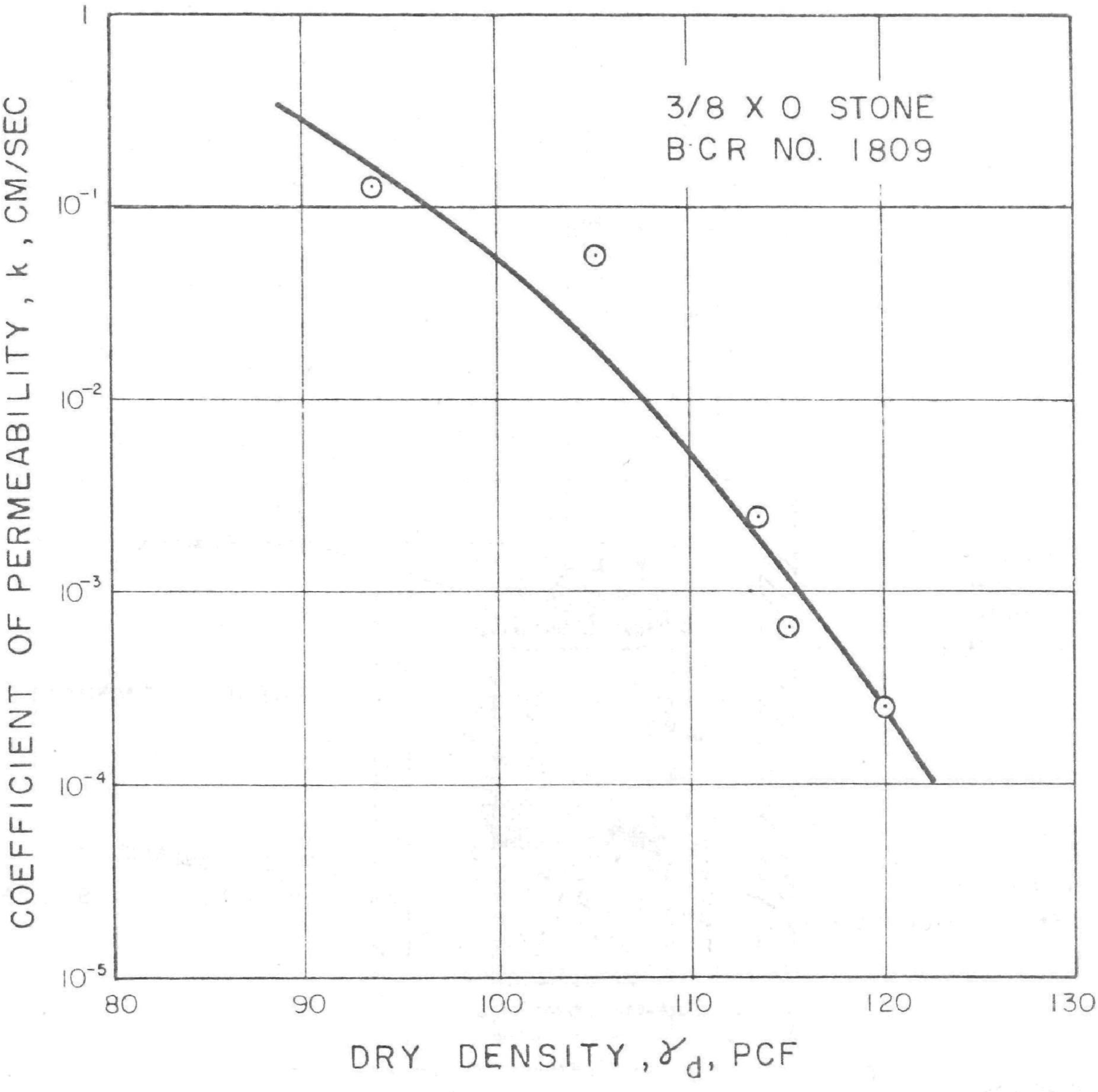


COBBLES	GRAVEL		SAND		
	COARSE	FINE	COARSE	MEDIUM	FINE

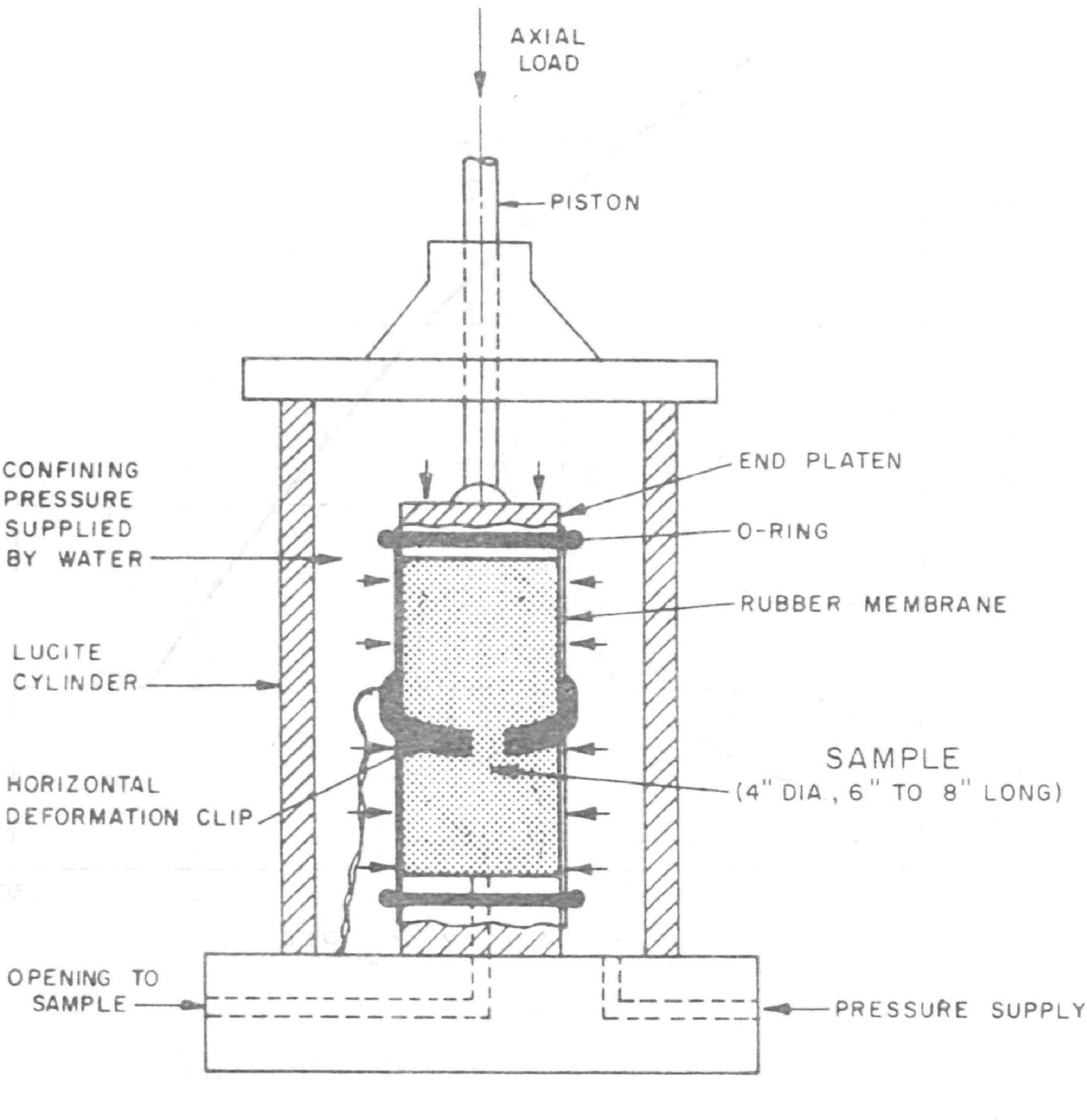
LIMESTONE DESCRIPTION				
	MATERIAL	STONE SIZE	PERCENT PASSING NO 200 SIEVE	TYPE OF WATER
———	1809	1/2 X 0	1.9	NONE
— — —	1809	1/2 X 0	8.5	FERRIC/FERROUS
········	1809	1/2 X 0	7.9	FERROUS
—·—	1809	1/2 X 0	10.7	FERRIC

GRAIN SIZE DISTRIBUTIONS BEFORE AND AFTER MINE WATER PERCOLATION
STONE NO. 1809, 1/2 X 0 SIZE

FIGURE 22

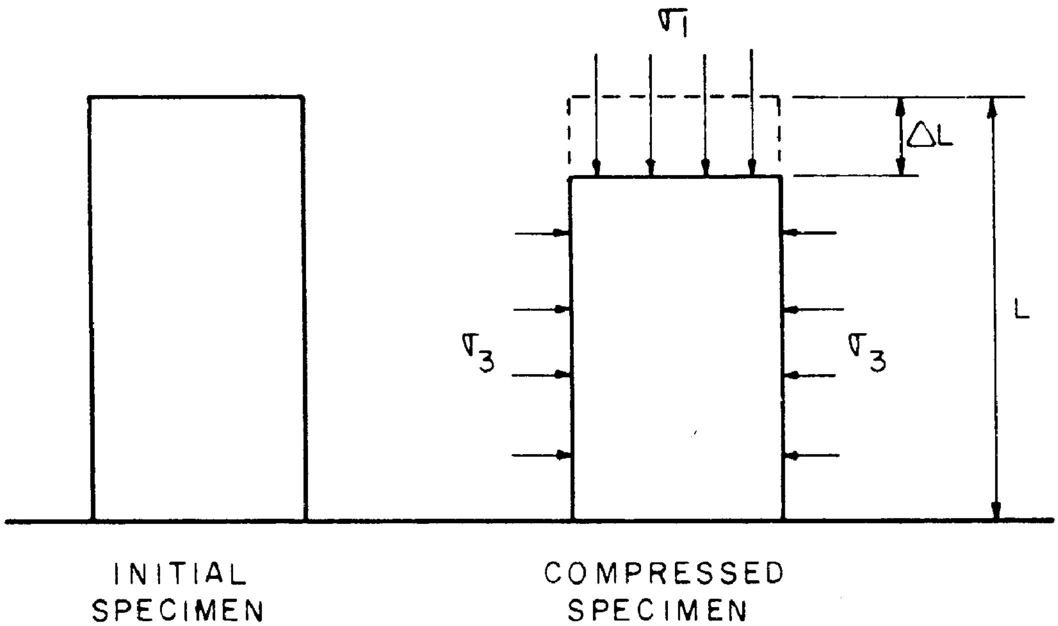


PERMEABILITY VS. DRY DENSITY
FIGURE 23



TRIAXIAL CELL

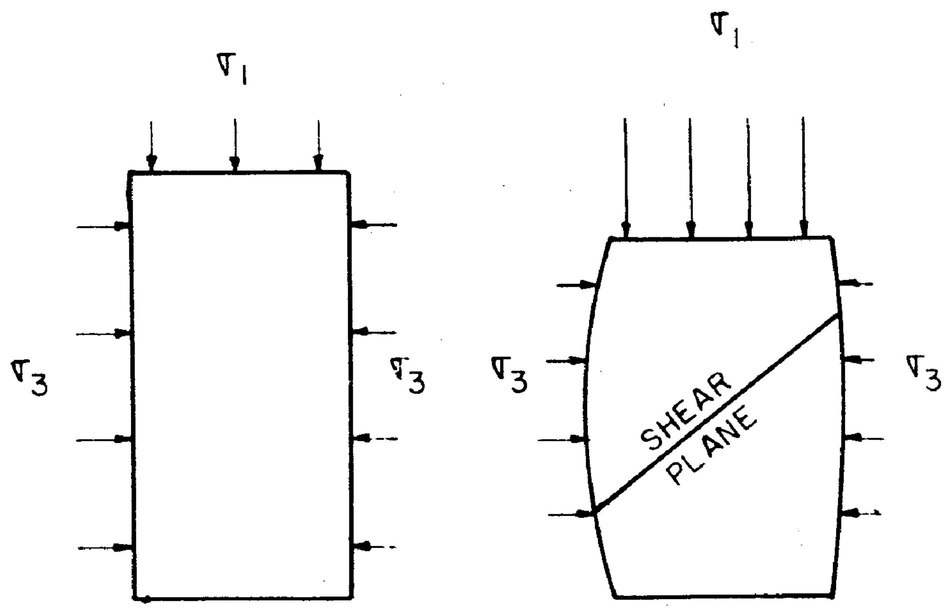
FIGURE 24



AXIAL COMPRESSION, $\epsilon_1 = \frac{\Delta L}{L} \times 100\ \%$

CONSTANT DIAMETER STRESS RATIO, $K_0 = \sigma_3 / \sigma_1$

CONSTANT DIAMETER COMPRESSION TEST
CONSTANT DIAMETER
FIGURE 25



SPECIMEN CONSOLIDATED UNDER ALL-AROUND CONFINING PRESSURE $\sigma_1 = \sigma_3 = C$

SPECIMEN SHEARED BY INCREASING σ_1 AND KEEPING $\sigma_3 = C$

CONSOLIDATED DRAINED TRIAXIAL TEST
CONSTANT σ_3
FIGURE 26

be uncemented and, therefore, behaved as granular materials. Granular materials derive their strength from particle stresses on the failure plane. The shear strength is derived from cohesion and friction components and may be expressed as:

$$S = C + N \tan \phi$$

where S = Shear strength

C = Cohesion

N = Normal stress on failure plane

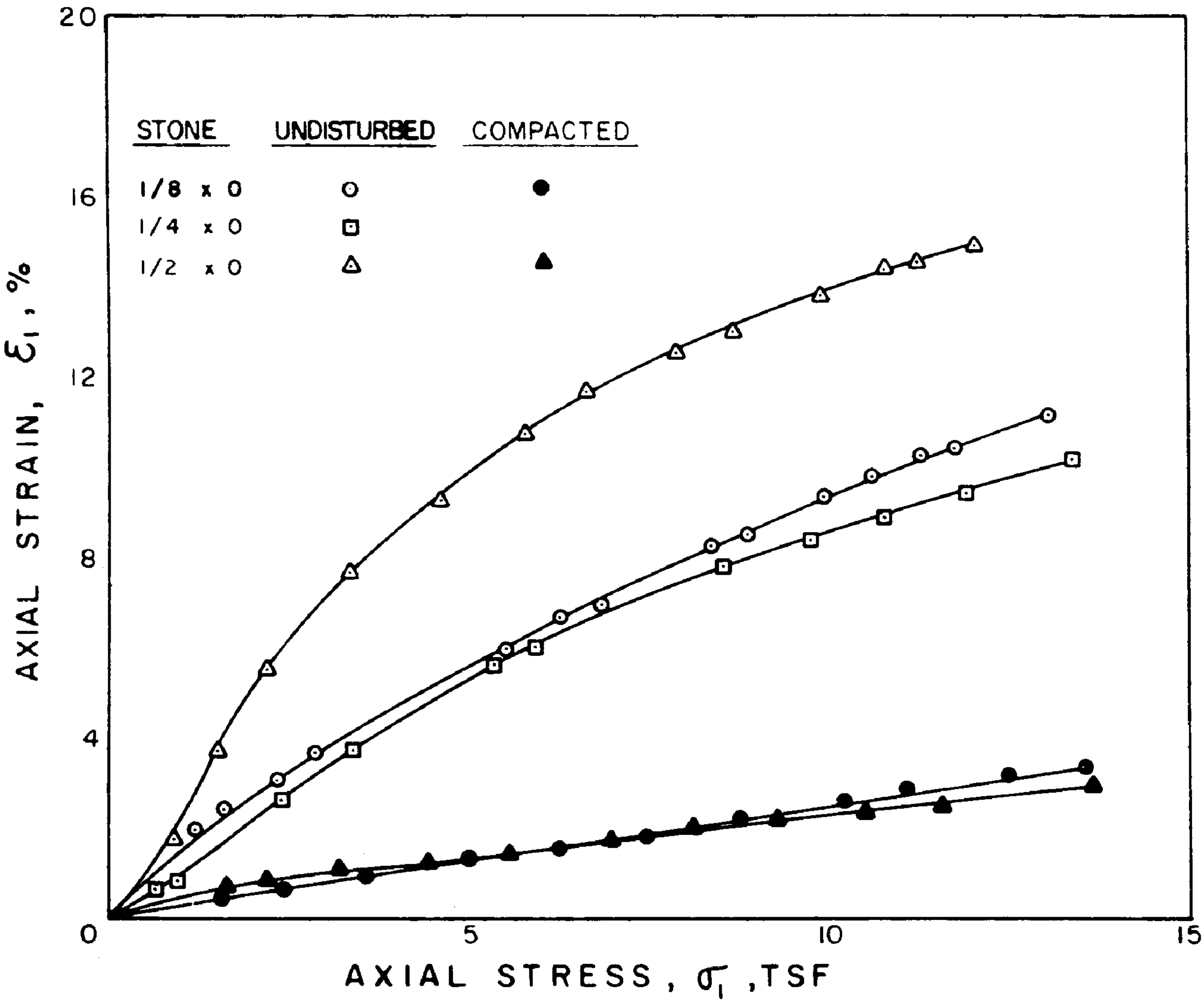
ϕ = Angle of internal friction

The cohesion and angle of internal friction are the strength parameters and are normally evaluated in the triaxial shear test.

A mine seal can develop a normal stress, and hence, shear strength from two mechanisms: (1) the hydrostatic pressure on the seal tending to push the seal out of the opening will tend to expand the seal and increase the confining pressure; (2) settlement of the roof will transfer part of the overburden load to the limestone seal.

Compression tests were conducted on trimmed undisturbed specimens from ten vessels and on remolded specimens from one vessel. In the latter case, a remolded specimen had to be used because it was impossible to trim a specimen from the collapsed material in Vessel 58. Since the compression data showed the limestones to be very compressible, two additional tests were conducted on remolded and compacted material prepared at a greater density than measured in the test vessels to determine the effect of density on the stiffness of the limestones. Typical axial stress-strain curves for three different stone sizes are shown in Figure 27 and all compression test data are summarized in Table 13.

The stress-strain compression data show the in-place limestones subjected to mine water percolation to be very compressible. The low stiffness of the limestones is the result of the loose placement of the stone and subsequent erosion of the limestone by mine water percolation. The effect of density variation can be seen from the stress-strain curves in Figure 27 and from the compression versus density plot in Figure 28.



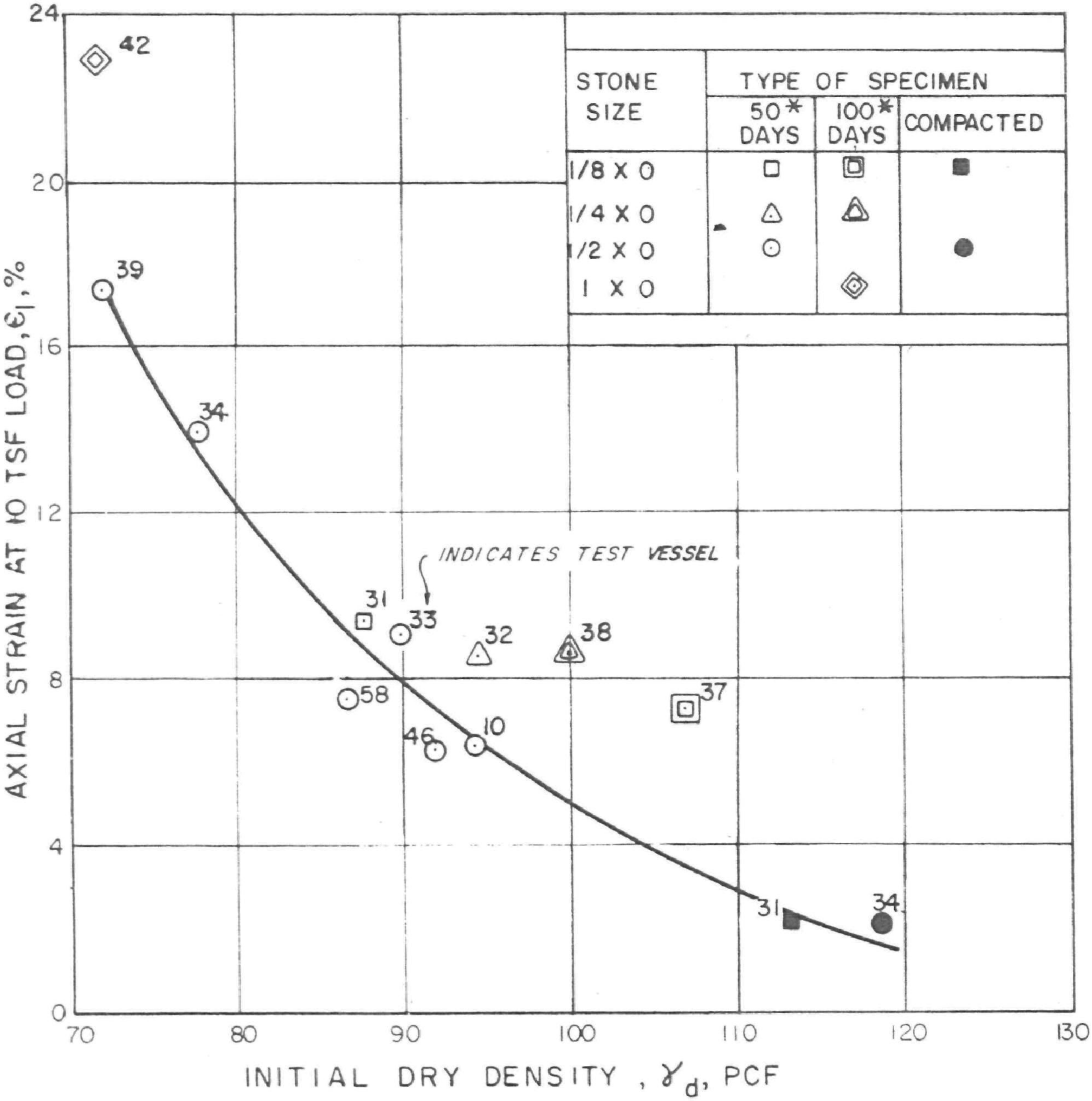
STRESS-STRAIN CURVES FROM
CONSTANT DIAMETER COMPRESSION TESTS

FIGURE 27

TABLE 13

SUMMARY OF COMPRESSION TEST RESULTS, LAB CYCLE I

Test Vessel No.	Stone Size	Type of Specimen	Dry Density, γ_d, PCF Initial	Final	Axial Strain at 10 TSF Load ϵ_1 %	$k_o = \sigma_3/\sigma_1$
	Ferric Water					
10	1/2 x 0	Remolded	94.3	101.7	6.4	.43
	Ferrous Water					
58	1/2 x 0	Remolded	86.8	92.0	7.5	.45
	Ferric-Ferrous Water					
31	1/8 x 0	Undisturbed	87.5	96.9	9.4	.43
31	1/8 x 0	Compacted	113.0	117.8	2.5	.34
32	1/4 x 0	Undisturbed	94.5	105.8	8.6	.44
34	1/2 x 0	Undisturbed	77.2	90.5	14.0	.46
34	1/2 x 0	Compacted	118.8	120.9	2.3	.36
39	1/2 x 0	Undisturbed	72.2	92.3	17.4	.43
46	1/2 x 0	Undisturbed	92.0	99.3	6.2	.43
33	1/2 x50	Undisturbed	90.0	102.8	9.1	.38
37	1/8 x 0	Undisturbed	106.8	117.2	7.0	.45
38	1/4 x 0	Undisturbed	100.0	111.9	8.5	.41
42	1 x 0	Undisturbed	72.7	96.9	22.5	.53



* UNDISTURBED SPECIMENS AT IN-PLACE DENSITIES SUBJECTED TO 50 AND 100 DAYS MINE WATER PERCOLATION.

COMPRESSIBILITY VS. DENSITY

FIGURE 28

The stress-strain curves of the three undisturbed samples in Figure 27 do not show the expected decrease of compressibility with an increase of particle size. It was anticipated that the 1/2 x 0 stone would be the least compressible and the compressibility would increase with the decrease of particle size as represented by the 1/4 x 0 and 1/8 x 0 stone, respectively. The deviation from the expected behavior is believed to be due to the low and variable densities, with the variations in density overshadowing the gradation effect.

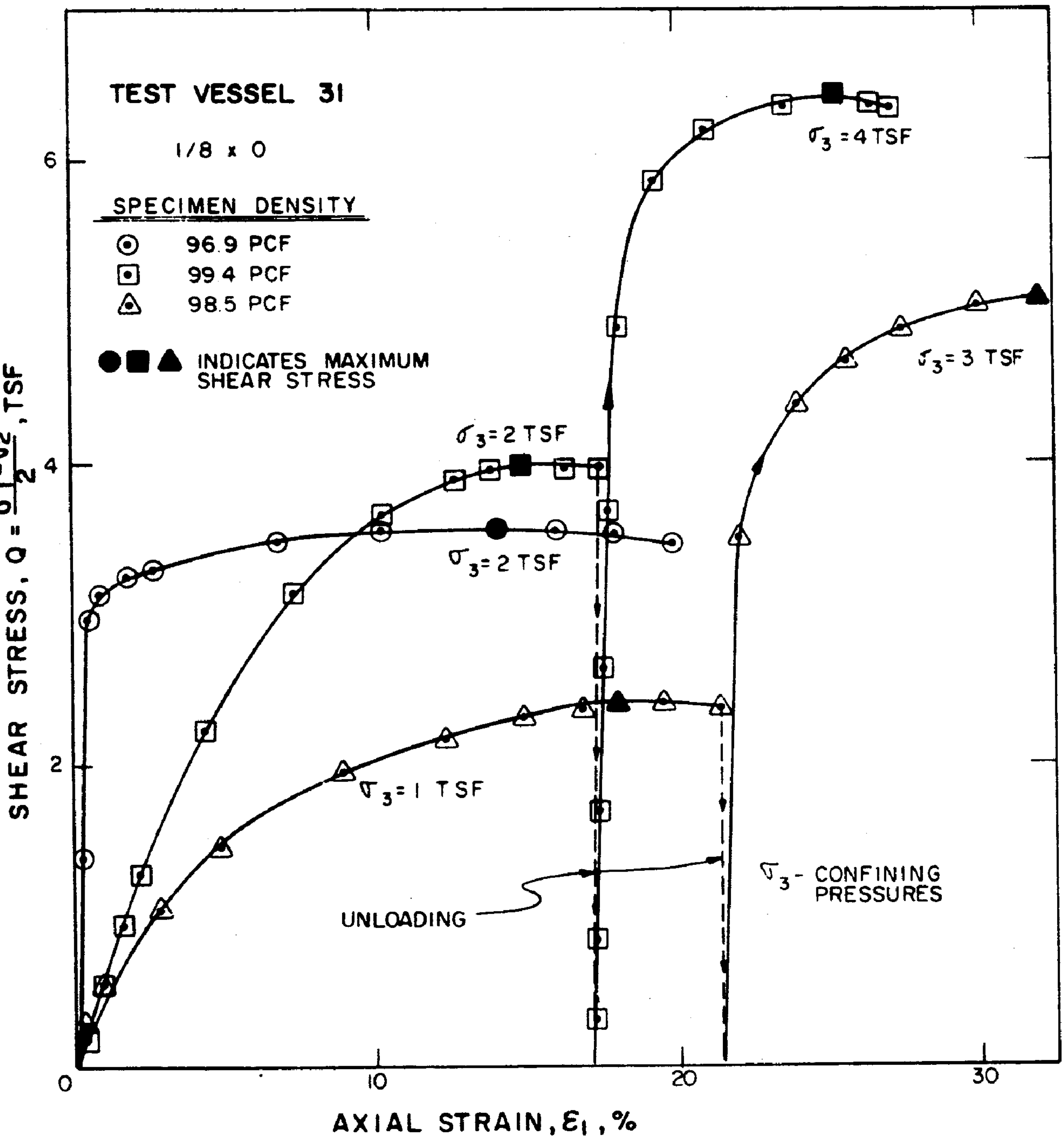
Finally, the specimens trimmed from the limestones subjected to 100 days mine water percolation specimens. This can be observed in Figure 28 where compressibility is related to dry density.

Triaxial tests were conducted on two or three specimens from each vessel to determine the shear strength parameters of the limestones following the mine water percolation tests.

The strength parameters were obtained from strength envelopes based on stress-strain curves from four to six tests at different confining pressures as illustrated in Figure 29. For some specimens more than one strength point was obtained by shearing the specimen at two different confining pressures. The shear strength parameters were obtained from a strength envelope established from the maximum shear stresses of the triaxial test in Figure 30.

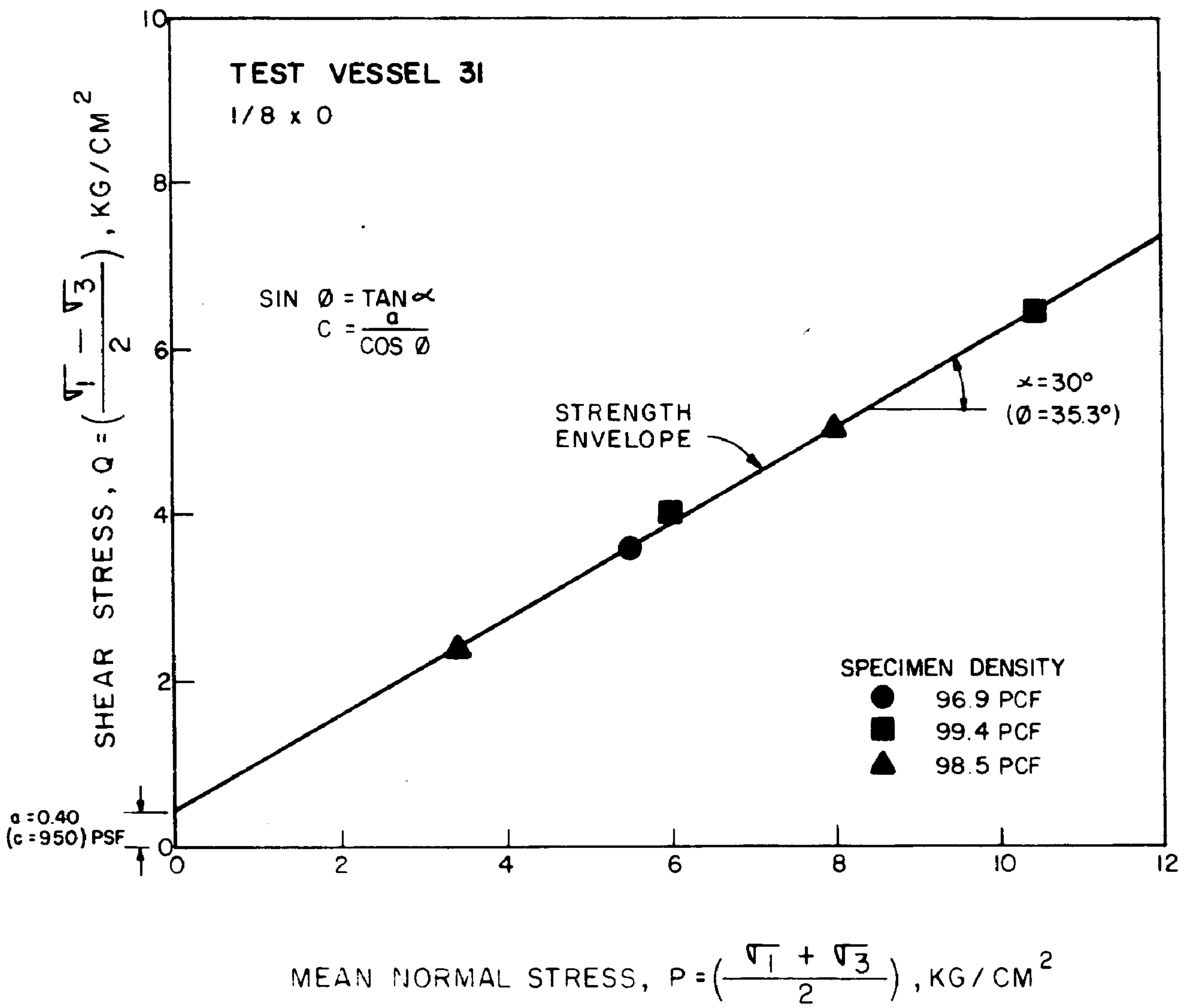
The results of all the tests are summarized in Table 14, where the average dry density, average axial strain at failure, cohesion, angle of internal friction and shear strength at a confining pressure of 2.0 TSF are given. Shear strengths developed by the stones at a given confining pressure are presented to permit a comparison of the shear strengths. These shear strengths are plotted against dry density in Figure 31.

The triaxial shear test data shows the limestones subjected to mine water percolation behave as granular materials whose shear strength is a function of the confining pressure and in-place density. For a typical confining pressure of 2.0 TSF, the shear strengths were mainly a function of the density, of the stone. Some decrease of strength was observed for the materials subjected to 100 days of percolation, however, the decrease is small.



STRESS-STRAIN CURVES FROM CONSOLIDATED DRAINED TRIAXIAL TESTS

FIGURE 29



STRAIN RATE = 0.06 IN./MIN
CONSOLIDATION TIME = 1/2 HOUR

SAMPLE DIMENSIONS
DIAMETER ~ 4.0 IN.
LENGTH ~ 6.0 IN.

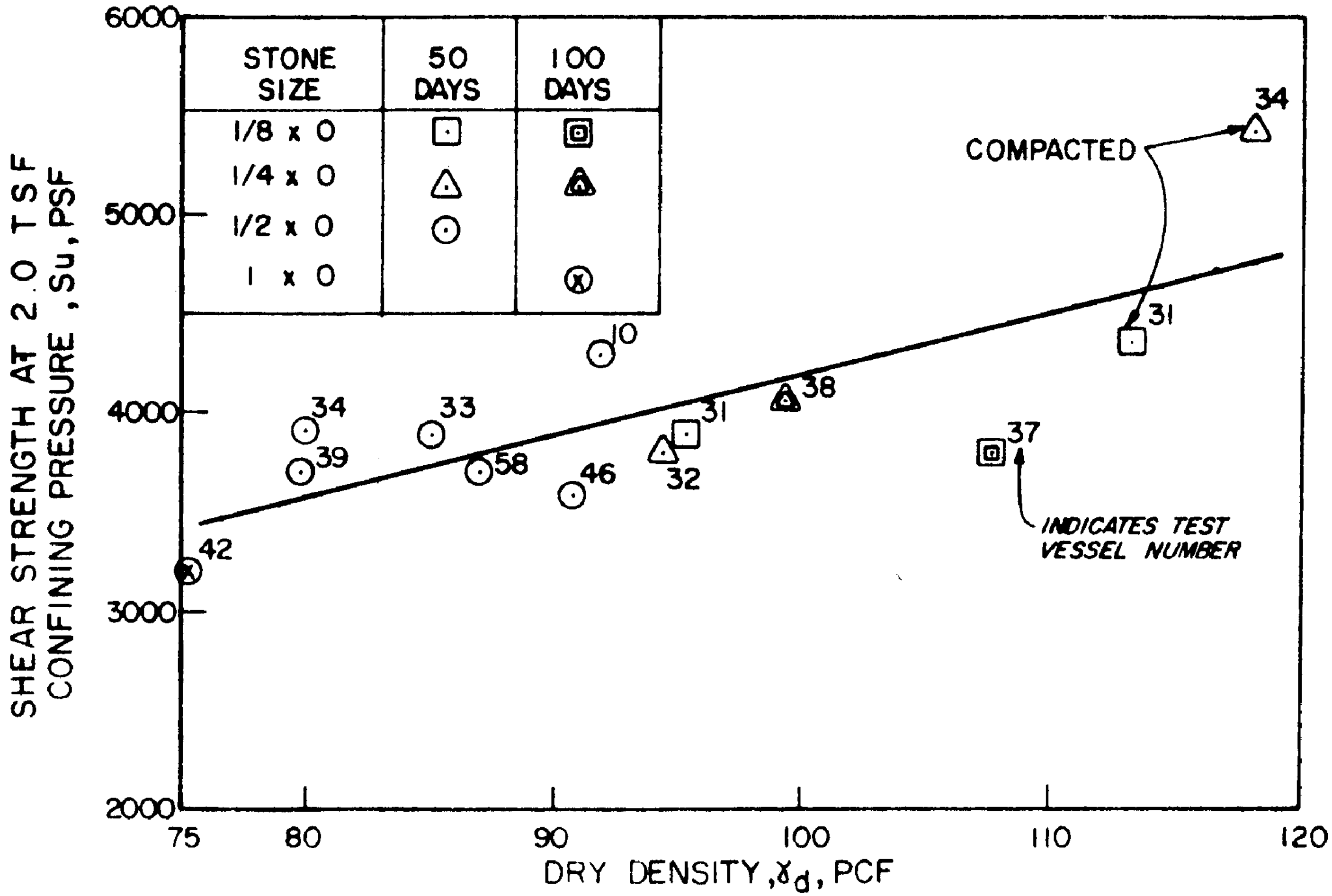
TYPICAL TRIAXIAL TEST STRENGTH DIAGRAM

FIGURE 30

TABLE 14

STRENGTH PARAMETERS AND SHEAR STRENGTH FOR A 2.0 TSF OVERPURDEN PRESSURE

Test Vessel	Stone Size	Type of Specimen	Average Dry Density γ_d, PCF	Average Axial Strain at Failure ϵ_1,%	Strength Parameters Cohesion C, PCF	Strength Parameters Friction Angle, ϕ	Shear[a] Strength Su, PSF
10	1/2 x 0	Undisturbed	9.17	15	1,600	35.5	4,300
58	1/2 x 0	Remolded	86.8	12	640	36.4	3,700
31	1/8 x 0	Undisturbed	95.1	18	950	35.3	3,900
31	1/8 x 0	Compacted	113.2	10	1,100	37.0	4,400
32	1/4 x 0	Undisturbed	94.2	19	700	35.3	3,800
34	1/2 x 0	Undisturbed	79.8	24	350	39.5	3,900
34	1/2 x 0	Compacted	118.0	6	2,700	37.0	5,400
39	1/2 x 0	Undisturbed	79.5	22	0	42.4	3,700
46	1/2 x 0	Undisturbed	90.5	23	0	41.5	3,600
33	1/2 x 50	Undisturbed	84.8	23	400	37.3	3,900
37	1/8 x 0	Undisturbed	107.7	18	0	43.8	3,800
38	1/4 x 0	Undisturbed	99.1	22	670	40.5	4,100
42*	1 x 0	Undisturbed	74.7	20	0	38.7	3,200



SHEAR STRENGTH VS. DENSITY

FIGURE 31

The investigation of the physical properties of limestones placed at low densities showed that they are not suitable for mine sealing. The low density produces a permeable limestone which is eroded by the mine water. Since the chemical reaction between the stone and mine water did not result in any cementation, the erosion left a very collapsible stone structure. The limestones subjected to mine water percolation were very compressible and had small shear strength.

Lab Cycle II

Lab Cycle I clearly indicated that the physical properties determining the suitability of a limestone as a mine plug, permeability, compressibility, and strength are a function of particle size distribution and density. Hence, Lab Cycle II was conducted to further investigate the effects of varying particle size distribution and placement density. In addition, additives which might aid in cementing the stone particles were investigated.

A total of twelve (12) specimens were tested in Lab Cycle II. Ten of these were subjected to ferric/ferrous test water, and two of these were tested with South Pittsburgh city water. Commercially available 3/8 to dust (called 3/8 x 0 size) grade of limestone No. 1809 was used to prepare all specimens.

Three additives were investigated. Portland cement, calcium sulfate hemihydrate (plaster of paris), and sodium silicate were blended with 3/8 x 0 stone in 5% concentrations. These three specimens were placed in test vessels at about 30% relative density. All three were tested on ferric/ferrous water.

Four specimens containing increased quantities of limestone fines were tested on ferric/ferrous water. Minus 50 mesh fines were obtained by screening 3/8" to dust stone. These fines were added to 3/8 x 0 stone in sufficient quantity to increase the fraction of material passing a No. 200 sieve by factors of 2 and 3. Each of these two materials was placed at both 30% and 60% relative density for a total of four specimens.

A "zoned" plug was also tested on ferric/ferrous water. The first foot of stone contained 5% ferric sulfate and 15% sodium silicate. This section was intended to be a water "pretreatment" area and was not considered to be part of the actual limestone plug. The remaining five feet of the specimen was 3/8 x 0 stone. The entire six foot long specimen was placed at about 30% relative density.

Four "blanks", 3/8 x 0 stone as received from the quarry, were tested. Two of these specimens were placed at about 30% and 60% relative density and tested on ferric/ferrous water. The other two were placed at about 0% and 30% relative density and tested on South Pittsburgh city water.

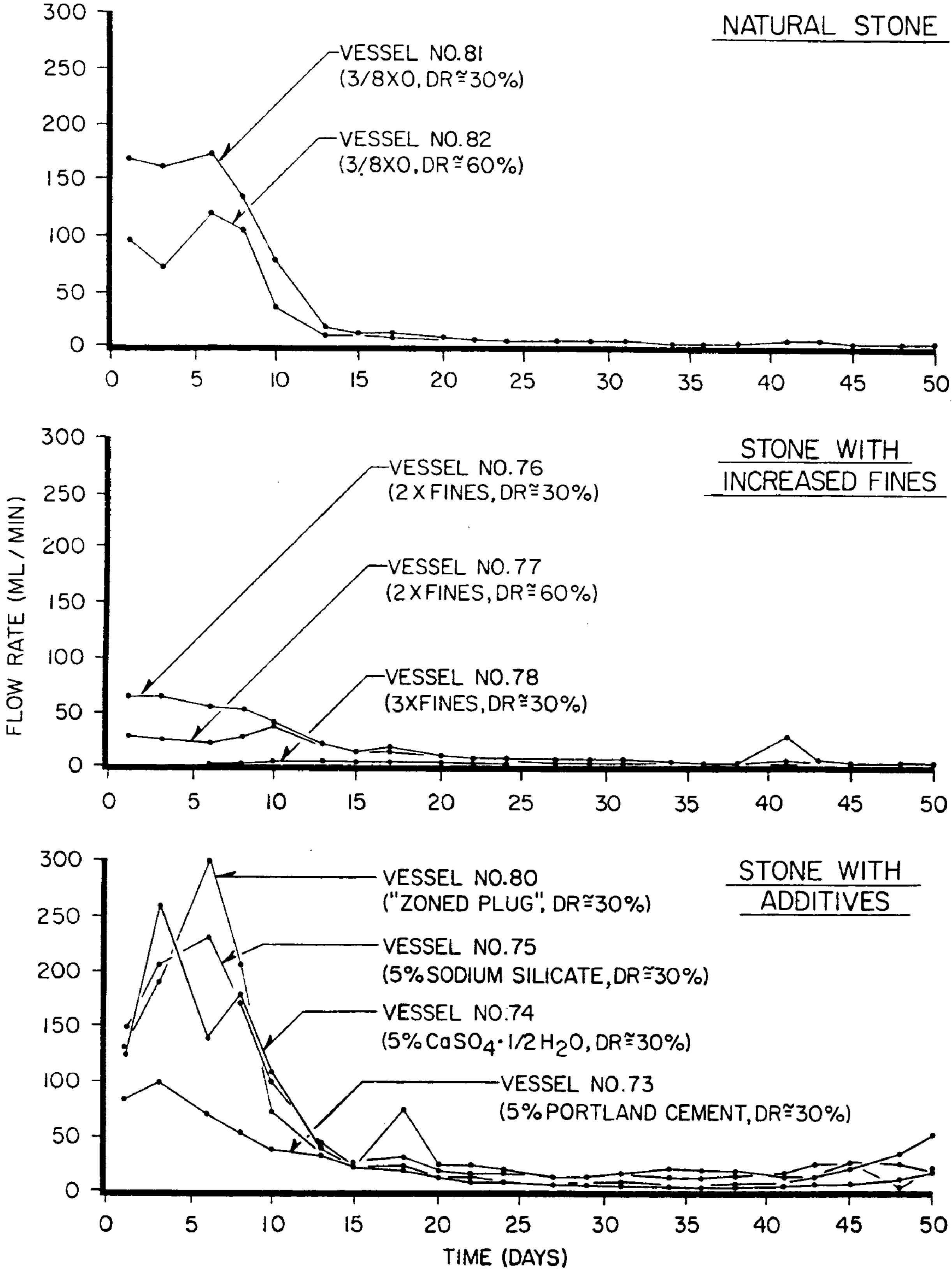
As in Lab Cycle I, the test vessels were assigned vessel numbers for identification purposes. A list of vessel numbers and specimen descriptions is presented in Table A81 in the Appendix.

Testing was performed in a manner similar to Lab Cycle I. Heads and flow rates were measured after 30 minutes, 3 hours, and 8 hours during the first day of testing. Effluent pH values were also recorded after 8 hours of testing. Beginning on the second day of testing (1 day after start-up) head, flow, pH, and specific conductance were recorded for each specimen on a Monday-Wednesday-Friday schedule. All specimens were tested for 50 days. Vessel effluent samples were collected after 1, 24 and 50 days of testing.

Flow and effluent composition data for the 12 specimens tested in Lab Cycle II are presented in Tables A82 through A93. These data show that all specimens tested on synthetic mine water effectively obstructed the flow of water and treated water which passed thorugh the stone. Flow and neutralization behaviors were generally more satisfactory than those observed in Lab Cycle I.

Flow histories for specimens tested on synthetic mine water are presented in Figure 32. Flow rates for Vessel No. 79 were always less than 0.5 ml/min, so this vessel's flow history was not included. The flow histories show that both increasing the placement density and increasing the fines content of the stone resulted in significantly lower flow rates. Increasing the fines content proved to be the most effective means of obstructing water flow.

Flow data for the two specimens tested on tap water also showed decreasing flow rates over the test period, indicating that physical effects are at least partly responsible for observed flow decreases. The flow magnitudes, however,



LAB CYCLE II - SPECIMEN FLOW HISTORIES

FIGURE 32

were much larger than for specimens tested on synthetic mine water. These data show a discontinuity at 10 days after start-up due to an air pressure failure. Although the two vessels operated without air pressure for only a few minutes, it is believed that the stones' grain structure was permanently affected.

Physical examinations, described in Lab Cycle I, were conducted on the ten test vessels from Lab Cycle II which were tested on ferric/ferrous water. A summary of the data is presented in Tables 15 to 23 and Figure 33 to 36 in the text, and details of particle size, compressibility and shear strength test data are given in the Appendix.

Discoloration of the limestones was observed for the entire length of the specimens containing additives, and the length of discoloration of the remaining stones was directly related to the quantity of fines and degree of compaction. The natural stone at DR = 30% (Vessel No. 81) showed the greatest discoloration while the stone with 3 x fines and placed at DR = 60% was discolored for only the first six inches from the influent end.

The surface measurement of the test specimens indicated some volume decrease in all test vessels. This data is included in Table 15. The following trends were observed:

1. Volume losses were largest for specimens with the highest fines content and smallest for specimens with the smallest fines content.

2. Higher placement densities resulted in lower volume losses.

3. Volume losses for specimens containing additives were comparable to losses for the corresponding natural stone.

These data indicate that stones must be placed at higher densities than DR = 60% to prevent excessive stone settlement. Furthermore, the degree of compaction must be increased with the percent of fines in the stone to compensate for the greater compressibility of fines.

The in-place densities, relative densities and porosities of trimmed cylindrical specimens from the test vessels are listed in Table 15. Evaluating the in-place densities

TABLE 15

VOLUME LOSS, DRY DENSITY AND POROSITY OF TRIMMED SPECIMENS
(AFTER 50 DAYS OF FERRIC-FERROUS MINE WATER PERCOLATION, 3/8 X 0 STONE, LAB CYCLE II)

Test Vessel	Material Description	Volume Loss, %	Dry Density			Porosity n, %
			γ_d, pcf	Avg γ_d, pcf	Dr[a], %	
81	Natural DR = 30	7	95.2 97.7 92.8	95.2	6 13 -2	42.4 41.0 43.9
82	Natural DR = 60	2	96.2 100.1 106.1	100.8	9 20 37	41.8 39.5 35.8
76	2 x Fines DR = 30	16	110.8 115.0 115.8	113.9	40 50 52	32.9 30.6 30.0
77	2 x Fines DR = 60	8	118.0 118.6 117.9	118.2	57 59 57	28.7 28.2 28.7
78	3 x Fines DR = 30	20	121.2 116.3 112.1	116.5	76 67 58	26.7 29.7 32.2
79	3 x Fines DR = 60	8	117.6 111.7 116.5	115.3	69 57 62	28.9 32.5 29.5
73	5% Cement DR = 30	3	99.0 86.5 97.0	94.2	17 -25 11	40.1 47.7 41.4
74	5% Calcium Sulfate Hemi-hydrate	7	88.2 103.7 106.0	99.3	-19 30 37	46.7 37.3 35.8
75	5% Sodium Silicate DR = 30	6	77.8 86.8 92.3	85.6	-63 -24 -5	52.9 47.5 44.3
80	Zoned DR = 30	8	90.4 95.7 100.8	97.7	-11 7 22	45.3 42.1 39.1

using relative density based on minimum and maximum densities (given in Table 16), the following observations can be made:

1. Relative densities smaller than the placement densities were measured in the natural stones in Vessels No. 81 and 82. A possible explanation for the low density could be the washing out of fines in the area of sampling.

2. Specimens from Vessel No. 77 and Vessel No. 78, where the stones were placed at DR = 30%, had average relative densities of 47 and 67 percent, respectively. This densification could have been caused by wetting of the stone combined with the confining pressure. This is supported by the large volume losses.

3. The negative relative densities in the stone with 5% sodium silicate indicate adverse chemical reaction leading to stone erosion.

TABLE 16

MINIMUM AND MAXIMUM DRY DENSITIES

Stone No.	Stone Size	Description	Minimum Dry[a] Density, PCF	Maximum Dry[b] Density, PCF
1809	3/8 x 0	Natural	94.6	139.0
1809	3/8 x 0	2 x Fines	98.6	141.6
1809	3/8 x 0	3 x Fines	90.7	138.0

[a]Minimum by ASTM Method, D-2049

[b]Maximum by Modified Proctor Test, ASTM Method, D-1577

Finally, the comparison of the minimum and maximum densities of the three stones indicates the stone with 2 x fines can be placed at higher densities than the other two stones, resulting in better physical properties.

The comparison of the particle size distribution of the stones before and after percolation testing indicates an increase of fines in all materials (Table 17). The increase of fines is probably the result of precipitate

TABLE 17

INCREASE IN FINES DUE TO
MINE WATER PERCOLATION

Test Vessel	Stone Size	Type of Water	Sample Description	Percent of Material Passing No. 200 Sieve	
				Before	After
Lab Cycle II - 50 Days Percolation - Stone No. 1809					
81	3/8 x 0	F/F	Natural DR = 30	6.9	8.7
82	3/8 x 0	F/F	DR = 60	6.9	8.6
76	3/8 x 0	F/F	2xFines DR = 30	11.6	14.1
77	3/8 x 0	F/F	DR = 60	11.6	16.5
78	3/8 x 0	F/F	3xFines DR = 30	21.1	24.9
79	3/8 x 0	F/F	DR = 60	21.1	25.6

F/F = Ferric - Ferrous

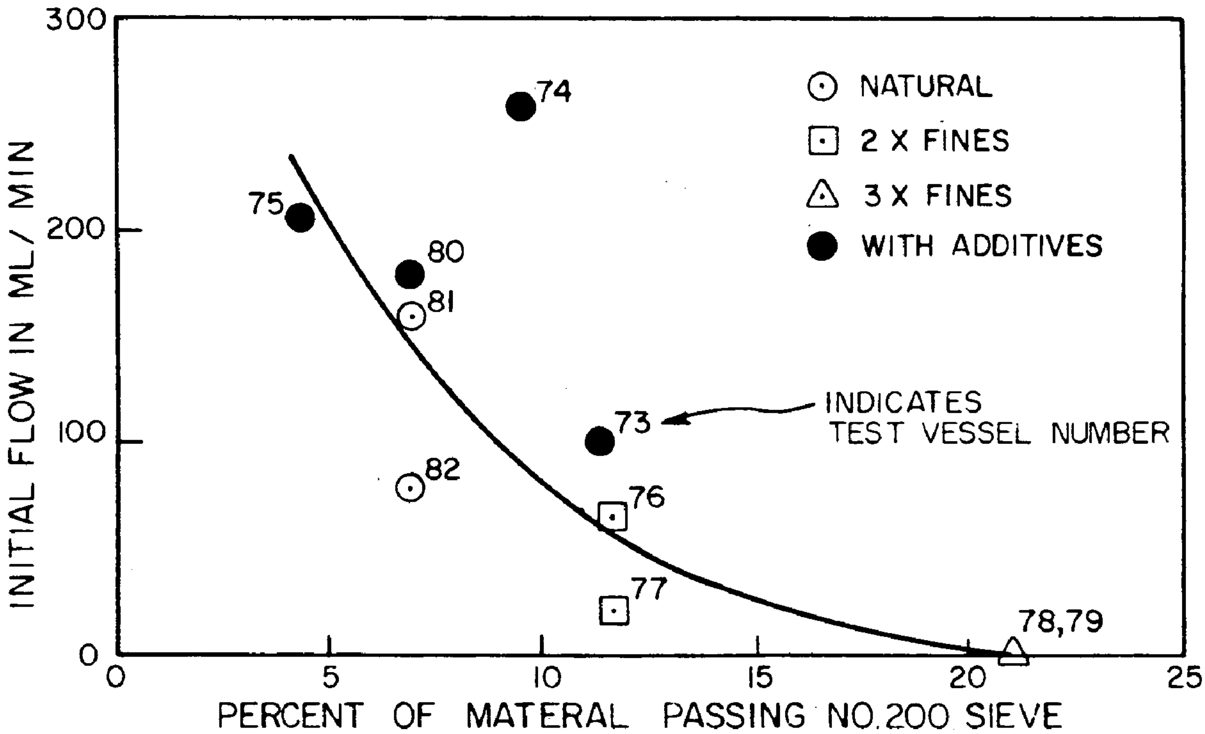
DR = Relative Density in Percent

accumulation. It can be concluded that the decrease of flow experienced in all vessels was at least partially due to precipitates plugging the stone voids.

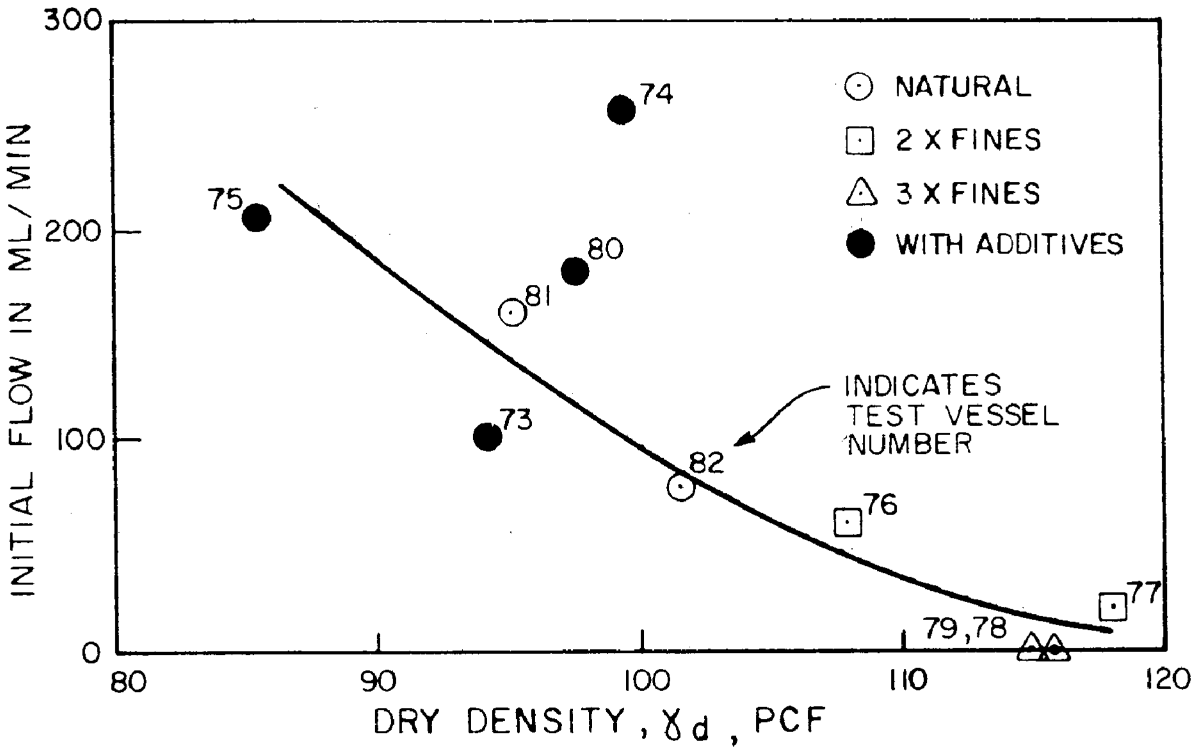
The initial flow of the synthetic mine water through the vessels was found to be related to the percent of fines and density of the stones. To illustrate this, the initial flow after three days of percolation has been plotted against percent of material passing the No. 200 sieve in Figure 33 and density in Figure 34.

Triaxial tests were conducted on trimmed cylindrical specimens on all test vessel materials. The compression test results are shown in Table 18 and Figure 35, and shear strength in Table 19 and Figure 36.

These results illustrate that the compressibility and shear strength are independent of the particle size distribution in the mixes tested and are directly related in the material density. The good agreement of the behavior of the specimens from materials with additives with the natural stones indicates that the additives did not increase the stiffness of the material nor increase its shear strength.



LAB CYCLE II SPECIMENS
INITIAL FLOW VS. FINES CONTENT
FIGURE 33

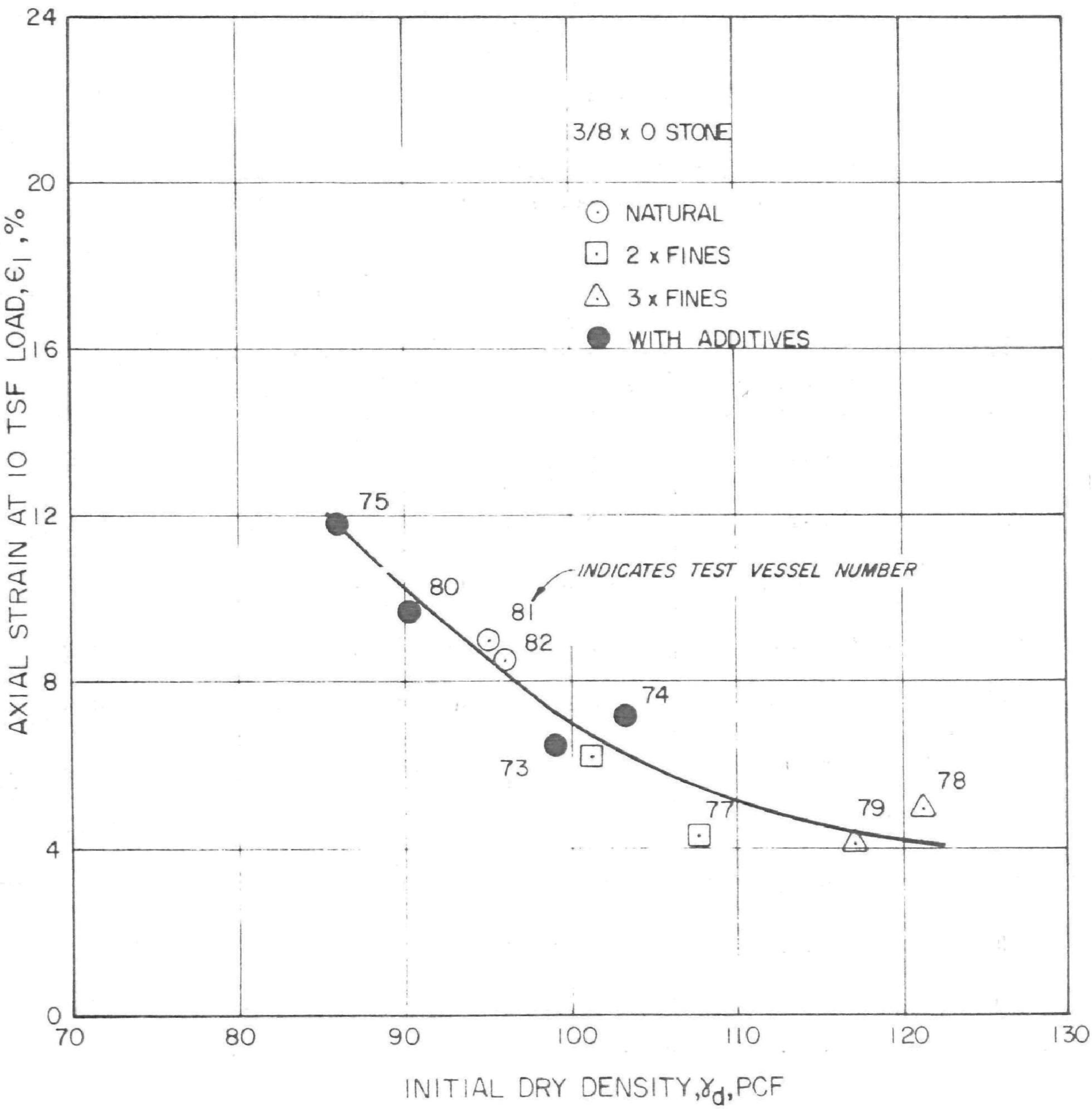


LAB CYCLE II SPECIMENS
INITIAL FLOW VS. DENSITY
FIGURE 34

TABLE 18

SUMMARY OF COMPRESSION TEST RESULTS, LAB CYCLE II
(3/8 x 0 Stone, Trimmed Undisturbed Specimens)

Test Vessel	Material Description	Dry Density, γ_d, pcf		Axial Strain @ 10 tsf Load, ε_1, %	$k_o = \sigma_3/\sigma_1$
		Initial	Final		
81	Natural	95.2	106.5	9.0	0.43
82	Natural	96.2	107.7	8.6	0.43
76	2 x Fines	110.8	119.8	6.2	0.43
77	2 x Fines	118.0	124.5	4.3	0.35
78	3 x Fines	121.2	128.7	4.9	0.42
79	3 x Fines	117.6	123.6	4.1	0.42
73	5% Cement	99.0	108.4	6.5	0.41
74	5% $CaSO_4$	103.7	114.6	7.2	0.37
75	5% $NaSiO_2$	86.8	100.6	11.8	0.45
80	Zoned	90.4	102.2	9.6	0.40



LAB CYCLE II SPECIMENS
COMPRESSIBILITY VS. DENSITY

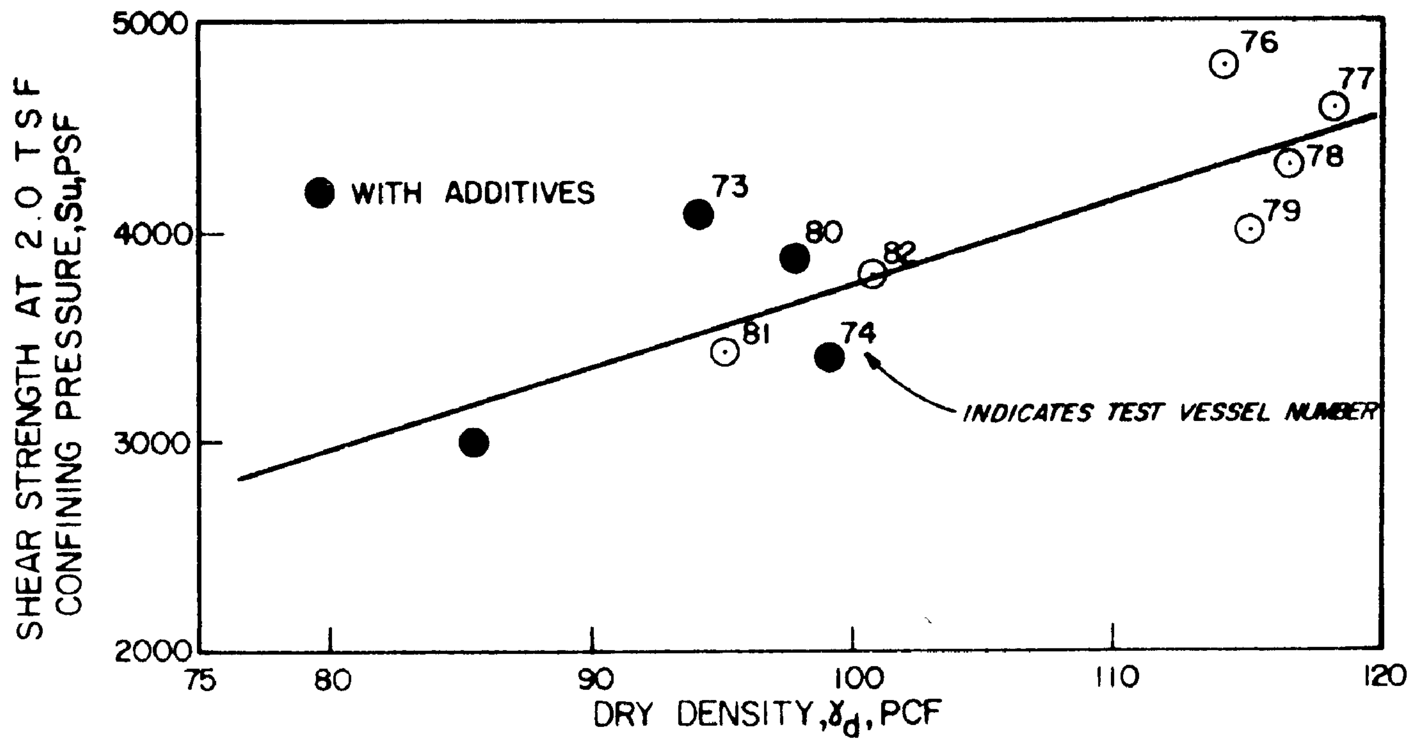
FIGURE 35

TABLE 19

STRENGTH PARAMETERS AND SHEAR STRENGTH FOR
A 2.0 TSF OVERBURDEN PRESSURE, 3/8 x 0 STONE, LAB CYCLE II

Test Vessel	Material Description	Average Dry Density γ_d, pcf	Average Axial Strain at Failure ε_1,%	Strength Parameters		Shear[a] Strength Su, psf
				Cohesion C, pcf	Friction Angle, ϕ	
81	Natural	95.2	16	750	34.6	3,400
82	Natural	100.8	15	750	37.8	3,800
76	2 x Fines	113.9	12	1,500	39.6	4,800
77	2 x Fines	118.2	11	1,000	42.4	4,600
78	3 x Fines	116.5	16	560	43.4	4,300
79	3 x Fines	115.3	8	600	40.5	4,000
73	5% Cement	94.2		900	38.8	4,100
74	5% Ca	99.3	13	0	40.5	3,400
75	5% $NaSO_2$	85.6	18	360	33.2	3,000
80.	Zoned	97.7	15	650	38.3	3,800

[a] Shear strength at a confining pressure of 2.0 tsf.



LAB CYCLE II SPECIMENS
SHEAR STRENGTH VS. DENSITY
FIGURE 36

SECTION VII

ACKNOWLEDGEMENTS

The support of the project by the Office of Research and Monitoring of the Environmental Protection Agency and the help provided by Dr. James M. Shackelford, the Project Officer, and Mr. Ernst P. Hall, Chief of the Pollution Control Analysis Branch, is acknowledged with sincere thanks.

Messrs. Martin Wielesky and Ed Wielesky of the Winfield Lime and Stone Company, Mr. Hutchinson of the Elkins Limestone Company, and Mr. Garn of the Mineral Pigments and Metals Company provided valuable technical support during the investigative portion of this study.

The principal investigators of this study were Mr. R. G. Penrose, Jr., of the Cyrus Wm. Rice Division - NUS Corporation and Mr. I. Holubec of E. D'Appolonia Consulting Engineers, Inc.

REFERENCES

1. Halliburton Company, "New Mine Sealing Techniques for Water Pollution Abatement", FWPCA Publication No. 14010 DMO.

2. Bituminous Coal Research, Inc., "Studies in Limestone Treatment of Acid Mine Drainage", FWQA Publication No. 14010 EIZ 01/70.

APPENDIX A

TABLE A1

SPECIMENS TESTED ON FERRIC WATER

VESSEL NO.	DESCRIPTION
1	Stone #1809, 1/2 x 0 size containing 10% slag
2	Stone #1809, 1 x 0 size containing 10% slag
3	Stone #1809, 1/2 x 0 size containing 5% bentonite
4	Stone #1809, 1 x 0 size containing 5% bentonite
5	Stone #1809, 1/2 x 0 size containing 10% flyash
6	Stone #1809, 1 x 0 size containing 10% flyash
7	Stone #1809, 1/8 x 0 size
8	Stone #1809, 1/4 x 0 size
9	Stone #1809, 1/2 x 50 m size
10	Stone #1809, 1/2 x 0 size
11	Stone #1809, 1 x 50 m size
12	Stone #1809, 1 x 0 size
13	Stone #1355, 1/8 x 0 size
14	Stone #1355, 1/4 x 0 size
15	Stone #1355, 1/2 x 50 m size
16	Stone #1355, 1/2 x 0 size
17	Stone #1355, 1 x 50 m size
18	Stone #1355, 1 x 0 size
19	Stone #1337, 1/8 x 0 size
20	Stone #1337, 1/4 x 0 size
21	Stone #1337, 1/2 x 0 size
22	Stone #1337, 1/2 x 50 m size
23	Stone #1337, 1 x 50 m size
24	Stone #1337, 1 x 0 size

TABLE A2

SPECIMENS TESTED ON FERRIC/FERROUS WATER

VESSEL NO.	DESCRIPTION
25	Stone #1809, 1/2 x 0 size containing 10% slag
26	Stone #1809, 1 x 0 size containing 10% slag
27	Stone #1809, 1/2 x 0 size containing 5% bentonite
28	Stone #1809, 1 x 0 size containing 5% bentonite
29	Stone #1809, 1/2 x 0 size containing 10% flyash
30	Stone #1809, 1 x 0 size containing 10% flyash
31	Stone #1809, 1/8 x 0 size
32	Stone #1809, 1/4 x 0 size
33	Stone #1809, 1/2 x 50 m size
34	Stone #1809, 1/2 x 0 size
35	Stone #1809, 1 x 50 m size
36	Stone #1809, 1 x 0 size
37	Stone #1355, 1/8 x 0 size
38	Stone #1355, 1/4 x 0 size
39	Stone #1355, 1/2 x 0 size
40	Stone #1355, 1/2 x 50 m size
41	Stone #1355, 1 x 50 m size
42	Stone #1355, 1 x 0 size
43	Stone #1337, 1/8 x 0 size
44	Stone #1337, 1/4 x 0 size
45	Stone #1337, 1/2 x 50 m size
46	Stone #1337, 1/2 x 0 size
47	Stone #1337, 1 x 50 m size
48	Stone #1337, 1 x 0 size

TABLE A3

SPECIMENS TESTED ON FERROUS WATER

VESSEL NO.	DESCRIPTION
49	Stone #1809, 1/2 x 0 size containing 10% slag
50	Stone #1809, 1 x 0 size containing 10% slag
51	Stone #1809, 1/2 x 0 size containing 5% bentonite
52	Stone #1809, 1 x 0 size containing 5% bentonite
53	Stone #1809, 1/2 x 0 size containing 10% flyash
54	Stone #1809, 1 x 0 size containing 10% flyash
55	Stone #1809, 1/8 x 0 size
56	Stone #1809, 1/4 x 0 size
57	Stone #1809, 1/2 x 50 m size
58	Stone #1809, 1/2 x 0 size
59	Stone #1809, 1 x 50 m size
60	Stone #1809, 1 x 0 size
61	Stone #1355, 1/8 x 0 size
62	Stone #1355, 1/4 x 0 size
63	Stone #1355, 1/2 x 50 m size
64	Stone #1355, 1/2 x 0 size
65	Stone #1355, 1 x 50 m size
66	Stone #1355, 1 x 0 size
67	Stone #1337, 1/8 x 0 size
68	Stone #1337, 1/4 x 0 size
69	Stone #1337, 1/2 x 50 m size
70	Stone #1337, 1/2 x 0 size
71	Stone #1337, 1 x 50 m size
72	Stone #1337, 1 x 0 size

TABLE A4

INITIAL PARTICLE SIZE DISTRIBUTIONS
MATERIAL NO. 1809

(Percent of Material Smaller by Weight)

Sieve Size	Stone Size					
	1 x 0	1 x 50	1/2 x 0	1/2 x 50	1/4 x 0	1/8 x 0
1 1/2	100.0	100.0	---	---	---	---
3/4	94.0	96.2	100.0	100.0	---	---
3/8	61.7	67.5	84.0	79.8	100.0	---
4	33.9	39.2	42.5	40.1	88.3	100.0
8	19.6	21.5	24.9	22.0	58.1	65.9
16	10.4	9.7	14.2	10.1	34.2	33.3
30	5.5	3.5	8.1	3.6	19.5	16.6
50	3.1	0.5	4.8	0.4	10.9	9.0
100	1.8	0.2	2.9	0.1	6.1	5.5
200	1.2	0.1	1.9	0.1	3.9	3.9

Sieve Size	Stone Size					
	Flyash Added		Slag Added		Bentonite Added	
	1 x 0	1/2 x 0	1 x 0	1/2 x 0	1 x 0	1/2 x 0
1 1/2	100.0	---	100.0	---	100.0	---
3/4	97.1	100.0	95.8	100.0	93.0	100.0
3/8	69.5	83.3	60.8	78.4	65.3	82.6
4	44.6	51.3	35.0	40.3	40.5	43.9
8	30.3	33.8	21.5	25.3	26.3	25.7
16	20.4	21.8	12.5	15.2	16.6	15.0
30	14.2	14.7	7.0	9.1	11.4	9.6
50	10.8	10.9	3.9	5.6	8.7	6.9
100	8.9	8.9	2.3	3.5	6.9	5.2
200	7.5	7.4	1.4	2.3	5.2	4.0

TABLE A5

INITIAL PARTICLE SIZE DISTRIBUTIONS
MATERIAL NO. 1355

(Percent of Material Smaller by Weight)

Sieve Size	Stone Size					
	1 x 0	1 x 50	1/2 x 0	1/2 x 50	1/4 x 0	1/8 x 0
1 1/2	100.0	100.0	---	---	---	---
3/4	87.6	88.6	100.0	100.0	---	---
3/8	65.6	67.3	90.0	91.6	100.0	---
4	35.5	35.5	47.8	43.5	77.6	100.0
8	20.4	18.8	25.5	21.5	42.0	84.5
16	11.8	10.0	13.8	9.7	23.8	51.6
30	6.6	5.2	7.5	4.0	15.4	32.6
50	4.0	2.2	4.5	0.9	10.6	20.5
100	2.7	1.6	3.0	0.5	7.7	13.1
200	1.9	1.3	2.1	0.4	5.6	8.5

TABLE A6

INITIAL PARTICLE SIZE DISTRIBUTIONS
MATERIAL NO. 1377

(Percent of Material Smaller by Weight)

Sieve Size	Stone Size					
	1 x 0	1 x 50	1/2 x 0	1/2 x 50	1/4 x 0	1/8 x 0
1 1/2	100.0	100.0	---	---	---	---
3/4	87.9	82.4	100.0	100.0	---	---
3/8	73.2	60.7	91.5	90.4	100.0	---
4	43.8	28.1	53.1	42.5	79.8	100.0
8	27.6	13.7	34.5	21.0	46.2	85.1
16	19.9	6.9	25.5	11.8	32.6	58.8
30	16.1	3.9	20.9	7.2	25.7	45.6
50	13.6	2.0	17.5	4.1	21.3	36.4
100	10.7	1.5	13.7	3.1	16.7	26.9
200	6.9	1.2	8.8	2.6	10.8	16.1

TABLE A7

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 1
(STONE #1809, 1/2 x 0 SIZE CONTAINING 10% SLAG)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	875.	3.2	1800	7.6	126.	265.	1002.	234.
2	72.0	680.	3.5	1750					
3	72.0	610.	3.2	1900					
4	72.0	600.	3.1	1750					
5	72.0	570.	3.0	1600					
6	72.0	500.	3.4	1800					
7	72.0	315.	3.2	1700	5.6	74.4	230.	978.	605.
8	72.0	240.	3.2	1650					
9	72.0	220.	3.0	1800					
10	72.0	214.	3.1	1650					
11	72.0	200.	3.2	1850					
12	72.0	200.	3.1	1750					
13	72.0	230.	3.1	1850					
14	72.0	200.	3.1	1900	9.0	125.	205.	1057.	400.
15	72.0	180.	2.9	1650					
16	72.0	176.	3.1	1800					
17	72.0	177.	3.0	1750					
18	72.0	180.	3.0	1550					
19	72.0	190.	2.8	1950					
20	72.0	180.	3.0	2250					
21	72.0	180.	3.0	1900	6.8	146.	213.	1128.	485.
22	72.0	190.	3.1	1900					
23	72.0	190.	3.2	2000					
24	72.0	180.	3.0	2000					
25	72.0	155.	3.2	1850					
26	72.0	186.	2.7	2150					
27	72.0	176.	3.1	1850					
28	72.0	180.	3.1	1350	8.5	146.	183.	1062.	479.
29	72.0	175.	3.0	1850					
30	72.0	172.	2.7	2350					
31	72.0	164.	2.6	2600					
32	72.0	164.	3.3	1750					
33	72.0	144.	2.9	1750					
34	72.0	132.	2.9	2000					
35	72.0	112.	3.0	2100	11.0	139.	270.	1220.	495.
36	72.0	150.	2.8	2150					
37	72.0	114.	3.0	2100					
38	72.0	100.	3.0	2050					
39	72.0	100.	2.9	2000					
40	72.0	90.	3.1	2100					
41	72.0	92.	3.1	2050					
42	72.0	84.	3.0	2100	7.0	118.	265.	1234.	460.
43	72.0	88.	3.1	2050					
44	72.0	90.	3.4	1800					
45	72.0	80.	3.5	1950					
46	72.0	84.	2.9	2100					
47	72.0	80.	2.9	1900					
48	72.0	84.	2.8	1950					
49	72.0	76.	2.5	2150	9.0	122.	223.	1236.	541.
50	72.0	80.	2.4	2100					
51	72.0	60.	2.6	2300					
52	72.0	70.	2.7	2250					
53	72.0	54.	3.2	2400					

*Start-up date was 3/16/72.

TABLE A8

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 2
(STONE #1809, 1 x 0 SIZE CONTAINING 10% SLAG)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	240.	3.0	1800	8.0	146.	177.	989.	511.
2	72.0	2220.	3.0	1600					
3	72.0	2080.	2.8	1850					
4	72.0	1920.	2.9	1750					
5	72.0	1900.	2.7	1750					
6	72.0	1640.	3.2	1550					
7	72.0	1560.	3.1	1650	8.0	158.	117.	978.	547.
8	72.0	1340.	3.0	1700					
9	72.0	1300.	2.9	1650					
10	72.0	1300.	2.8	1700					
11	72.0	1250.	2.9	1800					
12	72.0	1240.	2.7	2050					
13	72.0	1320.	2.8	1850					
14	72.0	1260.	2.8	2050	10.0	185.	103.	1093.	710.
15	72.0	1260.	2.9	1800					
16	72.0	1260.	2.9	1800					
17	72.0	1230.	2.7	1950					
18	72.0	1230.	2.5	1750					
19	72.0	1230.	2.9	2550					
20	72.0	1260.	3.9	2650					
21	72.0	1280.	2.8	1900	9.6	167.	105.	1117.	760.
22	72.0	1230.	2.8	2200					
23	72.0	1230.	2.9	2150					
24	72.0	1200.	2.7	2300					
25	72.0	1190.	3.0	1900					
26	72.0	1200.	2.4	2600					
27	72.0	1160.	3.2	1750					
28	72.0	1120.	2.9	2100	11.5	169.	98.	1092.	772.
29	72.0	1096.	2.7	2200					
30	72.0	1080.	2.2	2600					
31	72.0	1080.	2.5	2950					
32	72.0	920.	3.1	1750					
33	72.0	552.	2.7	1750					
34	72.0	450.	6.7	2100					
35	72.0	450.	2.6	2550	8.0	179.	145.	1253.	764.
36	72.0	400.	2.5	2500					
37	72.0	400.	2.6	2400					
38	72.0	380.	2.5	2450					
39	72.0	190.	2.5	2300					
40	72.0	370.	2.7	2250					
41	72.0	360.	2.8	2250					
42	72.0	352.	2.7	2300	10.0	182.	135.	1229.	820.
43	72.0	340.	2.5	2650					
44	72.0	330.	2.9	2250					
45	72.0	330.	3.0	2450					
46	72.0	344.	2.5	2550					
47	72.0	328.	2.6	2250					
48	72.0	328.	2.4	2550					
49	72.0	320.	2.2	2800	9.0	170.	107.	1241.	791.
50	72.0	320.	2.1	2050					
51	72.0	320.	2.2	2900					
52	72.0	320.	2.3	2800					
53	72.0	348.	2.6	3250					

*Start-up date was 3/16/72.

TABLE A9

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 3
(STONE #1809, 1/2 x 0 SIZE CONTAINING 5% BENTONITE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (µmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	25.	5.7	2000	< 1.0	33.9	335.	1078.	10.8
2	72.0	25.	5.7	1800					
3	72.0	13.	5.7	2100					
4	72.0	10.	5.5	2000					
5	72.0	20.	5.2	1800					
6	72.0	25.	5.2	1750					
7	72.0	20.	5.3	1850	< 1.0	34.9	346.	990.	18.0
8	72.0	20.	5.7	1950					
9	72.0	18.	5.8	1850					
10	72.0	12.	5.5	1650					
11	72.0	25.	6.4	1900					
12	72.0	10.	6.2	2000					
13	72.0	25.	6.3	1950					
14	72.0	25.	5.9	2050	< 1.0	0.84	426.	1075.	69.0
15	72.0	9.	6.7	2000					
16	72.0	5.	6.7	2100					
17	72.0	7.	6.3	1950					
18	72.0	10.	6.2	1800					
19	72.0	12.	6.2	2100					
20	72.0	12.	6.9	2200					
21	72.0	12.	6.7	2000	< 1.0	1.2	463.	1070.	83.0
22	72.0	15.	6.4	2100					
23	72.0	10.	6.5	2050					
24	72.0	10.	6.5	2050					
25	72.0	15.	6.3	2050					
26	72.0	10.	6.7	2150					
27	72.0	10.	6.7	2050					
28	72.0	10.	7.0	2000	< 1.0	0.84	446.	964.	< 4.0
29	72.0	8.	6.7	2050					
30	72.0	10.	6.3	2150					
31	72.0	10.	6.3	2100					
32	72.0	10.	5.7	2050					
33	72.0	10.	6.2	1850					
34	72.0	10.	6.4	1950					
35	72.0	10.	6.0	2100	< 1.0	0.57	495.	1167.	< 4.0
36	72.0	10.	6.6	2200					
37	72.0	8.	6.1	2200					
38	72.0	12.	6.6	2100					
39	72.0	10.	6.6	2100					
40	72.0	5.	6.0	2200					
41	72.0	8.	6.5	2200					
42	72.0	8.	7.3	1600	< 1.0	0.23	598.	1197.	< 4.0
43	72.0	7.	6.4	2200					
44	72.0	6.	6.1	2200					
45	72.0	7.	6.5	2100					
46	72.0	8.	6.6	2150					
47	72.0	4.	5.9	2050					
48	72.0	3.	6.4	2050					
49	72.0	3.	7.2	2150	< 1.0	0.14	466.	1155.	23.0
50	72.0	16.	6.9	2150					
51	72.0	6.	6.1	2100					
52	72.0	7.	6.3	2150					
53	72.0	4.	6.6	2150					

*Start-up date was 3/16/72.

TABLE A10

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 4
(STONE #1809, 1 x 0 SIZE CONTAINING 5% BENTONITE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	150.	3.3	1750	7.2	93.3	245.	1028.	10.8
2	72.0	75.	3.6	1700					
3	72.0	46.	3.7	1750					
4	72.0	15.	6.1	2000					
5	72.0	10.	5.7	1900					
6	72.0	14.	5.8	2100					
7	72.0	13.	5.8	1700	1.3	25.4	300.	1020.	7.2
8	72.0	15.	6.2	1700					
9	72.0	10.	6.2	1850					
10	72.0	18.	5.9	1650					
11	72.0	20.	5.1	1700					
12	72.0	7.	5.2	1800					
13	72.0	20.	3.7	1750					
14	72.0	20.	5.0	1850	3.0	54.4	298.	1117.	65.0
15	72.0	3.	6.6	1750					
16	72.0	65.	6.6	1850					
17	72.0	8.	6.4	1750					
18	72.0	20.	6.7	1750					
19	72.0	14.	6.6	1900					
20	72.0	6.	6.6	2150					
21	72.0	14.	7.1	1900	< 1.0	25.5	400.	1100.	22.0
22	72.0	20.	7.0	1950					
23	72.0	10.	6.4	1850					
24	72.0	20.	6.8	1850					
25	72.0	20.	6.7	1800					
26	72.0	14.	6.2	1850					
27	72.0	12.	6.2	1850					
28	72.0	10.	6.6	1750	2.0	48.4	354.	1033.	< 4.0
29	72.0	10.	5.7	1750					
30	72.0	10.	4.4	1850					
31	72.0	10.	3.9	1900					
32	72.0	10.	6.6	1750					
33	72.0	16.	6.2	1550					
34	72.0	16.	6.5	1750					
35	72.0	12.	5.7	1900	2.0	47.4	420.	1231.	31.9
36	72.0	10.	5.9	1950					
37	72.0	7.	6.0	1900					
38	72.0	10.	4.9	1800					
39	72.0	13.	5.8	1750					
40	72.0	8.	5.8	1800					
41	72.0	12.	6.4	1900					
42	72.0	12.	6.3	1900	1.7	47.9	400.	1168.	26.0
43	72.0	12.	6.3	1900					
44	72.0	11.	6.6	1800					
45	72.0	10.	7.0	1800					
46	72.0	8.	3.3	2000					
47	72.0	4.	3.1	2000					
48	72.0	3.	3.0	2100					
49	72.0	3.	2.7	2150	1.0	91.4	293.	1309.	300.
50	72.0	8.	2.7	2000					
51	72.0	5.	3.0	2000					
52	72.0	4.	3.0	2050					
53	72.0	4.	3.7	2150					

*Start-up date was 3/16/72.

TABLE A11

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 5
(STONE #1809, 1/2 x 0 SIZE CONTAINING 10% FLYASH)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	125.	6.5	1800	10.0	0.16	492.	982.	<4.0
2	72.0	75.	6.8	1850					
3	72.0	69.	5.8	2000					
4	72.0	50.	6.3	1950					
5	72.0	50.	5.4	1850					
6	72.0	65.	6.3	2150					
7	72.0	88.	6.0	1800	< 1.0	1.4	415.	919.	104.
8	72.0	50.	6.2	1900					
9	72.0	56.	6.3	1850					
10	72.0	40.	6.6	1900					
11	72.0	50.	6.8	1950					
12	72.0	28.	6.2	2050					
13	72.0	40.	6.5	1950					
14	72.0	45.	6.2	2050	< 1.0	0.06	480.	1055.	69.0
15	72.0	31.	6.8	2050					
16	72.0	28.	6.7	2000					
17	72.0	29.	6.7	2000					
18	72.0	35.	6.7	1800					
19	72.0	30.	6.8	2150					
20	72.0	28.	6.8	2300					
21	72.0	30.	7.0	2050	< 1.0	0.06	505.	1101.	85.0
22	72.0	30.	7.0	2100					
23	72.0	30.	6.9	2100					
24	72.0	30.	6.9	2050					
25	72.0	25.	6.7	2100					
26	72.0	24.	6.8	2100					
27	72.0	28.	7.1	2000					
28	72.0	20.	7.2	2100	< 1.0	<0.03	476.	1042.	19.2
29	72.0	17.	7.1	2050					
30	72.0	20.	6.4	2200					
31	72.0	20.	6.6	2200					
32	72.0	20.	7.1	2150					
33	72.0	20.	6.7	1850					
34	72.0	20.	7.0	2000					
35	72.0	16.	6.6	2200	< 1.0	<0.03	538.	1186.	217.
36	72.0	50.	6.7	2200					
37	72.0	14.	6.6	2200					
38	72.0	28.	6.7	2150					
39	72.0	28.	6.8	2100					
40	72.0	15.	6.2	2150					
41	72.0	20.	6.8	2100					
42	72.0	20.	7.0	2150	< 1.0	0.05	612.	1133.	<4.0
43	72.0	24.	6.8	2150					
44	72.0	21.	6.7	2050					
45	72.0	22.	6.8	2100					
46	72.0	24.	6.5	2150					
47	72.0	17.	5.6	2050					
48	72.0	16.	6.2	2100					
49	72.0	16.	6.1	2100	< 1.0	0.03	506.	1155.	15.4
50	72.0	20.	6.4	2150					
51	72.0	45.	5.9	2300					
52	72.0	14.	6.2	2150					
53	72.0	14.	6.5	2250					

*Start-up date was 3/16/72.

TABLE A12

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 6
(STONE #1809, 1 x 0 SIZE CONTAINING 10% FLYASH)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	75.	6.8	2050	< 1.0	<0.03	480.	1072.	< 4.0
2	72.0	60.	6.5	1900					
3	72.0	35.	6.3	2000					
4	72.0	25.	6.5	1900					
5	72.0	30.	6.3	1850					
6	72.0	47.	6.5	2050					
7	72.0	162.	6.3	1650	< 1.0	19.0	395.	918.	7.2
8	72.0	95.	6.6	1750					
9	72.0	60.	6.7	1800					
10	72.0	56.	6.7	1800					
11	72.0	60.	6.8	1800					
12	72.0	42.	6.7	2000					
13	72.0	50.	6.7	1900					
14	72.0	50.	6.4	2100	< 1.0	0.75	467.	1100.	16.0
15	72.0	27.	6.7	2000					
16	72.0	26.	6.6	2050					
17	72.0	30.	6.9	1900					
18	72.0	30.	7.0	1750					
19	72.0	24.	7.2	2200					
20	72.0	20.	7.1	1850					
21	72.0	24.	7.2	2100	< 1.0	<0.03	500.	1147.	36.0
22	72.0	25.	7.2	2100					
23	72.0	30.	7.3	2100					
24	72.0	20.	7.3	2050					
25	72.0	45.	6.9	2100					
26	72.0	28.	7.1	2050					
27	72.0	24.	7.1	2000					
28	72.0	18.	7.2	2100	< 1.0	0.05	532.	1069.	27.0
29	72.0	13.	6.8	2100					
30	72.0	16.	6.9	2250					
31	72.0	16.	7.1	2300					
32	72.0	16.	7.3	2250					
33	72.0	18.	7.1	1950					
34	72.0	20.	7.2	2000					
35	72.0	14.	6.9	2150	< 1.0	<0.03	538.	1166.	81.4
36	72.0	15.	7.0	2200					
37	72.0	12.	7.0	2250					
38	72.0	18.	7.0	2150					
39	72.0	18.	7.0	2150					
40	72.0	12.	6.7	2250					
41	72.0	14.	7.0	2150					
42	72.0	16.	7.0	2150	< 1.0	0.05	606.	1174.	< 4.0
43	72.0	16.	7.0	2200					
44	72.0	16.	7.1	2100					
45	72.0	16.	7.3	2100					
46	72.0	16.	6.7	2200					
47	72.0	12.	6.0	2150					
48	72.0	12.	6.6	2100					
49	72.0	10.	6.4	2100	< 1.0	<0.03	499.	1162.	76.8
50	72.0	16.	6.5	2150					
51	72.0	13.	6.7	2250					
52	72.0	15.	6.6	2200					
53	72.0	10.	6.8	2200					

*Start-up date was 3/16/72.

TABLE A13

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 7
(STONE #1809, 1/8 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	175.	6.2	1700	< 1.0	0.03	479.	1013.	<4.0
2	72.0	125.	6.4	1900					
3	72.0	98.	6.5	2000					
4	72.0	100.	6.5	1850					
5	72.0	100.	6.7	1800					
6	72.0	79.	6.6	2250					
7	72.0	70.	6.4	1750	< 1.0	0.03	412.	939.	<4.0
8	72.0	40.	6.6	1850					
9	72.0	42.	6.8	1850					
10	72.0	25.	7.0	1850					
11	72.0	25.	7.0	1950					
12	72.0	26.	6.9	2000					
13	72.0	25.	6.9	1950					
14	72.0	35.	6.7	2100	< 1.0	0.03	471.	1056.	47.0
15	72.0	21.	6.6	2000					
16	72.0	19.	6.3	2050					
17	72.0	18.	7.0	1900					
18	72.0	30.	7.1	1800					
19	72.0	22.	7.3	2150					
20	72.0	20.	7.2	1650					
21	72.0	26.	7.4	2250	< 1.0	<0.03	510.	1151.	255.
22	72.0	25.	7.3	2200					
23	72.0	25.	7.9	2150					
24	72.0	25.	7.3	2100					
25	72.0	25.	7.0	2100					
26	72.0	20.	7.1	2150					
27	72.0	22.	7.2	2100					
28	72.0	18.	7.0	2100	< 1.0	0.87	516.	1029.	34.6
29	72.0	19.	7.2	2100					
30	72.0	22.	6.8	2300					
31	72.0	24.	7.0	2300					
32	72.0	18.	7.2	2150					
33	72.0	24.	7.2	1900					
34	72.0	8.	7.3	1900					
35	72.0	8.	7.2	2050	< 1.0	0.23	478.	1105.	15.4
36	72.0	14.	7.2	2150					
37	72.0	9.	7.2	2250					
38	72.0	10.	6.9	2100					
39	72.0	28.	6.9	2100					
40	72.0	11.	6.6	2150					
41	72.0	12.	6.9	2100					
42	72.0	12.	6.2	2050	< 1.0	20.0	581.	1186.	<4.0
43	72.0	12.	6.9	2150					
44	72.0	10.	7.1	2050					
45	72.0	11.	7.3	2050					
46	72.0	10.	6.7	2100					
47	72.0	6.	6.1	2000					
48	72.0	6.	6.5	2100					
49	72.0	6.	6.2	2000	< 1.0	23.0	456.	1181.	30.7
50	72.0	12.	6.4	2100					
51	72.0	10.	6.9	2150					
52	72.0	12.	6.8	2100					
53	72.0	6.	6.8	2150					

*Start-up date was 3/16/72.

TABLE A14

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 8
(STONE #1809, 1/4 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	275.	5.7	1750	< 1.0	37.0	390.	977.	202.
2	72.0	250.	5.3	1600					
3	72.0	210.	6.6	1700					
4	72.0	200.	6.5	1600					
5	72.0	175.	6.0	1500					
6	72.0	222.	6.7	1900					
7	72.0	132.	6.5	1600	1.3	31.0	346.	960.	< 4.0
8	72.0	130.	6.6	1750					
9	72.0	120.	6.7	1750					
10	72.0	100.	6.6	1700					
11	72.0	90.	6.6	1750					
12	72.0	86.	6.9	1900					
13	72.0	90.	6.7	1850					
14	72.0	80.	6.7	2000	1.0	22.0	417.	1064.	59.1
15	72.0	90.	5.7	1750					
16	72.0	59.	5.7	1850					
17	72.0	61.	6.5	1800					
18	72.0	60.	6.9	1750					
19	72.0	50.	7.0	2050					
20	72.0	52.	7.0	1700					
21	72.0	44.	6.4	2050	< 1.0	24.5	478.	1170.	79.0
22	72.0	40.	7.3	2100					
23	72.0	60.	7.8	2050					
24	72.0	45.	7.0	1850					
25	72.0	40.	7.3	2000					
26	72.0	36.	6.7	1950					
27	72.0	46.	6.3	1900					
28	72.0	22.	6.7	1850	< 1.0	41.4	427.	1076.	15.4
29	72.0	29.	6.7	1900					
30	72.0	28.	6.5	2000					
31	72.0	32.	6.3	2000					
32	72.0	28.	6.9	1850					
33	72.0	24.	6.8	1800					
34	72.0	28.	7.0	1850					
35	72.0	14.	7.0	2150	< 1.0	11.5	538.	1197.	< 4.0
36	72.0	14.	7.3	2300					
37	72.0	12.	7.2	2350					
38	72.0	16.	7.1	2250					
39	72.0	16.	7.1	2200					
40	72.0	13.	6.7	2300					
41	72.0	16.	7.2	2250					
42	72.0	12.	6.9	2200	< 1.0	0.17	628.	1216.	< 4.0
43	72.0	12.	7.1	2250					
44	72.0	12.	7.2	2250					
45	72.0	10.	7.4	2150					
46	72.0	12.	7.1	2250					
47	72.0	6.	6.3	2200					
48	72.0	10.	6.9	2150					
49	72.0	8.	6.7	2200	< 1.0	0.34	519.	1184.	19.2
50	72.0	14.	6.9	2200					
51	72.0	10.	6.9	2250					
52	72.0	8.	7.1	2250					
53	72.0	6.	7.0	2100					

*Start-up date was 3/16/72.

TABLE A15

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 9
(STONE #1809, 1/2 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	43.5	3420.	3.0	1700	< 1.0	153.	146.	975.	< 4.0
2	47.0	3190.	3.1	1650					
3	49.0	3470.	3.0	1950					
4	48.5	3300.	3.2	1700					
5	49.0	3240.	2.9	1700					
6	59.5	3340.	3.3	1500					
7	60.5	3060.	3.0	1650	10.0	161.	101.	1000.	598.
8	59.0	2780.	3.0	1650					
9	59.0	2780.	3.0	1700					
10	59.0	3200.	2.8	1650					
11	60.5	2830.	2.9	1800					
12	59.5	2720.	2.7	2100					
13	61.0	2420.	2.8	1950					
14	61.5	2380.	2.8	2050	10.0	193.	90.	1092.	598.
15	61.0	2460.	2.6	1900					
16	62.0	2510.	2.7	2000					
17	60.0	2450.	2.8	1850					
18	60.0	2420.	2.8	1550					
19	61.0	2500.	3.1	2350					
20	59.0	2340.	2.8	2150					

*Start-up date was 3/16/72.

TABLE A16

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 10
(STONE #1809, 1/2 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	240.	7.1	1800	4.5	35.0	377.	1011.	637.
2	72.0	175.	5.2	1650					
3	72.0	140.	5.3	1750					
4	72.0	120.	5.5	1700					
5	72.0	110.	6.6	1800					
6	72.0	170.	5.7	1950					
7	72.0	130.	5.5	1700	< 1.0	0.58	412.	935.	<4.0
8	72.0	90.	5.8	1800					
9	72.0	90.	5.6	1800					
10	72.0	84.	6.3	1800					
11	72.0	120.	6.3	1850					
12	72.0	74.	6.0	1950					
13	72.0	90.	6.2	1900					
14	72.0	75.	6.0	1950	< 1.0	0.09	441.	999.	101.
15	72.0	70.	6.2	1750					
16	72.0	68.	6.1	1900					
17	72.0	62.	6.2	1900					
18	72.0	61.	5.9	1850					
19	72.0	58.	6.5	2100					
20	72.0	60.	6.2	1400					
21	72.0	48.	6.8	2200	< 1.0	0.18	505.	1165.	137.
22	72.0	45.	7.3	2100					
23	72.0	50.	7.3	2100					
24	72.0	44.	7.1	1900					
25	72.0	50.	7.0	2050					
26	72.0	46.	6.8	2100					
27	72.0	48.	7.0	2000					
28	72.0	52.	7.0	2100	< 1.0	0.05	502.	1020.	38.4
29	72.0	36.	6.6	2050					
30	72.0	40.	6.6	2300					
31	72.0	40.	6.8	2300					
32	72.0	44.	7.0	2100					
33	72.0	44.	7.0	1850					
34	72.0	40.	6.9	2050					
35	72.0	44.	6.9	2250	< 1.0	<0.03	550.	1193.	<4.0
36	72.0	40.	6.8	2150					
37	72.0	35.	7.0	2200					
38	72.0	50.	6.9	2150					
39	72.0	44.	6.9	2100					
40	72.0	35.	5.8	2200					
41	72.0	44.	6.9	2200					
42	72.0	144.	6.1	2100	< 1.0	0.15	606.	1162.	<4.0
43	72.0	36.	6.9	2250					
44	72.0	33.	7.1	2100					
45	72.0	36.	7.3	2150					
46	72.0	36.	6.9	2200					
47	72.0	30.	6.3	2100					
48	72.0	30.	6.6	2200					
49	72.0	28.	6.5	2200	< 1.0	0.04	519.	1193.	19.2
50	72.0	40.	6.6	2100					
51	72.0	31.	6.7	2200					
52	72.0	30.	7.2	2100					
53	72.0	26.	7.0	2250					

*Start-up date was 3/16/72.

TABLE A17

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 11
(STONE #1809, 1 x 50 M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	23.5	3480.	2.8	1800	9.0	154.	141.	978.	637.
2	26.0	3785.	3.0	1650					
3	26.0	3460.	2.7	2100					
4	27.0	3330.	3.0	1650					
5	27.0	3230.	2.8	1800					
6	2[illegible]	2840.	3.1	1500					
7	25.0	2770.	2.9	1600	6.3	160.	95.	967.	590.
8	25.0	2750.	3.0	1650					
9	25.0	2460.	2.8	1800					
10	25.5	2400.	2.8	1600					
11	27.0	2420.	2.8	1900					
12	28.0	2340.	2.4	2050					
13	29.0	2320.	2.8	2000					
14	29.5	2330.	2.8	2050	9.0	189.	90.	1071.	685.
15	30.0	2270.	2.6	1850					
16	30.5	2220.	2.7	2050					
17	29.5	2170.	2.6	1950					
18	30.0	2200.	2.6	1700					
19	32.0	2160.	3.0	2400					
20	31.0	2120.	2.7	1300					

*Start-up date was 3/16/72.

TABLE A18

FLOW AND EFFLUENT COMPOSITION DATA FOR TEST VESSEL NO. 12 (STONE #1809, 1 x 0 SIZE)

*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
	29.0	3890.	2.8	1750	8.8	160.	125.	1025.	652.
	30.0	3795.	3.1	1650					
	32.0	3820.	2.7	2200					
	32.5	3680.	2.9	1700					
	34.0	3530.	2.6	2000					
	28.5	3200.	3.0	1500					
	31.5	3110.	2.8	1650	8.9	163.	90.	973.	648.
	30.5	2850.	2.9	1700					
	32.5	2740.	2.8	1800					
	33.5	2700.	2.8	1750					
	34.0	1720.	.7	1850					
	36.5	2620.	2.5	2200					
	39.5	2650.	2.7	2100					
	38.5	2530.	2.7	2200	10.0	193.	90.	1160.	846.
	40.0	2500.	2.6	2000					
	40.5	2400.	2.8	2100					
	42.5	2475.	2.5	2100					
	43.0	2420.	2.6	1750					
	45.0	1460.	2.9	2550					
	43.0	2360.	2.6	2750					

ate was 3/16/72.

TABLE A19

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 13
(STONE #1355, 1/8 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	50.	6.3	1900	1.0	13.0	417.	999.	299.
2	72.0	30.	6.3	1700					
3	72.0	30.	5.5	1750					
4	72.0	20.	5.3	1750					
5	72.0	40.	5.4	1650					
6	72.0	23.	5.5	1700					
7	72.0	39.	5.6	1800	< 1.0	2.3	452.	928.	205.
8	72.0	35.	5.8	1800					
9	72.0	26.	5.9	1850					
10	72.0	20.	6.5	1850					
11	72.0	50.	6.3	1850					
12	72.0	16.	5.9	1950					
13	72.0	30.	6.5	1950					
14	72.0	30.	6.1	2050	< 1.0	0.04	482.	1081.	104.
15	72.0	14.	6.4	1900					
16	72.0	14.	6.7	2050					
17	72.0	18.	6.4	1900					
18	72.0	20.	6.3	1700					
19	72.0	16.	6.3	2200					
20	72.0	14.	6.2	2100					
21	72.0	16.	7.5	2250	< 1.0	<0.03	525.	1170.	126.
22	72.0	15.	7.6	2150					
23	72.0	20.	7.7	2150					
24	72.0	12.	7.4	2100					
25	72.0	15.	7.4	2100					
26	72.0	14.	7.3	2150					
27	72.0	14.	7.3	2150					
28	72.0	16.	7.1	2050	< 1.0	0.03	499.	882.	407.
29	72.0	9.	7.3	2100					
30	72.0	14.	7.1	2150					
31	72.0	12.	7.3	2300					
32	72.0	10.	7.3	2200					
33	72.0	12.	7.3	1900					
34	72.0	16.	7.2	1950					
35	72.0	16.	7.2	2150	< 1.0	<0.03	550.	1145.	15.4
36	72.0	16.	7.2	2150					
37	72.0	12.	7.2	2250					
38	72.0	16.	7.2	2100					
39	72.0	16.	7.2	2100					
40	72.0	15.	6.5	2250					
41	72.0	12.	7.2	2150					
42	72.0	10.	6.6	2150	< 1.0	0.35	519.	1171.	<4.0
43	72.0	16.	7.2	2250					
44	72.0	10.	7.3	2150					
45	72.0	11.	7.5	2050					
46	72.0	10.	7.1	2200					
47	72.0	8.	6.5	2100					
48	72.0	8.	6.8	2150					
49	72.0	10.	6.6	2150	< 1.0	0.03	518.	1142.	23.0
50	72.0	16.	6.8	2150					
51	72.0	15.	7.0	2300					
52	72.0	11.	6.2	2200					
53	72.0	10.	7.1	2300					

*Start-up date was 3/16/72.

TABLE A20

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 14
(STONE #1355, 1/4 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	125.	6.1	1800	< 1.0	0.89	447.	974.	< 4.0
2	72.0	75.	5.8	1800					
3	72.0	71.	6.1	1900					
4	72.0	75.	5.8	1850					
5	72.0	60.	5.8	1800					
6	72.0	76.	6.0	2050					
7	72.0	84.	5.9	1750	< 1.0	3.3	418.	937.	10.8
8	72.0	55.	6.2	1850					
9	72.0	56.	6.4	1850					
10	72.0	40.	6.7	1750					
11	72.0	75.	6.7	1750					
12	72.0	38.	6.6	1950					
13	72.0	35.	6.8	2000					
14	72.0	35.	6.4	2050	< 1.0	0.69	47.1	1063.	126.
15	72.0	19.	6.6	1900					
16	72.0	21.	5.7	1950					
17	72.0	17.	6.7	1850					
18	72.0	20.	6.7	1650					
19	72.0	22.	6.8	2100					
20	72.0	16.	6.9	2050					
21	72.0	18.	7.3	2250	< 1.0	<0.03	520.	1199.	50.5
22	72.0	20.	7.6	2100					
23	72.0	30.	7.8	2100					
24	72.0	20.	7.6	2000					
25	72.0	15.	7.4	2100					
26	72.0	14.	7.3	2150					
27	72.0	16.	7.3	2100					
28	72.0	16.	6.7	2000	< 1.0	0.03	519.	1015.	38.4
29	72.0	14.	7.0	2150					
30	72.0	14.	7.0	2250					
31	72.0	14.	7.2	2300					
32	72.0	14.	7.3	2300					
33	72.0	14.	7.3	1950					
34	72.0	16.	7.2	1950					
35	72.0	16.	7.0	2200	< 1.0	<0.03	550.	1164.	19.2
36	72.0	16.	7.0	2250					
37	72.0	12.	7.1	2250					
38	72.0	14.	7.1	2150					
39	72.0	16.	7.2	2100					
40	72.0	13.	6.3	2250					
41	72.0	14.	7.3	2150					
42	72.0	12.	6.8	2150	< 1.0	0.06	511.	1172.	<4.0
43	72.0	24.	7.1	2250					
44	72.0	13.	7.4	2100					
45	72.0	12.	7.5	2050					
46	72.0	12.	7.0	2200					
47	72.0	8.	6.5	2150					
48	72.0	9.	6.8	2150					
49	72.0	12.	6.7	2200	< 1.0	0.03	526.	1140.	61.4
50	72.0	20.	6.6	2100					
51	72.0	14.	6.9	2400					
52	72.0	10.	7.0	2450					
53	72.0	10.	7.1	2350					

*Start-up date was 3/16/72.

TABLE A21

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 15
(STONE #1355, 1/2 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	58.0	3450.	2.9	1800	3.8	161.	160.	1036.	511.
2	59.5	3420.	3.2	1550					
3	72.0	3420.	3.2	1700					
4	57.0	3300.	3.0	1650					
5	56.0	3160.	2.8	1750					
6	51.5	2820.	3.2	1500					
7	53.0	2720.	2.9	1600	10.0	150.	98.	989.	533.
8	52.0	2530.	3.0	1600					
9	52.0	2480.	3.0	1700					
10	51.5	2380.	2.8	1650					
11	51.5	2360.	2.8	1800					
12	52.0	2340.	2.6	2050					
13	50.5	2310.	2.7	2050					
14	50.0	2370.	2.8	1950	10.0	193.	90.	1111.	654.
15	48.5	2200.	2.7	1850					
16	50.0	2200.	2.7	2100					
17	48.0	2130.	2.6	1950					
18	48.0	2180.	2.7	1550					
19	49.0	2100.	2.9	2350					
20	48.0	2000.	3.1	2200					

*Start-up date was 3/16/72.

TABLE A22

FLOW AND EFFLUENT COMPOSITION DATA FOR TEST VESSEL NO. 16 (STONE #1355, 1/2 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	275.	6.1	1500	4.5	50.9	340.	985.	7.2
2	72.0	250.	5.0	1550					
3	72.0	220.	4.0	1650					
4	72.0	250.	3.8	1550					
5	72.0	240.	3.6	1550					
6	72.0	300.	5.2	1650					
7	72.0	196.	3.5	1550	4.0	71.4	267.	973.	126.
8	72.0	200.	3.5	1600					
9	72.0	176.	3.4	1600					
10	72.0	166.	3.2	1600					
11	72.0	180.	3.1	1700					
12	72.0	152.	3.0	1800					
13	72.0	160.	3.0	1900					
14	72.0	165.	3.0	1950	3.8	118.	225.	1060.	356.
15	72.0	150.	2.9	1750					
16	72.0	142.	2.9	1800					
17	72.0	138.	2.8	1800					
18	72.0	150.	2.9	1550					
19	72.0	140.	3.3	2100					
20	72.0	140.	3.1	1950					
21	72.0	136.	3.0	2000	7.2	140.	210.	1160.	388.
22	72.0	135.	3.3	1950					
23	72.0	150.	3.4	1900					
24	72.0	140.	3.2	1850					
25	72.0	130.	3.2	1850					
26	72.0	140.	2.9	2050					
27	72.0	146.	3.3	1750					
28	72.0	132.	3.1	2000	8.5	135.	186.	1069.	626.
29	72.0	130.	2.8	1950					
30	72.0	132.	3.2	2150					
31	72.0	128.	3.1	2550					
32	72.0	104.	3.4	1750					
33	72.0	88.	3.7	1600					
34	72.0	68.	3.5	1850					
35	72.0	72.	3.1	2050	10.2	131.	285.	1205.	457.
36	72.0	64.	3.0	2100					
37	72.0	62.	2.9	2000					
38	72.0	66.	3.0	2000					
39	72.0	70.	3.0	1950					
40	72.0	55.	2.6	1900					
41	72.0	60.	3.2	2000					
42	72.0	60.	2.9	2100	10.0	119.	242.	1215.	502.
43	72.0	56.	3.0	2200					
44	72.0	70.	3.2	1900					
45	72.0	60.	3.4	2000					
46	72.0	56.	2.9	2050					
47	72.0	50.	3.1	1900					
48	72.0	50.	2.8	2100					
49	72.0	48.	2.5	2100	8.0	125.	211.	1211.	522.
50	72.0	58.	2.5	2050					
51	72.0	60.	2.6	2450					
52	72.0	54.	2.9	2150					
53	72.0	52.	3.0	2400					

*Start-up date was 3/16/72.

TABLE A23

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 17
(STONE #1355, 1 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	58.0	3650.	2.9	1750	8.5	150.	160.	999.	526.
2	59.5	3600.	3.4	1600					
3	72.0	3480.	3.0	1800					
4	59.0	3420.	2.8	1700					
5	58.5	3260.	2.7	1800					
6	52.5	2920.	3.1	1500					
7	50.5	2760.	2.8	1550	10.0	141.	99.	982.	515.
8	17.5	2600.	3.0	1700					
9	48.0	2520.	2.9	1650					
10	47.5	2420.	2.8	1800					
11	47.0	242.	2.7	1800					
12	47.5	2400.	2.7	2100					
13	46.5	1370.	2.7	2100					
14	46.5	2330.	2.8	2050	10.0	190.	94.	1110.	741.
15	44.5	2280.	2.6	1850					
16	45.5	2180.	2.7	2000					
17	44.0	2250.	2.5	2000					
18	43.0	2220.	2.6	1500					
19	44.0	2140.	2.9	2400					
20	41.5	2100.	2.5	2200					

*Start-up date was 3/16/72.

TABLE A24

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 18
(STONE #1355, 1 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	1900.	2.9	1650	8.0	123.	200.	1006.	389.
2	72.0	1660.	3.5	1700					
3	72.0	1520.	3.1	1750					
4	72.0	1480.	2.8	1750					
5	72.0	1400.	2.9	1650					
6	72.0	1100.	3.2	1550					
7	72.0	1010.	3.0	1700	8.8	140.	143.	972.	421.
8	72.0	820.	3.0	1700					
9	72.0	760.	3.0	1700					
10	72.0	720.	3.0	1600					
11	72.0	720.	2.9	1650					
12	72.0	680.	2.7	1900					
13	72.0	330.	2.9	1850					
14	72.0	650.	2.9	2000	3.5	168.	135.	1086.	601.
15	72.0	620.	2.8	1750					
16	72.0	600.	2.9	1850					
17	72.0	600.	2.7	1900					
18	72.0	600.	2.7	1400					
19	72.0	620.	3.1	2200					
20	72.0	620.	2.9	2250					
21	72.0	600.	2.8	2100	10.0	138.	125.	1126.	711.
22	72.0	555.	3.0	2050					
23	72.0	560.	3.1	2050					
24	72.0	540.	2.9	2150					
25	72.0	550.	3.2	1800					
26	72.0	540.	2.6	2250					
27	72.0	528.	3.1	1750					
28	72.0	500.	3.0	1800	11.5	138.	140.	1051.	584.
29	72.0	500.	2.8	2000					
30	72.0	600.	2.7	2400					
31	72.0	492.	2.8	2900					
32	72.0	414.	3.2	1750					
33	72.0	368.	3.2	1650					
34	72.0	348.	3.1	2000					
35	72.0	332.	2.7	2450	11.0	166.	175.	1221.	797.
36	72.0	360.	2.5	2300					
37	72.0	325.	2.6	2250					
38	72.0	340.	2.6	2400					
39	72.0	140.	2.6	2200					
40	72.0	310.	2.8	2100					
41	72.0	308.	2.9	2100					
42	72.0	316.	2.8	2150	11.0	176.	147.	1211.	373.
43	72.0	308.	2.6	2650					
44	72.0	330.	2.8	2250					
45	72.0	310.	2.9	2350					
46	72.0	304.	2.6	2500					
47	72.0	296.	2.6	2200					
48	72.0	312.	2.4	2550					
49	72.0	300.	2.2	2700	10.0	161.	112.	1221.	787.
50	72.0	320.	2.2	2400					
51	72.0	310.	2.3	2900					
52	72.0	310.	2.3	2750					
53	72.0	300.	2.7	3000					

*Start-up date was 3/16/72.

TABLE A25

FLOW AND EFFLUENT COMPOSITION DATA FOR TEST VESSEL NO. 19 (STONE #1337, 1/8 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	25.	6.9	2000	< 1.0	0.29	161.	972.	25.2
2	72.0	10.	6.0	1950					
3	72.0	9.	5.7	1850					
4	72.0	10.	6.1	1950					
5	72.0	8.	5.7	1850					
6	72.0	22.	5.9	1850					
7	72.0	12.	5.6	1900	< 1.0	0.04	291.	942.	14.4
8	72.0	20.	5.8	1900					
9	72.0	16.	6.0	1950					
10	72.0	14.	6.5	1900					
11	72.0	25.	6.3	1900					
12	72.0	13.	6.3	2050					
13	72.0	25.	6.5	1950					
14	72.0	20.	6.4	2150	< 1.0	0.31	311.	1025.	62.4
15	72.0	11.	6.7	1800					
16	72.0	11.	6.8	2100					
17	72.0	11.	6.7	2050					
18	72.0	15.	6.7	1950					
19	72.0	16.	6.8	2250					
20	72.0	140.	6.2	2150					
21	72.0	16.	7.3	2250	< 1.0	<0.03	343.	1169.	140.
22	72.0	20.	6.9	2150					
23	72.0	30.	7.1	2150					
24	72.0	20.	6.9	2050					
25	72.0	20.	6.5	2150					
26	72.0	14.	6.4	2150					
27	72.0	14.	6.8	2100					
28	72.0	16.	7.1	2000	< 1.0	<0.03	303.	980.	15.4
29	72.0	9.	7.2	2050					
30	72.0	14.	6.4	2150					
31	72.0	14.	6.4	2250					
32	72.0	10.	6.8	2300					
33	72.0	20.	6.4	1750					
34	72.0	20.	6.3	2000					
35	72.0	14.	6.4	2150	< 1.0	<0.03	353.	1196.	24.2
36	72.0	14.	6.7	2200					
37	72.0	8.	6.5	2200					
38	72.0	16.	7.0	2100					
39	72.0	16.	7.3	2100					
40	72.0	11.	6.1	2250					
41	72.0	16.	6.4	2150					
42	72.0	12.	7.2	2250	< 1.0	0.05	322.	1119.	<4.0
43	72.0	24.	6.7	2250					
44	72.0	14.	6.3	2150					
45	72.0	13.	6.4	2050					
46	72.0	12.	7.1	2200					
47	72.0	12.	6.0	2100					
48	72.0	8.	6.4	2100					
49	72.0	10.	6.6	2150	< 1.0	<0.03	342.	1155.	177.
50	72.0	18.	6.7	2100					
51	72.0	12.	6.8	2550					
52	72.0	15.	6.5	2150					
53	72.0	14.	6.3	2250					

*Start-up date was 3/16/72.

TABLE A26

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 20
(STONE #1337, 1/4 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	75.	6.4	2100	< 1.0	0.03	330.	1058.	144.
2	72.0	60.	6.1	1900					
3	72.0	59.	6.4	1950					
4	72.0	45.	6.3	1950					
5	72.0	45.	6.1	1800					
6	72.0	62.	6.3	2000					
7	72.0	120.	7.1	1650	1.5	8.2	227.	917.	< 4.0
8	72.0	120.	6.2	1700					
9	72.0	80.	6.3	1600					
10	72.0	80.	6.3	1650					
11	72.0	75.	6.3	1750					
12	72.0	52.	6.6	1850					
13	72.0	65.	6.5	1750					
14	72.0	55.	6.6	1900	< 1.0	14.0	244.	1035.	18.0
15	72.0	50.	6.7	1850					
16	72.0	35.	6.2	1850					
17	72.0	35.	6.4	1800					
18	72.0	35.	6.8	1600					
19	72.0	84.	6.8	2050					
20	72.0	42.	6.7	2100					
21	72.0	38.	7.1	2050	< 1.0	13.0	275.	1130.	43.2
22	72.0	40.	7.2	1950					
23	72.0	50.	6.8	2000					
24	72.0	40.	7.2	1950					
25	72.0	40.	7.2	1950					
26	72.0	32.	6.5	1950					
27	72.0	32.	6.8	1900					
28	72.0	32.	6.3	1800	< 1.0	18.3	240.	999.	19.2
29	72.0	25.	6.7	1900					
30	72.0	20.	6.3	2000					
31	72.0	24.	6.5	2050					
32	72.0	24.	6.9	2100					
33	72.0	20.	6.8	1800					
34	72.0	20.	6.8	1900					
35	72.0	20.	6.7	2100	< 1.0	0.06	310.	1205.	11.5
36	72.0	22.	6.4	2150					
37	72.0	16.	6.8	2150					
38	72.0	22.	6.8	2100					
39	72.0	24.	6.6	2000					
40	72.0	15.	6.9	2150					
41	72.0	20.	6.7	2100					
42	72.0	16.	7.0	2100	< 1.0	0.08	279.	1172.	7.8
43	72.0	20.	6.8	2150					
44	72.0	18.	6.8	2050					
45	72.0	18.	6.7	2050					
46	72.0	20.	7.0	2100					
47	72.0	12.	6.0	2050					
48	72.0	8.	6.5	2050					
49	72.0	12.	6.6	2050	< 1.0	< 0.03	293.	1168.	123.
50	72.0	18.	6.6	1950					
51	72.0	12.	5.6	2200					
52	72.0	25.	6.9	2050					
53	72.0	12.	6.6	2100					

*Start-up date was 3/16/72.

TABLE A27

FLOW AND EFFLUENT COMPOSITION DATA FOR TEST VESSEL NO. 21 (STONE #1337, 1/2 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	125.	5.7	1750	2.0	6.5	255.	1038.	18.0
2	72.0	15.	5.4	1650					
3	72.0	81.	6.7	1750					
4	72.0	650.	3.4	1600					
5	72.0	380.	3.2	1600					
6	72.0	340.	4.2	1550					
7	72.0	232.	3.4	1600	7.5	108.	135.	944.	245.
8	72.0	200.	3.2	1700					
9	72.0	166.	3.2	1700					
10	72.0	136.	3.1	1600					
11	72.0	50.	6.4	1750					
12	72.0	34.	6.6	1900					
13	72.0	50.	6.4	1700					
14	72.0	40.	6.6	1950	< 1.0	5.5	255.	1127.	14.5
15	72.0	34.	6.7	1800					
16	72.0	22.	6.0	1900					
17	72.0	17.	6.6	1900					
18	72.0	25.	6.7	1850					
19	72.0	24.	7.0	2100					
20	72.0	20.	6.8	1900					
21	72.0	24.	7.1	2100	< 1.0	<0.03	278.	1204.	32.4
22	72.0	30.	7.1	2000					
23	72.0	30.	7.1	2000					
24	72.0	14.	7.1	1900					
25	72.0	25.	7.0	1950					
26	72.0	24.	6.8	1950					
27	72.0	26.	6.8	1850					
28	72.0	24.	3.3	1850	< 1.0	<0.03	253.	1016.	11.5
29	72.0	18.	6.7	1900					
30	72.0	20.	6.7	2000					
31	72.0	20.	7.0	2200					
32	72.0	24.	7.1	2100					
33	72.0	28.	6.9	1750					
34	72.0	26.	7.0	1800					
35	72.0	20.	6.8	2050	< 1.0	0.07	285.	1151.	10.8
36	72.0	24.	6.6	2050					
37	72.0	22.	6.9	2000					
38	72.0	24.	6.9	2000					
39	72.0	24.	6.9	2000					
40	72.0	18.	6.9	2050					
41	72.0	28.	6.8	2000					
42	72.0	24.	7.0	2050	< 1.0	0.08	260.	1119.	< 4.0
43	72.0	28.	6.8	2100					
44	72.0	24.	7.0	1900					
45	72.0	22.	6.9	1900					
46	72.0	24.	7.0	2050					
47	72.0	28.	6.2	1950					
48	72.0	26.	6.5	2000					
49	72.0	20.	6.2	2050	< 1.0	<0.03	291.	1175.	100.
50	72.0	24.	6.6	1900					
51	72.0	23.	6.0	2200					
52	72.0	24.	6.8	2000					
53	72.0	22.	6.8	2100					

*Start-up date was 3/16/72.

TABLE A28

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 22
(STONE #1337, 1/2 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	37.5	3680.	2.8	1750	8.5	155.	108.	1081.	547.
2	39.0	3785.	3.3	1500					
3	38.0	3720.	3.0	1650					
4	39.0	3710.	2.8	1650					
5	38.0	3480.	2.8	1750					
6	30.5	3200.	3.0	1550					
7	37.5	3000.	3.0	1500	8.8	164.	85.	975.	529.
8	37.5	2810.	2.9	1700					
9	39.5	2680.	2.9	1700					
10	41.0	2660.	2.8	1750					
11	42.0	1630.	2.8	1850					
12	46.5	2600.	2.6	2050					
13	49.0	1530.	2.7	2050					
14	47.5	2520.	2.8	2000	14.0	187.	82.	1086.	701.
15	47.0	2430.	2.6	1900					
16	49.0	2340.	2.7	2100					
17	48.0	2360.	2.7	1750					
18	48.0	2350.	2.7	1650					
19	50.0	2280.	3.0	2350					
20	52.0	2280.	2.8	2300					

*Start-up date was 3/16/72.

TABLE A29

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 23
(STONE #1337, 1 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	34.0	3790.	2.7	1850	6.0	160.	110.	992.	583.
2	36.0	3785.	3.2	1600					
3	36.0	3720.	2.9	~~1750~~					
4	36.5	3680.	2.8	1700					
5	36.5	3540.	2.7	1850					
6	30.0	3160.	3.0	1550					
7	33.0	2800.	3.0	1600	10.0	167.	74.	983.	580.
8	33.5	2670.	2.9	1750					
9	35.0	2680.	2.8	1700					
10	36.0	2580.	2.8	1850					
11	37.0	1540.	2.7	1900					
12	41.5	2540.	2.6	2200					
13	45.0	1450.	2.7	2150					
14	45.5	2460.	2.7	2050	10.0	190.	81.	1093.	701.
15	45.0	2370.	2.6	2000					
16	47.0	2300.	2.6	2050					
17	46.5	2280.	2.6	1800					
18	47.0	2290.	2.6	1750					
19	49.0	2280.	2.9	2450					
20	50.0	2160.	2.6	2550					

*Start-up date was 3/16/72.

TABLE A30

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 24
(STONE #1337, 1 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	2420.	2.8	1800	8.5	135.	127.	987.	464.
2	72.0	2250.	3.5	1650					
3	72.0	2020.	2.9	1800					
4	72.0	1580.	2.9	1700					
5	72.0	1700.	2.8	1650					
6	72.0	1480.	3.2	1550					
7	72.0	1450.	3.1	1550	8.5	144.	95.	966.	414.
8	72.0	1360.	3.0	1650					
9	72.0	1280.	2.9	1750					
10	72.0	1180.	2.9	1650					
11	72.0	1120.	2.8	1750					
12	72.0	1000.	2.7	2000					
13	72.0	1020.	2.8	1850					
14	72.0	890.	2.9	2000	10.0	181.	96.	1091.	657.
15	72.0	880.	2.7	1850					
16	72.0	860.	2.2	1850					
17	72.0	740.	2.7	1750					
18	72.0	740.	2.7	1650					
19	72.0	760.	3.1	2200					
20	72.0	740.	2.8	2400					
21	72.0	620.	2.9	1950	9.6	180.	95.	1111.	641.
22	72.0	605.	3.1	2000					
23	72.0	640.	3.2	2050					
24	72.0	610.	2.9	1900					
25	72.0	500.	3.2	1850					
26	72.0	480.	2.8	2100					
27	72.0	170.	3.3	1750					
28	72.0	128.	3.3	1800	9.5	85.0	155.	1015.	365.
29	72.0	110.	3.0	1900					
30	72.0	44.	3.2	2050					
31	72.0	48.	3.8	2150					
32	72.0	48.	5.6	2000					
33	72.0	24.	6.9	2450					
34	72.0	22.	6.9	2500					
35	72.0	20.	6.8	2650	< 1.0	0.37	405.	923.	< 4.0
36	72.0	20.	6.9	2650					
37	72.0	16.	7.0	2500					
38	72.0	22.	7.0	2350					
39	72.0	22.	6.9	2100					
40	72.0	20.	7.1	2300					
41	72.0	28.	6.9	2150					
42	72.0	24.	7.2	1850	< 1.0	0.18	276.	1260.	< 4.0
43	72.0	28.	6.9	2150					
44	72.0	22.	7.1	2050					
45	72.0	30.	7.0	2000					
46	72.0	24.	7.0	2000					
47	72.0	18.	6.3	2000					
48	72.0	20.	6.6	2000					
49	72.0	20.	6.4	1900	< 1.0	0.07	253.	1131.	23.0
50	72.0	32.	6.6	1850					
51	72.0	20.	6.4	2050					
52	72.0	21.	7.0	1900					
53	72.0	20.	6.9	2100					

*Start-up date was 3/16/72.

TABLE A31

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 25
(STONE #1809, 1/2 x 0 SIZE CONTAINING 10% SLAG)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	150.	5.8	1900	12.0	14.0	417.	1012.	10.8
2	72.0	104.	5.6	1900					
3	72.0	100.	5.7	1850					
4	72.0	74.	6.2	1850					
5	72.0	116.	5.2	2050					
6	72.0	60.	5.3	1750					
7	72.0	85.	5.2	1750	3.0	7.6	406.	1024.	<4.0
8	72.0	68.	5.8	1800					
9	72.0	46.	6.4	1750					
10	72.0	50.	6.2	1850					
11	72.0	33.	5.8	1950					
12	72.0	35.	6.1	1900					
13	72.0	40.	5.9	1950					
14	72.0	23.	6.3	1650	< 1.0	0.12	420.	1089.	39.0
15	72.0	25.	5.2	1900					
16	72.0	22.	6.2	1800					
17	72.0	24.	5.9	1800					
18	72.0	24.	6.4	2050					
19	72.0	28.	6.5	2050					
20	72.0	24.	7.0	2050					
21	72.0	25.	6.6	1950	30.0	0.08	455.	1155.	14.4
22	72.0	30.	6.5	2000					
23	72.0	20.	6.7	2000					
24	72.0	25.	6.2	1900					
25	72.0	24.	6.4	1850					
26	72.0	22.	6.3	1850					
27	72.0	56.	6.8	1800					
28	72.0	21.	7.0	1900	< 1.0	<0.03	433.	1002.	< 4.0
29	72.0	28.	6.4	1900					
30	72.0	28.	6.7	1800					
31	72.0	28.	6.8	1750					
32	72.0	28.	6.5	1600					
33	72.0	28.	7.3	1750					
34	72.0	28.	7.3	1950					
35	72.0	28.	7.1	1950	< 1.0	<0.03	445.	1075.	11.5
36	72.0	22.	7.4	2100					
37	72.0	26.	7.2	1950					
38	72.0	26.	7.3	1950					
39	72.0	21.	6.1	1950					
40	72.0	25.	7.1	1850					
41	72.0	24.	7.3	1900					
42	72.0	24.	6.5	2050	< 1.0	0.10	435.	1126.	<4.0
43	72.0	21.	7.2	1900					
44	72.0	20.	7.2	1850					
45	72.0	24.	7.2	1850					
46	72.0	18.	6.1	1850					
47	72.0	18.	6.1	1850					
48	72.0	18.	6.0	1900					
49	72.0	28.	7.0	1800	< 1.0	0.05	442.	1085.	30.7
50	72.0	21.	6.6	2050					
51	72.0	23.	7.0	2000					
52	72.0	22.	6.9	2050					
53	72.0	24.	7.0	2100					

*Start-up date was 3/17/72.

TABLE A32

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 26
(STONE #1809, 1 x 0 SIZE CONTAINING 10% SLAG)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	49.0	3480.	3.2	1800	32.5	172.	167.	1094.	446.
2	52.0	3330.	2.8	2050					
3	49.5	3490.	2.8	1900					
4	51.5	3300.	2.7	2000					
5	43.5	3320.	2.8	1850					
6	46.0	3180.	2.8	1750					
7	51.0	3100.	2.8	1900	90.0	184.	108.	1064.	594.
8	51.0	2920.	2.8	1850					
9	52.0	2720.	2.8	1800					
10	52.0	2650.	2.8	2000					
11	54.5	2480.	2.4	2450					
12	52.0	2290.	2.6	2350					
13	51.5	2080.	2.8	2150					
14	62.5	1900.	2.7	1950	100.	177.	107.	1095.	640.
15	60.5	1830.	2.4	2200					
16	59.0	1760.	2.5	2050					
17	57.0	1680.	2.7	1900					
18	59.0	1500.	3.1	2400					
19	72.0	1640.	3.0	2100					
20	72.0	1720.	2.9	2100					
21	72.0	1610.	2.8	2350	120.	184.	113.	1138.	659.
22	72.0	1610.	2.8	2250					
23	72.0	1560.	3.3	1700					
24	72.0	1470.	3.3	1600					
25	72.0	1320.	3.1	1800					
26	72.0	1120.	3.0	1950					
27	72.0	1080.	3.0	2000					
28	72.0	1050.	2.6	2100	150.	175.	113.	1009.	632.
29	72.0	1040.	2.7	2300					
30	72.0	840.	3.2	1850					
31	72.0	378.	3.5	1450					
32	72.0	72.	6.3	1700					
33	72.0	48.	6.8	2200					
34	72.0	48.	7.1	2250					
35	72.0	60.	6.9	2150	30.0	5.2	515.	1248.	16.9
36	72.0	42.	7.2	2150					
37	72.0	54.	7.3	2000					
38	72.0	50.	7.0	1950					
39	72.0	40.	6.7	1900					
40	72.0	32.	7.2	1900					
41	72.0	32.	7.2	2000					
42	72.0	32.	6.8	2050	< 1.0	3.8	465.	1172.	< 4.0
43	72.0	29.	7.3	1850					
44	72.0	40.	7.2	1900					
45	72.0	32.	7.1	1900					
46	72.0	24.	6.2	1900					
47	72.0	26.	6.4	1900					
48	72.0	28.	6.2	2050					
49	72.0	36.	6.6	1850	1.8	13.0	455.	1103.	115.
50	72.0	32.	6.5	2150					
51	72.0	40.	6.8	2050					
52	72.0	40.	6.8	2000					
53	72.0	44.	6.9	2250					

*Start-up date was 3/17/72.

TABLE A33

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 27
(STONE #1809, 1/2 x 0 SIZE CONTAINING 5% BENTONITE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	1540.	3.0	1900	50.0	175.	161.	1024.	576.
2	72.0	1410.	2.8	2100					
3	72.0	1270.	2.7	1950					
4	72.0	1180.	2.7	2050					
5	72.0	1240.	2.7	1900					
6	72.0	960.	2.8	1750					
7	72.0	940.	2.8	1950	100.	182.	117.	1009.	612.
8	72.0	890.	2.8	1650					
9	72.0	840.	2.8	1800					
10	72.0	840.	2.8	1950					
11	72.0	820.	2.4	2450					
12	72.0	780.	2.7	2300					
13	72.0	770.	2.8	2200					
14	72.0	660.	2.7	1900	90.0	179.	115.	1060.	640.
15	72.0	660.	2.4	2100					
16	57.0	650.	2.6	2050					
17	72.0	640.	2.6	1900					
18	72.0	620.	3.0	2400					
19	72.0	560.	2.9	2200					
20	72.0	560.	2.8	2150					
21	72.0	550.	2.8	2400	130.	186.	120.	1136.	684.
22	72.0	550.	2.9	2300					
23	72.0	550.	3.2	1700					
24	72.0	500.	3.3	1550					
25	72.0	440.	3.1	1850					
26	72.0	380.	3.0	1900					
27	72.0	360.	3.0	1900					
28	72.0	350.	2.6	2100	110.	172.	125.	1006.	611.
29	72.0	244.	2.7	2350					
30	72.0	240.	3.2	1900					
31	72.0	60.	3.6	1550					
32	72.0	20.	6.3	2100					
33	72.0	10.	7.0	2450					
34	72.0	10.	7.2	2550					
35	72.0	8.	7.2	2450	< 1.0	0.20	625.	1402.	< 4.0
36	72.0	5.	7.3	2450					
37	72.0	16.	6.7	2300					
38	72.0	12.	7.2	2100					
39	72.0	9.	6.8	2200					
40	72.0	8.	7.3	2100					
41	72.0	7.	7.2	2100					
42	72.0	8.	7.1	2200	< 1.0	0.39	450.	1179.	< 4.0
43	72.0	7.	7.5	2150					
44	72.0	7.	7.4	2200					
45	72.0	10.	7.4	2100					
46	72.0	4.	6.7	2100					
47	72.0	4.	6.8	2050					
48	72.0	4.	6.7	2150					
49	72.0	10.	7.3	2000	< 1.0	0.10	491.	1154.	108.
50	72.0	5.	6.9	2200					
51	72.0	5.	7.1	2100					
52	72.0	10.	7.1	2200					
53	72.0	4.	7.3	2250					

*Start-up date was 3/17/72.

TABLE A34

FLOW AND EFFLUENT COMPOSITION DATA FOR TEST VESSEL NO. 28 (STONE #1809, 1 x 0 SIZE CONTAINING 5% BENTONITE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	44.5	3560.	2.9	2100	37.5	180.	127.	1016.	713.
2	43.0	3600.	2.6	2400					
3	42.0	3580.	2.7	2200					
4	45.0	3400.	2.5	2350					
5	43.5	3460.	2.6	2050					
6	42.0	3270.	2.6	1900					
7	49.5	3220.	2.7	2100	100.	190.	87.	1037.	702.
8	49.5	3040.	2.6	2100					
9	50.0	2820.	2.6	2150					
10	50.5	2710.	2.6	2100					
11	51.0	2520.	2.4	2850					
12	49.5	2240.	2.5	2900					
13	49.5	2130.	2.8	2300					
14	62.0	1920.	2.8	2100	100.	181.	90.	1082.	658.
15	62.0	1850.	2.3	2350					
16	72.0	1720.	2.4	2200					
17	55.0	1580.	2.5	2050					
18	63.0	1500.	2.9	2650					
19	72.0	1320.	2.8	2500					
20	72.0	1320.	2.7	2300					
21	72.0	1245.	2.7	2550	110.	188.	95.	1144.	745.
22	72.0	1240.	2.7	2500					
23	72.0	1240.	3.1	1700					
24	72.0	1090.	3.1	1500					
25	72.0	960.	3.0	1850					
26	72.0	480.	2.9	2050					
27	72.0	440.	3.0	1850					
28	72.0	430.	2.5	2100	120.	177.	113.	1028.	611.
29	72.0	440.	2.6	2400					
30	72.0	380.	3.1	1950					
31	72.0	192.	3.3	1600					
32	72.0	56.	4.0	1450					
33	72.0	20.	6.8	2200					
34	72.0	20.	7.0	2250					
35	72.0	16.	7.0	2150	< 1.0	1.8	490.	1084.	< 4.0
36	72.0	14.	7.2	2100					
37	72.0	22.	6.6	1950					
38	72.0	18.	6.8	1900					
39	72.0	14.	6.9	2000					
40	72.0	16.	7.3	2100					
41	72.0	9.	7.0	2050					
42	72.0	11.	7.2	2100	< 1.0	0.56	475.	1160.	< 4.0
43	72.0	13.	7.2	2000					
44	72.0	13.	7.5	2000					
45	72.0	10.	7.4	2000					
46	72.0	6.	6.6	2000					
47	72.0	6.	7.0	2000					
48	72.0	8.	6.8	2050					
49	72.0	18.	7.1	1900		0.19	450.	1108.	46.1
50	72.0	7.	7.0	2100					
51	72.0	10.	7.4	2000					
52	72.0	11.	7.3	2050					
53	72.0	10.	7.2	1950					

*Start-up date was 3/17/72.

TABLE A35

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 29
(STONE #1809, 1/2 x 0 SIZE CONTAINING 10% FLYASH)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	150.	5.8	1950	12.5	14.0	452.	957.	14.4
2	72.0	150.	5.4	2000					
3	72.0	140.	5.6	1950					
4	72.0	122.	5.4	1800					
5	72.0	162.	5.4	2150					
6	72.0	164.	5.3	1800					
7	72.0	120.	5.2	1800	6.4	10.0	437.	1024.	<4.0
8	72.0	108.	5.8	1800					
9	72.0	96.	6.2	1800					
10	72.0	100.	6.3	1850					
11	72.0	84.	6.0	2000					
12	72.0	90.	6.2	1900					
13	72.0	90.	5.8	2050					
14	72.0	90.	6.3	1950	7.0	10.0	455.	1096.	18.0
15	72.0	76.	5.9	1950					
16	72.0	74.	6.1	1800					
17	72.0	80.	5.9	1800					
18	72.0	70.	6.4	2050					
19	72.0	80.	6.5	2050					
20	72.0	72.	6.6	2050					
21	72.0	75.	6.3	2000	30.0	34.0	473.	1086.	18.8
22	72.0	80.	6.3	1950					
23	72.0	75.	6.3	1900					
24	72.0	70.	5.8	1950					
25	72.0	54.	6.3	1950					
26	72.0	52.	6.7	1950					
27	72.0	56.	6.9	1900					
28	72.0	49.	6.6	2050	8.0	11.0	435.	1015.	<4.0
29	72.0	56.	6.3	2000					
30	72.0	48.	6.3	1850					
31	72.0	36.	6.3	1800					
32	72.0	36.	6.4	1650					
33	72.0	32.	7.0	1900					
34	72.0	32.	6.9	2050					
35	72.0	26.	6.8	2100	11.0	24.0	485.	1221.	107.
36	72.0	26.	6.9	2150					
37	72.0	32.	6.6	2000					
38	72.0	36.	6.7	1950					
39	72.0	17.	6.7	1900					
40	72.0	24.	7.0	1900					
41	72.0	24.	6.8	1900					
42	72.0	28.	6.9	2100	17.0	26.0	475.	1106.	<4.0
43	72.0	22.	7.6	2100					
44	72.0	20.	6.4	2150					
45	72.0	24.	7.0	1950					
46	72.0	16.	6.4	1850					
47	72.0	16.	6.6	1950					
48	72.0	16.	6.5	2050					
49	72.0	22.	6.6	1950	15.0	22.0	494.	1081.	<4.0
50	72.0	18.	6.9	2150					
51	72.0	20.	6.9	2050					
52	72.0	40.	7.0	2100					
53	72.0	20.	7.1	2100					

*Start-up date was 3/17/72.

TABLE A36

FLOW AND EFFLUENT COMPOSITION DATA FOR TEST VESSEL NO. 30 (STONE #1809, 1 x 0 SIZE CONTAINING 10% FLYASH)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	110.	6.1	2000	15.0	18.0	452.	1077.	21.6
2	72.0	77.	6.0	2000					
3	72.0	75.	6.0	2000					
4	72.0	68.	5.8	1900					
5	72.0	78.	5.8	2150					
6	72.0	230.	6.8	1800					
7	72.0	180.	5.7	1800	8.8	17.0	417.	986.	<4.0
8	72.0	150.	6.1	1700					
9	72.0	128.	6.4	1750					
10	72.0	150.	6.4	1850					
11	72.0	120.	6.7	2050					
12	72.0	120.	6.4	1850					
13	72.0	100.	6.2	2100					
14	72.0	100.	6.2	2000	8.0	14.0	442.	1088.	18.0
15	72.0	80.	5.8	2000					
16	72.0	73.	6.4	1850					
17	72.0	70.	6.4	1800					
18	72.0	72.	6.7	2100					
19	72.0	76.	6.7	2000					
20	72.0	70.	6.8	2150					
21	72.0	70.	6.8	2500	50.0	42.0	463.	1104.	21.6
22	72.0	80.	6.8	1950					
23	72.0	70.	6.9	1900					
24	72.0	65.	6.6	1950					
25	72.0	54.	6.6	1950					
26	72.0	50.	6.8	2000					
27	72.0	52.	6.8	1950					
28	72.0	49.	6.6	1650	30.0	33.0	475.	1031.	<4.0
29	72.0	52.	6.5	2000					
30	72.0	48.	6.6	1900					
31	72.0	40.	6.6	1900					
32	72.0	44.	6.7	1750					
33	72.0	40.	7.0	2000					
34	72.0	36.	6.8	2150					
35	72.0	36.	6.8	2100	12.0	20.0	510.	1124.	256.
36	72.0	34.	6.8	2150					
37	72.0	42.	6.7	2050					
38	72.0	44.	6.7	2000					
39	72.0	36.	6.7	1900					
40	72.0	32.	7.0	1900					
41	72.0	36.	6.8	2000					
42	72.0	36.	6.8	2100	19.0	28.0	482.	1121.	<4.0
43	72.0	33.	7.0	1900					
44	72.0	40.	7.1	2000					
45	72.0	32.	6.9	1900					
46	72.0	28.	6.3	1850					
47	72.0	28.	6.5	2000					
48	72.0	28.	6.5	2050					
49	72.0	32.	6.5	1950	15.0	26.0	448.	1086.	154.
50	72.0	31.	6.6	2100					
51	72.0	31.	6.8	2050					
52	72.0	64.	7.0	2050					
53	72.0	32.	7.1	2250					

*Start-up date was 3/17/72.

TABLE A37

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 31
(STONE #1809, 1/8 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	320.	5.6	2000	11.3	13.0	457.	1043.	< 4.0
2	72.0	280.	6.3	2000					
3	72.0	200.	6.3	2050					
4	72.0	184.	6.1	1900					
5	72.0	150.	6.1	2250					
6	72.0	200.	6.9	1900					
7	72.0	140.	6.0	1900	7.6	12.0	464.	1013.	< 4.0
8	72.0	130.	6.3	1850					
9	72.0	120.	6.7	1850					
10	72.0	120.	6.5	1950					
11	72.0	100.	6.9	2250					
12	72.0	125.	6.5	2000					
13	72.0	90.	6.4	2150					
14	72.0	80.	6.5	2100	6.0	9.0	482.	1064.	36.0
15	72.0	66.	5.[illegible]	2050					
16	72.0	59.	6.5	1850					
17	72.0	60.	6.5	1900					
18	72.0	46.	6.8	2200					
19	72.0	48.	6.9	2200					
20	72.0	44.	6.9	2250					
21	72.0	50.	7.0	2050	2.4	21.0	510.	1144.	32.4
22	72.0	40.	7.0	2050					
23	72.0	50.	7.1	2250					
24	72.0	40.	6.8	2050					
25	72.0	28.	6.8	2000					
26	72.0	22.	6.9	2000					
27	72.0	20.	6.8	2100					
28	72.0	16.	6.6	2050	2.5	14.7	525.	1084.	< 4.0
29	72.0	20.	6.7	2100					
30	72.0	12.	7.1	2150					
31	72.0	8.	6.9	2150					
32	72.0	10.	7.1	2150					
33	72.0	9.	7.3	2000					
34	72.0	8.	7.2	2000					
35	72.0	8.	7.3	2100	1.2	0.14	495.	1107.	28.8
36	72.0	6.	7.2	2200					
37	72.0	16.	7.0	2200					
38	72.0	10.	7.3	2150					
39	72.0	16.	5.8	2200					
40	72.0	7.	7.2	2200					
41	72.0	7.	7.1	2150					
42	72.0	7.	7.2	2100	2.3	0.16	487.	1184.	< 4.0
43	72.0	6.	7.3	2100					
44	72.0	6.	6.6	2100					
45	72.0	7.	7.3	2250					
46	72.0	3.	6.9	2100					
47	72.0	2.	7.0	2100					
48	72.0	2.	6.8	2100					
49	72.0	8.				0.05	528.	1176.	76.8
50	72.0	5.	6.8	2150					
51	72.0	8.	7.4	2050					
52	72.0	3.	7.3	2200					
53	72.0	3.	7.3	2200					

*Start-up date was 3/17/72.

TABLE A38

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 32
(STONE #1809, 1/4 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	300.	6.5	2100	20.0	23.0	437.	980.	14.4
2	72.0	260.	6.5	2050					
3	72.0	190.	6.4	1950					
4	72.0	153.	6.3	2000					
5	72.0	176.	5.4	2200					
6	72.0	110.	6.9	1850					
7	72.0	120.	6.2	1900	2.5	4.0	453.	1019.	< 4.0
8	72.0	108.	6.5	1900					
9	72.0	96.	6.7	1850					
10	72.0	110.	6.6	1950					
11	72.0	76.	6.9	2250					
12	72.0	80.	6.8	2000					
13	72.0	70.	6.5	2100					
14	72.0	70.	6.6	2250	1.4	2.0	475.	1073.	145.
15	72.0	56.	5.2	1950					
16	72.0	56.	6.6	1850					
17	72.0	54.	5.9	1750					
18	72.0	52.	7.0	2200					
19	72.0	52.	7.0	2200					
20	72.0	50.	7.1	2250					
21	72.0	50.	7.2	2600	2.0	7.5	505.	1143.	25.2
22	72.0	60.	7.2	2050					
23	72.0	43.	7.1	2050					
24	72.0	40.	6.9	2100					
25	72.0	30.	7.0	2050					
26	72.0	26.	7.1	2000					
27	72.0	68.	6.6	2050					
28	72.0	21.	7.1	2150	< 1.0	0.12	550.	1084.	691.
29	72.0	24.	7.0	2150					
30	72.0	14.	7.2	2100					
31	72.0	12.	7.2	2150					
32	72.0	12.	7.2	1950					
33	72.0	12.	7.5	1900					
34	72.0	10.	7.3	2000					
35	72.0	10.	7.3	2150	< 1.0	< 0.03	525.	1217.	< 4.0
36	72.0	8.	7.3	2200					
37	72.0	12.	7.2	2200					
38	72.0	10.	7.4	2100					
39	72.0	6.	6.6	2200					
40	72.0	8.	7.4	2200					
41	72.0	8.	6.8	2000					
42	72.0	7.	7.3	2050	< 1.0	0.05	500.	1131.	< 4.0
43	72.0	6.	7.6	2150					
44	72.0	8.	6.3	2150					
45	72.0	5.	7.4	2150					
46	72.0	3.	6.8	2100					
47	72.0	3.	7.1	2050					
48	72.0	3.	6.9	2100					
49	72.0	8.	7.2	2000	< 1.0	< 0.03	494.	1157.	169.
50	72.0	6.	7.0	2150					
51	72.0	6.	6.5	2000					
52	72.0	10.	7.4	2200					
53	72.0	6.	7.3	2250					

*Start-up date was 3/17/72.

TABLE A39

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 33
(STONE #1809, 1/2 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	3070.	3.5	1750	50.0	166.	176.	1016.	526.
2	72.0	2890.	3.0	2000					
3	72.0	2500.	3.1	1900					
4	72.0	2044.	3.0	1900					
5	72.0	1340.	3.2	1650					
6	72.0	1060.	3.4	1600					
7	72.0	670.	3.3	1750	90.0	144.	184.	1033.	457.
8	72.0	600.	3.2	1750					
9	72.0	560.	3.2	1600					
10	72.0	520.	3.0	1700					
11	72.0	580.	3.0	2050					
12	72.0	530.	2.9	2050					
13	72.0	490.	3.1	1900					
14	72.0	310.	3.1	1950	80.0	153.	170.	1104.	455.
15	72.0	300.	2.7	1850					
16	72.0	320.	3.0	1750					
17	72.0	310.	3.0	1650					
18	72.0	230.	3.5	2050					
19	72.0	204.	3.7	1850					
20	72.0	164.	3.3	2050					
21	72.0	190.	3.5	2450	90.0	117.	263.	1137.	209.
22	72.0	190.	3.5	1850					
23	72.0	200.	3.8	1700					
24	72.0	180.	3.7	1600					
25	72.0	168.	3.7	1600					
26	72.0	152.	3.6	1650					
27	72.0	148.	3.3	1800					
28	72.0	150.	3.3	1850	80.0	122.	233.	997.	350.
29	72.0	168.	3.3	1900					
30	72.0	144.	3.7	1700					
31	72.0	92.	6.3	1450					
32	72.0	76.	6.8	1500					
33	72.0	60.	7.0	1800					
34	72.0	56.	6.8	2000					
35	72.0	60.	6.7	2000	16.0	31.0	455.	1062.	< 4.0
36	72.0	46.	6.9	2000					
37	72.0	60.	6.7	2100					
38	72.0	60.	6.5	1900					
39	72.0	48.	6.7	1850					
40	72.0	44.	7.5	2150					
41	72.0	52.	6.2	1900					
42	72.0	48.	6.7	2050	21.0	29.0	470.	1124.	12.0
43	72.0	50.	7.0	2000					
44	72.0	46.	6.6	2050					
45	72.0	48.	6.9	1900					
46	72.0	40.	6.2	1900					
47	72.0	36.	6.6	2000					
48	72.0	36.	6.4	2050					
49	72.0	44.	6.5	1950	3.1	29.0	466.	1098.	19.2
50	72.0	39.	6.5	2200					
51	72.0	35.	6.8	2000					
52	72.0	48.	7.0	1950					
53	72.0	70.	6.8	1950					

*Start-up date was 3/17/72.

TABLE A40

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 34
(STONE #1809, 1/2 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	39.0	3500.	3.2	1850	25.0	169.	167.	1068.	605.
2	39.0	3550.	2.8	2100					
3	39.0	3420.	2.7	1950					
4	42.5	3300.	2.7	2050					
5	37.0	3360.	2.8	1800					
6	51.0	3140.	3.1	1700					
7	58.5	3100.	3.0	1850	100.	180.	120.	1062.	612.
8	57.0	2940.	2.8	1900					
9	57.0	2780.	2.9	1750					
10	53.0	2650.	2.8	1950					
11	55.0	2520.	2.7	2400					
12	55.0	1170.	2.7	2350					
13	53.0	2000.	2.9	2050					
14	63.0	1880.	2.7	1750	90.0	174.	120.	1086.	700.
15	63.0	1780.	2.5	2150					
16	57.0	1610.	2.6	2000					
17	56.0	1580.	2.9	1650					
18	57.0	1460.	3.0	2300					
19	72.0	1720.	2.9	2100					
20	72.0	1600.	2.8	2200					
21	72.0	1580.	2.7	2250	110.	179.	125.	1161.	691.
22	72.0	1540.	3.0	2200					
23	72.0	1480.	3.3	1600					
24	72.0	1460.	3.0	2050					
25	72.0	1280.	3.1	1750					
26	72.0	1160.	3.0	1850					
27	72.0	1120.	3.0	2000					
28	72.0	1037.	2.7	2100	120.	174.	128.	1019.	603.
29	72.0	1120.	2.8	2350					
30	72.0	920.	3.3	1900					
31	72.0	480.	3.5	1450					
32	72.0	236.	3.8	1400					
33	72.0	140.	3.4	1900					
34	72.0	148.	3.1	2050					
35	72.0	160.	2.9	2150	80.0	149.	220.	1142.	458.
36	72.0	160.	3.0	2050					
37	72.0	176.	3.0	1850					
38	72.0	172.	3.1	1950					
39	72.0	160.	3.6	1650					
40	72.0	116.	7.2	1850					
41	72.0	128.	3.0	2000					
42	72.0	140.	3.0	2050	80.0	135.	237.	1194.	476.
43	72.0	150.	3.2	2000					
44	72.0	150.	3.2	2200					
45	72.0	132.	3.6	1550					
46	72.0	120.	2.6	1950					
47	72.0	124.	2.8	2000					
48	72.0	136.	2.6	2050					
49	72.0	142.	2.6	1900	40.0	141.	164.	1058.	518.
50	72.0	155.	2.2	2500					
51	72.0	170.	2.6	2350					
52	72.0	180.	3.0	2450					
53	72.0	192.	3.9	2150					

*Start-up date was 3/17/72.

TABLE A41

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 35
(STONE #1809, 1 x 50 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	33.0	3500.	3.1	1900	44.0	171.	161.	925.	576.
2	35.0	3570.	2.6	2200					
3	36.0	3380.	2.7	2000					
4	41.0	3360.	2.7	2150					
5	33.5	3380.	2.8	1850					
6	38.5	3220.	2.9	1750					
7	40.5	3120.	2.8	1900	80.0	183.	112.	1000.	680.
8	42.0	2960.	2.8	1950					
9	44.0	3200.	2.9	1800					
10	45.0	2690.	2.8	1950					
11	50.5	2600.	2.6	2550					
12	52.5	1250.	2.6	2350					
13	51.0	2140.	2.8	2100					
14	62.0	1920.	2.7	1800	100.	173.	120.	1106.	637.
15	60.0	1840.	2.4	2150					
16	67.0	1730.	2.6	1950					
17	65.0	1690.	2.6	1750					
18	72.0	1440.	3.0	2350					
19	72.0	1320.	3.0	2000					
20	72.0	1360.	2.8	2200					
21	72.0	1360.	2.8	2250	120.	181.	128.	1100.	680.
22	72.0	1320.	2.9	2200					
23	72.0	1240.	3.2	1750					
24	72.0	1230.	3.0	2100					
25	72.0	1120.	3.1	1750					
26	72.0	840.	3.1	1850					
27	72.0	760.	3.1	1800					
28	72.0	720.	2.8	2000	100.	164.	140.	1001.	595.
29	72.0	720.	2.7	2400					
30	72.0	600.	3.1	1850					
31	72.0	344.	3.4	1500					
32	72.0	244.	3.8	1400					
33	72.0	204.	3.1	2050					
34	72.0	212.	2.8	2200					
35	72.0	202.	2.7	2350	90.0	168.	165.	1168.	462.
36	72.0	216.	2.8	2200					
37	72.0	202.	2.7	2100					
38	72.0	220.	2.6	2200					
39	72.0	210.	3.2	1700					
40	72.0	184.	3.5	1800					
41	72.0	212.	2.8	2100					
42	72.0	192.	2.7	2350	100.	159.	165.	1195.	578.
43	72.0	190.	2.7	2300					
44	72.0	200.	3.0	2150					
45	72.0	180.	3.2	1600					
46	72.0	176.	2.3	2350					
47	72.0	192.	2.5	2350					
48	72.0	216.	2.4	2450					
49	72.0	144.	2.3	2250	50.0	164.	115.	1100.	649.
50	72.0	140.	2.4	2450					
51	72.0	120.	2.6	2300					
52	72.0	116.	3.1	2200					
53	72.0	106.	3.1	2550					

*Start-up date was 3/17/72.

TABLE A42

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 36
(STONE #1809, 1 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	31.0	3250.	3.0	1900	41.5	168.	161.	1035.	605.
2	31.0	3230.	2.7	2200					
3	31.5	3120.	2.8	2050					
4	32.0	3020.	2.6	2200					
5	24.0	3520.	2.8	1850					
6	26.0	2900.	2.7	1800					
7	27.0	2660.	2.9	1950	100.	188.	108.	1027.	684.
8	27.5	2680.	2.8	1950					
9	29.5	2580.	2.8	1800					
10	31.0	2490.	2.8	1950					
11	34.5	2340.	2.6	2650					
12	37.5	2030.	2.6	2400					
13	38.0	1870.	2.8	2150					
14	46.0	1730.	2.7	1900	90.0	177.	115.	1104.	624.
15	45.5	1690.	2.7	2150					
16	43.0	1580.	2.5	1950					
17	43.0	1510.	2.7	1800					
18	43.0	1300.	3.0	2350					
19	72.0	1920.	2.9	2150					
20	72.0	1960.	2.8	2200					

*Start-up date was 3/17/72.

TABLE A43

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 37
(STONE #1355, 1/8 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	75.	5.7	2100	< 1.0	0.97	500.	1034.	32.4
2	72.0	68.	5.4	2050					
3	72.0	50.	5.6	1950					
4	72.0	52.	5.4	2000					
5	72.0	54.	5.4	2050					
6	72.0	82.	5.6	1900					
7	72.0	100.	5.5	1900	5.2	8.6	475.	1010.	25.2
8	72.0	106.	5.8	1900					
9	72.0	140.	6.4	1750					
10	72.0	190.	6.2	1900					
11	72.0	180.	5.8	2250					
12	72.0	205.	6.2	1950					
13	72.0	175.	5.7	2100					
14	72.0	140.	6.1	1900	7.2	12.0	475.	1092.	18.0
15	72.0	122.	5.8	2050					
16	72.0	113.	6.1	1850					
17	72.0	110.	6.3	1700					
18	72.0	88.	6.4	2300					
19	72.0	72.	6.3	2400					
20	72.0	68.	6.4	2150					
21	72.0	65.	6.3	2100	3.6	32.0	495.	1123.	21.6
22	72.0	60.	6.4	2050					
23	72.0	60.	6.2	2050					
24	72.0	50.	6.1	2100					
25	72.0	36.	6.4	2000					
26	72.0	30.	6.4	2000					
27	72.0	28.	6.9	2100					
28	72.0	21.	6.7	2100	3.2	15.4	553.	1119.	< 4.0
29	72.0	24.	6.3	2150					
30	72.0	16.	6.3	2000					
31	72.0	12.	6.6	1900					
32	72.0	12.	6.7	2000					
33	72.0	10.	6.4	1900					
34	72.0	10.	6.4	1950					
35	72.0	10.	7.1	2150	< 1.0	3.0	513.	1113.	14.2
36	72.0	8.	6.7	2150					
37	72.0	14.	6.8	2200					
38	72.0	10.	6.9	2150					
39	72.0	10.	5.9	2200					
40	72.0	8.	3.1	2000					
41	72.0	8.	7.2	2100					
42	72.0	7.	7.3	2200	1.4	3.1	512.	1155.	< 4.0
43	72.0	7.	6.1	2100					
44	72.0	4.	7.2	2150					
45	72.0	5.	6.4	2100					
46	72.0	4.	6.2	2050					
47	72.0	3.	6.5	2050					
48	72.0	3.	5.9	2050					
49	72.0	8.	6.8	2000	< 1.0	23.0	462.	1174.	< 4.0
50	72.0	6.	5.5	2150					
51	72.0	6.	6.0	2100					
52	72.0	7.	6.3	2100					
53	72.0	12.	6.1	2200					

*Start-up date was 3/17/72.

TABLE A43 (CONT'D.)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
55	72.0	50.	6.2	2100					
56	72.0	76.	6.3	2000	11.0	47.0	475.	1130.	227.
57	72.0	46.	6.8	2000					
58	72.0	44.	6.8	2100					
59	72.0	33.	6.6	2300					
60	72.0	32.	6.6	2300					
61	72.0	38.	6.6	2200					
62	72.0	68.	6.0	2050					
63	72.0	60.	7.2	2300	2.0	42.0	537.	1206.	76.8
66	72.0	44.	6.6	2350					
67	72.0	34.	6.1	2350					
68	72.0	40.	6.0	2200					
69	72.0	40.	6.0	2150					
70	72.0	32.	6.4	2150	19.0	47.0	488.	1166.	<4.0
73	72.0	26.	6.1	2050					
74	72.0	22.	6.3	2100					
75	72.0	15.	6.3	2000					
76	72.0	20.	7.0	1950					
77	72.0	16.	6.6	2050	< 1.0	35.0	450.	1114.	8.0
80	72.0	11.	6.4	2000					
81	72.0	13.	6.3	1900					
82	72.0	17.	6.6	2000					
83	72.0	19.	6.5	2000					
84	72.0	10.	6.7	2200	12.0	35.6	570.	1235.	4.0
87	72.0	2.	6.6	2150					
88	72.0	1.	6.5	2100					
89	72.0	1.	6.3	2100					
90	72.0	2.	6.8	2250					
91	72.0	2.	6.1	2200	< 1.0	11.7	620.	2065.	11.7
94	72.0	2.	6.0	2200					
95	72.0	2.	6.0	2250					
96	72.0	2.	6.3	1800					
97	72.0	3.	6.0	2100					
98	72.0	2.	6.3	1800	< 1.0	10.2	550.	1355.	<4.0
101	72.0	2.	6.0	2100					

*Start-up date was 3/17/72.

TABLE A44

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 38
(STONE #1355, 1/4 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	240.	6.0	1950	19.0	25.0	445.	1031.	18.0
2	72.0	200.	6.1	2050					
3	72.0	170.	6.0	1950					
4	72.0	165.	5.9	1950					
5	72.0	132.	5.9	2250					
6	72.0	120.	5.9	1800					
7	72.0	130.	6.0	1850	< 1.0	2.9	446.	1011.	< 4.0
8	72.0	110.	6.5	1800					
9	72.0	98.	6.8	1800					
10	72.0	125.	6.7	1950					
11	72.0	80.	6.4	2050					
12	72.0	75.	6.7	1950					
13	72.0	70.	6.1	2050					
14	72.0	60.	7.0	2250	< 1.0	0.95	453.	1090.	29.0
15	72.0	58.	5.7	2050					
16	72.0	47.	6.6	1750					
17	72.0	55.	6.9	1800					
18	72.0	46.	7.0	2250					
19	72.0	48.	6.9	2100					
20	72.0	52.	7.1	2100					
21	72.0	40.	7.0	2050	2.0	0.10	470.	1187.	18.0
22	72.0	50.	7.3	2000					
23	72.0	45.	7.1	1950					
24	72.0	35.	7.2	1950					
25	72.0	34.	6.8	1900					
26	72.0	34.	6.9	1850					
27	72.0	40.	7.0	1900					
28	72.0	33.	7.2	1950	< 1.0	0.17	445.	1065.	< 4.0
29	72.0	30.	6.8	2000					
30	72.0	26.	6.9	1850					
31	72.0	24.	7.0	1750					
32	72.0	28.	7.1	1650					
33	72.0	24.	6.9	1650					
34	72.0	24.	6.8	1900					
35	72.0	22.	7.3	2000	< 1.0	< 0.03	460.	1079.	< 4.0
36	72.0	18.	7.1	2050					
37	72.0	24.	7.1	1950					
38	72.0	22.	7.1	1950					
39	72.0	20.	6.8	1900					
40	72.0	20.	6.3	2150					
41	72.0	24.	7.2	1900					
42	72.0	20.	6.2	2000	< 1.0	0.06	472.	1146.	< 4.0
43	72.0	20.	7.2	1950					
44	72.0	17.	7.4	2000					
45	72.0	20.	6.9	1850					
46	72.0	14.	6.7	1800					
47	72.0	14.	6.7	1900					
48	72.0	14.	6.4	2000					
49	72.0	20.	7.4	1950	< 1.0	< 0.03	390.	1131.	69.1
50	72.0	16.	6.4	2100					
51	72.0	18.	6.6	2050					
52	72.0	20.	6.7	2150					
53	72.0	16.	6.6	2200					

*Start-up date was 3/17/72.

TABLE A44 (CONT'D.)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
55	72.0	27.	6.6	2100					
56	72.0	52.	6.7	2100	< 1.0	0.54	510.	1070.	46.1
57	72.0	35.	7.2	2100					
58	72.0	42.	7.0	2100					
59	72.0	36.	6.9	2200					
60	72.0	48.	6.7	2150					
61	72.0	64.	6.6	2050					
62	72.0	28.	6.2	1950					
63	72.0	32.	7.0	2150	16.0	0.34	512.	1233.	34.6
66	72.0	28.	7.1	2300					
67	72.0	22.	6.3	2250					
68	72.0	24.	6.5	2300					
69	72.0	24.	6.3	1900					
70	72.0	32.	6.9	2050	< 1.0	0.03	495.	1153.	< 4.0
73	72.0	28.	6.3	2100					
74	72.0	20.	6.4	2250					
75	72.0	17.	6.6	1800					
76	72.0	39.	7.0	2200					
77	72.0	26.	6.8	1850	6.5	52.0	375.	1125.	12.0
80	72.0	18.	6.8	2100					
81	72.0	28.	6.4	1800					
82	72.0	42.	6.2	2250					
83	72.0	108.	6.7	2150					
84	72.0	16.	6.5	2400	2.6	9.5	700.	1504.	6.0
87	72.0	7.	6.9	2100					
88	72.0	7.	7.0	2100					
89	72.0	5.	7.0	2250					
90	72.0	8.	7.4	2200					
91	72.0	8.	6.6	2200	< 1.0	0.18	550.	1276.	7.8
94	72.0	7.	6.5	2100					
95	72.0	7.	6.8	2100					
96	72.0	6.	6.7	1650					
97	72.0	7.	6.5	1850					
98	72.0	6.	6.8	1650	< 1.0	0.06	458.	1208.	< 4.0
101	72.0	7.	6.5	1850					

*Start-up date was 3/17/72.

TABLE A45

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 39
(STONE #1355, 1/2 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	440.	6.3	1850	30.0	52.4	360.	985.	28.8
2	72.0	280.	6.4	1900					
3	72.0	240.	6.1	1850					
4	56.5	191.	6.1	1850					
5	72.0	260.	6.1	2000					
6	72.0	178.	6.0	1750					
7	72.0	135.	6.2	1850	8.0	21.0	449.	1040.	86.4
8	72.0	114.	5.8	1800					
9	72.0	104.	6.5	1800					
10	72.0	110.	6.4	1800					
11	72.0	100.	6.3	1900					
12	72.0	100.	6.3	1750					
13	72.0	85.	6.3	1950					
14	72.0	80.	6.1	1850	30.0	52.9	362.	1072.	18.0
15	72.0	78.	5.0	1800					
16	72.0	73.	6.0	1700					
17	72.0	75.	6.5	1500					
18	72.0	72.	6.5	1950					
19	72.0	60.	7.6	2150					
20	72.0	50.	7.1	2050					
21	72.0	55.	7.0	2050	2.8	25.0	473.	1123.	324.
22	72.0	60.	7.1	2000					
23	72.0	45.	6.9	2050					
24	72.0	45.	6.6	1900					
25	72.0	42.	6.8	1950					
26	72.0	44.	6.8	1950					
27	72.0	44.	6.5	1900					
28	72.0	50.	6.7	2000	6.0	24.5	470.	1046.	< 4.0
29	72.0	42.	6.7	2100					
30	72.0	44.	6.8	1850					
31	72.0	36.	6.9	1750					
32	72.0	44.	7.0	1600					
33	72.0	36.	6.3	1850					
34	72.0	36.	6.6	1950					
35	72.0	36.	6.7	2050	6.0	33.0	470.	1069.	77.6
36	72.0	34.	6.8	2050					
37	72.0	50.	6.6	1950					
38	72.0	40.	6.6	1900					
39	72.0	52.	6.6	1850					
40	72.0	28.	6.9	1800					
41	72.0	32.	6.8	1950					
42	72.0	32.	6.4	2050	17.0	38.0	465.	1115.	< 4.0
43	72.0	28.	6.8	1900					
44	72.0	28.	7.0	2050					
45	72.0	28.	6.7	1850					
46	72.0	22.	6.2	1850					
47	72.0	24.	7.1	1900					
48	72.0	24.	6.1	2050					
49	72.0	36.	6.5	1900	15.0	35.0	398.	1090.	65.3
50	72.0	20.	6.2	2100					
51	72.0	32.	6.5	2050					
52	72.0	36.	6.7	2100					
53	72.0	40.	6.6	2150					

*Start-up date was 3/17/72.

TABLE A46

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 40
(STONE #1355, 1/2 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PH ACIDI (mg/l
1	56.0	3150.	3.5	1750	45.0	157.	185.	996.	522.
2	72.0	3220.	3.0	2000					
3	56.5	3200.	2.9	1900					
4	35.5	3060.	2.8	1900					
5	49.0	3100.	3.0	1800					
6	50.5	2920.	2.9	1700					
7	49.5	2920.	3.0	1850	80.0	183.	117.	1037.	612.
8	49.0	2740.	2.9	1850					
9	47.0	2560.	2.9	1650					
10	45.5	2460.	2.9	1850					
11	46.5	2320.	2.5	2350					
12	44.5	2005.	2.7	2350					
13	42.0	1930.	2.8	2050					
14	44.0	1830.	2.9	2000	90.0	178.	115.	1088.	593.
15	43.5	1640.	2.6	2200					
16	39.0	1600.	2.6	1700					
17	38.0	1510.	2.9	1700					
18	37.5	1460.	3.0	2250					
19	72.0	2680.	6.9	2250					
20	72.0	2720.	2.8	2050					

*Start-up date was 3/17/72.

TABLE A47

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 41
(STONE #1355, 1 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	35.5	2760.	3.2	1800	45.0	116.	174.	1015.	508.
2	36.0	3600.	2.9	2100					
3	34.5	2700.	2.8	1900					
4	72.0	2620.	2.7	2000					
5	28.0	2580.	2.7	1850					
6	29.5	2500.	2.8	1750					
7	28.0	2460.	2.8	1900	90.0	188.	115.	1047.	659.
8	28.0	2380.	2.8	1900					
9	28.0	2160.	2.8	1800					
10	28.5	2190.	2.8	1900					
11	29.5	1980.	2.4	2600					
12	28.0	1720.	2.6	2400					
13	26.5	1630.	2.6	2150					
14	25.0	1500.	2.8	2050	90.0	180.	110.	1055.	720.
15	25.5	1340.	2.7	2200					
16	72.0	1260.	2.5	1950					
17	23.0	1150.	2.6	1800					
18	21.5	1140.	3.0	2300					
19	72.0	2720.	2.9	2150					
20	47.0	2680.	2.7	2200					

*Start-up date was 3/17/72.

TABLE A48

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 42
(STONE #1355, 1 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	1310.	3.7	1800	35.0	147.	245.	1096.	302.
2	72.0	2790.	3.1	1950					
3	72.0	870.	2.0	1950					
4	72.0	820.	3.1	1750					
5	72.0	840.	3.2	1750					
6	72.0	740.	3.0	1700					
7	72.0	670.	3.1	1850	80.0	140.	196.	1045.	425.
8	72.0	694.	3.1	1750					
9	72.0	640.	3.1	1700					
10	72.0	610.	3.0	1800					
11	72.0	600.	2.7	2200					
12	72.0	590.	2.8	2050					
13	72.0	770.	3.0	2050					
14	72.0	530.	2.9	2050	80.0	157.	165.	1100.	523.
15	72.0	520.	3.0	2000					
16	72.0	510.	2.7	1850					
17	72.0	490.	2.7	1650					
18	72.0	520.	3.1	2250					
19	72.0	520.	3.1	2050					
20	72.0	520.	3.0	2050					
21	72.0	480.	3.0	2050	100.	137.	163.	1136.	572.
22	72.0	480.	3.3	2000					
23	72.0	460.	3.5	1700					
24	72.0	440.	3.6	2000					
25	72.0	420.	3.2	1650					
26	72.0	400.	3.3	1800					
27	72.0	380.	3.2	1750					
28	72.0	390.	2.9	1800	100.	137.	165.	1000.	522.
29	72.0	380.	2.9	2150					
30	72.0	320.	3.4	1750					
31	72.0	96.	5.7	1450					
32	72.0	36.	7.0	2050					
33	72.0	64.	6.7	1850					
34	72.0	64.	6.8	2000					
35	72.0	54.	6.9	2100	< 1.0	4.5	505.	1175.	32.6
36	72.0	54.	6.9	2100					
37	72.0	56.	6.8	2000					
38	72.0	50.	6.9	2000					
39	72.0	49.	6.8	1850					
40	72.0	44.	6.8	1850					
41	72.0	52.	6.1	1900					
42	72.0	56.	6.7	2100	< 1.0	1.5	487.	1183.	< 4.0
43	72.0	50.	6.9	1750					
44	72.0	36.	7.0	2000					
45	72.0	32.	6.9	2000					
46	72.0	32.	6.6	1900					
47	72.0	30.	7.0	2050					
48	72.0	28.	6.5	2100					
49	72.0	34.	6.8	2000	< 1.0	3.2	408.	1116.	69.1
50	72.0	46.	6.2	2150					
51	72.0	44.	6.6	2000					
52	72.0	42.	6.7	2100					
53	72.0	42.	6.5	2000					

*Start-up date was 3/17/72.

TABLE A48 (CONT'D.)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
55	72.0	63.	6.6	2000					
56	72.0	60.	6.7	1900	25.0	65.0	417.	1078.	42.2
57	72.0	46.	6.8	1850					
58	72.0	40.	6.4	2150					
59	72.0	40.	6.8	2100					
60	72.0	40.	6.6	1950					
61	72.0	60.	6.6	1850					
62	72.0	48.	6.2	1950					
63	72.0	52.	6.9	2050	22.0	44.0	512.	1209.	53.8
66	72.0	56.	6.8	2250					
67	72.0	48.	6.2	2250					
68	72.0	140.	4.3	1800					
69	72.0	68.	6.3	2000					
70	72.0	14.	7.1	2250	< 1.0	0.19	600.	1433.	< 4.0
73	72.0	10.	6.7	2150					
74	72.0	9.	6.8	2200					
75	72.0	8.	6.8	2250					
76	72.0	10.	7.2	2000					
77	72.0	11.	7.0	2000	< 1.0	0.18	455.	1262.	< 4.0
80	72.0	16.	7.3	1900					
81	72.0	20.	6.3	1850					
82	72.0	16.	6.6	1900					
83	72.0	152.	6.8	1950					
84	72.0	18.	6.5	2400	< 1.0	0.21	700.	1423.	26.0
87	72.0	9.	7.3	2050					
88	72.0	10.	7.6	2150					
89	72.0	8.	7.2	2100					
90	72.0	16.	7.6	2200					
91	72.0	15.	6.7	2200	< 1.0	0.10	540.	812.	11.7
94	72.0	8.	6.5	2050					
95	72.0	9.	7.0	2100					
96	72.0	14.	6.9	1600					
97	72.0	14.	7.0	1950					
98	72.0	8.	7.0	1750	< 1.0	0.06	438.	1165.	< 4.0
101	72.0	8.	6.8	1750					

*Start-up date was 3/17/72.

TABLE A49

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 43
(STONE #1337, 1/8 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	15.	5.8	2000	1.0	0.04	143.	1091.	10.8
2	72.0	12.	6.0	2000					
3	72.0	15.	6.2	2100					
4	72.0	12.	5.7	1950					
5	72.0	11.	5.7	1950					
6	72.0	26.	5.6	2050					
7	72.0	70.	5.5	2000	< 1.0	8.0	355.	1044.	108.
8	72.0	16.	6.3	2000					
9	72.0	22.	7.0	1950					
10	72.0	25.	6.7	2000					
11	72.0	94.	6.4	2100					
12	72.0	25.	6.7	2150					
13	72.0	20.	6.5	2100					
14	72.0	19.	7.1	2150	< 1.0	6.2	315.	1058.	431.
15	72.0	13.	6.5	2100					
16	72.0	17.	6.3	1900					
17	72.0	20.	6.7	1850					
18	72.0	16.	6.8	2200					
19	72.0	24.	6.3	2000					
20	72.0	18.	7.0	2250					
21	72.0	20.	6.1	1900	< 1.0	0.80	333.	1141.	64.8
22	72.0	20.	6.7	2150					
23	72.0	20.	6.2	2100					
24	72.0	25.	6.3	2150					
25	72.0	20.	6.4	1900					
26	72.0	18.	6.7	1900					
27	72.0	20.	7.1	1950					
28	72.0	17.	6.8	2000	< 1.0	7.1	298.	1017.	< 4.0
29	72.0	28.	6.5	2000					
30	72.0	18.	6.6	1850					
31	72.0	18.	6.9	1800					
32	72.0	28.	7.5	1600					
33	72.0	20.	7.1	1700					
34	72.0	20.	7.0	2000					
35	72.0	14.	7.2	2100	< 1.0	0.12	305.	1056.	154.
36	72.0	12.	7.1	2050					
37	72.0	18.	7.0	2050					
38	72.0	17.	7.3	2000					
39	72.0	11.	7.0	2050					
40	72.0	16.	7.3	1800					
41	72.0	24.	6.6	1950					
42	72.0	16.	7.0	2100	< 1.0	0.11	322.	1106.	< 4.0
43	72.0	12.	7.2	2100					
44	72.0	9.	7.3	2050					
45	72.0	10.	7.1	2000					
46	72.0	8.	6.8	1800					
47	72.0	8.	7.1	1950					
48	72.0	8.	6.8	2050					
49	72.0	20.	6.9	2000	< 1.0	2.3	254.	1100.	73.0
50	72.0	18.	6.5	2150					
51	72.0	11.	6.6	1850					
52	72.0	22.	6.8	2100					
53	72.0	28.	6.7	2050					

*Start-up date was 3/17/72.

TABLE A50

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 44
(STONE #1337, 1/4 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	100.	6.2	2000	5.5	11.0	294.	999.	14.4
2	72.0	79.	6.3	2000					
3	72.0	90.	6.3	1950					
4	72.0	76.	5.9	1900					
5	72.0	140.	6.0	1950					
6	72.0	220.	6.0	1700					
7	72.0	260.	6.0	1700	22.0	2.7	224.	1035.	36.0
8	72.0	220.	6.3	1650					
9	72.0	166.	6.2	1650					
10	72.0	150.	6.3	1750					
11	72.0	122.	6.5	1950					
12	72.0	140.	6.4	1800					
13	72.0	90.	6.7	2000					
14	72.0	130.	6.2	1900	5.0	5.4	252.	1105.	46.8
15	72.0	96.	5.4	1800					
16	72.0	104.	6.3	1700					
17	72.0	100.	6.2	1650					
18	72.0	90.	6.7	2050					
19	72.0	100.	6.7	2200					
20	72.0	96.	6.8	2000					
21	72.0	100.	7.3	2150	40.0	34.0	235.	1114.	10.8
22	72.0	90.	7.0	1800					
23	72.0	90.	7.0	1900					
24	72.0	80.	6.7	1850					
25	72.0	70.	6.5	1800					
26	72.0	64.	6.6	1900					
27	72.0	68.	6.7	1850					
28	72.0	65.	6.4	1850	40.0	24.0	255.	1021.	26.9
29	72.0	60.	6.4	1950					
30	72.0	52.	6.7	1750					
31	72.0	32.	7.0	1700					
32	72.0	40.	7.3	1650					
33	72.0	32.	7.1	1850					
34	72.0	28.	6.8	2000					
35	72.0	28.	6.8	2050	8.0	10.0	275.	1151.	8.1
36	72.0	24.	6.9	2000					
37	72.0	32.	6.7	1950					
38	72.0	28.	6.6	1950					
39	72.0	16.	7.1	1850					
40	72.0	32.	7.2	1850					
41	72.0	16.	6.7	1950					
42	72.0	19.	6.8	2100	7.0	11.0	297.	1178.	< 4.0
43	72.0	11.	7.1	2050					
44	72.0	11.	7.3	2050					
45	72.0	18.	7.0	1950					
46	72.0	10.	6.5	1850					
47	72.0	10.	6.9	1950					
48	72.0	10.	6.5	2050					
49	72.0	13.	6.7	1950	1.0	6.3	226.	1149.	57.6
50	72.0	39.	6.6	2050					
51	72.0	49.	6.7	1800					
52	72.0	54.	6.7	1900					
53	72.0	68.	6.7	2100					

*Start-up date was 3/17/72.

TABLE A51

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 45
(STONE #1337, 1/2 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	36.0	3320.	3.2	1750	35.0	174.	115.	1053.	504.
2	35.0	3300.	2.9	2000					
3	35.0	3300.	3.0	1850					
4	36.0	3180.	2.8	1900					
5	21.5	3200.	2.9	1750					
6	29.0	3080.	2.8	1750					
7	31.0	340.	3.0	1850	100.	190.	97.	1067.	695.
8	31.0	2800.	2.9	1850					
9	31.5	2680.	2.9	1650					
10	32.0	2560.	2.9	1850					
11	33.5	2420.	2.5	2400					
12	34.0	2100.	2.7	2350					
13	33.5	1940.	2.9	2050					
14	34.0	1710.	2.8	1900	80.0	180.	92.	1066.	512.
15	35.0	1760.	2.9	2150					
16	33.5	1590.	2.6	1850					
17	35.0	1530.	2.7	1600					
18	35.5	1460.	3.1	2200					
19	72.0	2960.	3.0	1900					
20	72.0	2960.	2.9	2050					

*Start-up date was 3/17/72.

TABLE A52

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 46
(STONE #1337, 1/2" x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (µmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	260.	5.0	1700	25.0	73.0	215.	1028.	86.4
2	41.0	97.	5.3	1850					
3	72.0	70.	5.4	1800					
4	72.0	60.	5.3	1800					
5	72.0	74.	5.2	1900					
6	72.0	124.	5.2	1650					
7	72.0	75.	5.2	1750	6.0	8.5	236.	1054.	21.6
8	72.0	58.	5.6	1700					
9	72.0	64.	6.2	1650					
10	72.0	70.	6.1	1700					
11	72.0	54.	6.7	1700					
12	72.0	50.	6.0	1850					
13	72.0	40.	5.7	1900					
14	72.0	60.	6.1	1850	< 1.0	0.29	252.	1103.	32.2
15	72.0	49.	5.8	1850					
16	72.0	45.	5.8	1700					
17	72.0	60.	5.6	1600					
18	72.0	34.	6.3	2000					
19	72.0	40.	6.2	2100					
20	72.0	72.	6.2	1950					
21	72.0	40.	7.4	1950	< 1.0	1.9	240.	1076.	10.8
22	72.0	50.	7.0	1850					
23	72.0	45.	6.9	1850					
24	72.0	40.	6.9	1850					
25	72.0	44.	6.7	1800					
26	72.0	44.	6.7	1800					
27	72.0	48.	6.7	1800					
28	72.0	31.	6.8	1900	< 1.0	0.04	263.	1101.	8.5
29	72.0	36.	6.8	1900					
30	72.0	36.	6.8	1700					
31	72.0	36.	6.8	1550					
32	72.0	52.	7.4	1450					
33	72.0	40.	7.2	1900					
34	72.0	44.	6.6	1950					
35	72.0	46.	6.7	1950	< 1.0	7.0	260.	1072.	11.5
36	72.0	38.	6.8	2000					
37	72.0	24.	6.7	1850					
38	72.0	28.	7.0	1950					
39	72.0	25.	5.6	1700					
40	72.0	28.	6.3	1900					
41	72.0	32.	6.7	1900					
42	72.0	32.	6.8	2000	< 1.0	0.05	287.	1138.	< 4.0
43	72.0	24.	7.8	1800					
44	72.0	28.	7.2	2000					
45	72.0	32.	6.9	1800					
46	72.0	26.	6.3	1800					
47	72.0	28.	6.6	1900					
48	72.0	34.	6.1	1900					
49	72.0	38.	6.4	1800	4.0	13.0	198.	1075.	< 4.0
50	72.0	29.	6.9	2150					
51	72.0	35.	6.6	1850					
52	72.0	28.	6.7	2050					
53	72.0	36.	6.7	2100					

*Start-up date was 3/17/72.

TABLE A53

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 47
(STONE #1337, 1 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	20.0	3300.	2.9	1850	37.0	178.	110.	1039.	374.
2	21.0	3280.	2.7	2200					
3	21.5	3140.	2.8	2000					
4	72.0	3000.	2.6	2100					
5	12.0	3060.	2.7	1900					
6	16.5	2940.	2.7	1850					
7	16.5	2860.	2.9	1950	90.0	194.	87.	999.	727.
8	18.0	2720.	2.8	1950					
9	18.0	2580.	2.8	1750					
10	19.0	2400.	2.8	1950					
11	19.5	2200.	2.4	2600					
12	19.5	1920.	2.6	2550					
13	19.5	1800.	2.8	2150					
14	13.0	1400.	2.8	2150	90.0	181.	82.	1141.	708.
15	19.0	1600.	2.9	2000					
16	17.0	1430.	2.5	2000					
17	19.0	1400.	2.6	1700					
18	17.0	1320.	3.0	2350					
19	29.5	3240.	2.9	2050					
20	35.0	3120.	2.8	2200					

*Start-up date was 3/17/72.

TABLE A54

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 48
(STONE #1337, 1 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	210.	4.8	1700	35.0	84.0	206.	1030.	144.
2	72.0	150.	4.7	1750					
3	72.0	110.	5.1	1700					
4	72.0	72.	5.3	1700					
5	72.0	100.	5.2	1850					
6	72.0	84.	5.1	1650					
7	72.0	70.	5.0	1750	21.2	27.0	231.	1095.	< 4.0
8	72.0	84.	5.5	1650					
9	72.0	86.	5.8	1650					
10	72.0	190.	6.0	1650					
11	72.0	80.	5.7	1800					
12	72.0	80.	5.8	1750					
13	72.0	80.	5.4	1850					
14	72.0	90.	6.0	1850	13.0	21.0	240.	1101.	28.9
15	72.0	72.	5.9	1850					
16	72.0	66.	5.6	1650					
17	72.0	80.	5.8	1600					
18	72.0	72.	6.0	2050					
19	72.0	92.	5.8	1900					
20	72.0	72.	6.0	1900					
21	72.0	75.	7.0	1850	40.0	42.0	228.	1119.	< 4.0
22	72.0	80.	6.9	1800					
23	72.0	75.	6.8	1800					
24	72.0	65.	6.7	1850					
25	72.0	56.	6.6	1800					
26	72.0	64.	6.6	1850					
27	72.0	68.	6.5	1750					
28	72.0	70.	6.2	1850	30.0	29.0	238.	1016.	15.7
29	72.0	68.	6.4	1900					
30	72.0	72.	6.7	1600					
31	72.0	72.	6.7	1450					
32	72.0	88.	7.0	1450					
33	72.0	84.	6.8	1750					
34	72.0	88.	6.4	1850					
35	72.0	84.	6.4	1900	26.0	28.0	238.	1075.	12.7
36	72.0	86.	6.5	1900					
37	72.0	100.	6.4	1750					
38	72.0	88.	6.4	1800					
39	72.0	80.	6.1	1650					
40	72.0	68.	6.3	1750					
41	72.0	76.	6.4	1850					
42	72.0	72.	6.6	1950	28.0	32.0	255.	1123.	< 4.0
43	72.0	70.	6.7	1850					
44	72.0	90.	7.0	1850					
45	72.0	72.	6.7	1650					
46	72.0	64.	6.0	1850					
47	72.0	64.	6.2	1850					
48	72.0	64.	5.9	1900					
49	72.0	76.	6.2	1750	25.0	27.0	176.	1062.	50.0
50	72.0	175.	6.3	2050					
51	72.0	74.	6.5	1800					
52	72.0	76.	6.6	1900					
53	72.0	79.	6.6	2000					

*Start-up date was 3/17/72.

TABLE A55

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 49
(STONE #1809, 1/2 x 0 SIZE CONTAINING 10% SLAG)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	600.	5.4	2000	190.	170.	350.	1268.	320.
2	72.0	400.	6.5	1900					
3	72.0	325.	5.6	1850					
4	72.0	265.	5.3	1850					
5	72.0	210.	5.3	1850					
6	72.0	188.	5.5	1850					
7	72.0	172.	5.6	1850	160.	156.	338.	1150.	324.
8	72.0	168.	5.5	1750					
9	72.0	180.	5.7	2200					
10	72.0	169.	5.7	1650					
11	72.0	174.	5.8	1650					
12	72.0	200.	6.0	1700					
13	72.0	166.	5.9	1850					
14	72.0	170.	5.9	1750	160.	149.	280.	1121.	216.
15	72.0	170.	2.8	2100					
16	72.0	160.	6.0	1800					
17	72.0	150.	5.2	1750					
18	72.0	141.	5.8	1650					
19	72.0	160.	5.5	1650					
20	72.0	144.	6.1	1950					
21	72.0	146.	6.2	1650	140.	146.	270.	1096.	212.
22	72.0	152.	6.1	1850					
23	72.0	150.	6.5	1800					
24	72.0	140.	6.5	1650					
25	72.0	130.	6.6	1600					
26	72.0	110.	6.6	1700					
27	72.0	110.	6.4	1500					
28	72.0	96.	6.4	1700	130.	128.	272.	947.	161.
29	72.0	84.	6.5	1700					
30	72.0	80.	6.2	1700					
31	72.0	76.	6.4	1750					
32	72.0	72.	6.7	1400					
33	72.0	64.	6.7	1350					
34	72.0	64.	6.8	1350					
35	72.0	72.	6.6	1650	80.0	114.	315.	900.	18.8
36	72.0	68.	5.9	1750					
37	72.0	70.	6.4	1900					
38	72.0	68.	5.9	1850					
39	72.0	100.	6.4	1750					
40	72.0	76.	6.4	1750					
41	72.0	55.	6.2	1400					
42	72.0	64.	6.7	1650	90.0	117.	297.	923.	55.0
43	72.0	60.	6.4	1800					
44	72.0	64.	6.5	2050					
45	72.0	56.	6.5	1900					
46	72.0	60.	6.6	1700					
47	72.0	60.	6.6	1400					
48	72.0	56.	6.2	1850					
49	72.0	56.	6.4	1800	90.0	123.	338.	1039.	23.0
50	72.0	59.	6.1	1800					
51	72.0	72.	6.2	1700					
52	72.0	80.	6.2	2000					
53	72.0	59.	6.5	1650					

*Start-up date was 3/15/72.

TABLE A56

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 50
(STONE #1809, 1 x 0 SIZE CONTAINING 10% SLAG)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	40.0	3785.	2.9	2150	200.	194.	233.	1196.	562.
2	35.0	3800.	3.0	2100					
3	35.5	3785.	3.2	2050					
4	33.0	3840.	2.9	2150					
5	34.5	2900.	2.6	2500					
6	34.5	3720.	2.8	2450					
7	34.0	3660.	2.8	2100	200.	202.	171.	1220.	763.
8	33.0	3560.	2.7	2050					
9	28.5	3180.	2.9	2050					
10	28.0	3000.	2.9	1900					
11	30.0	2900.	3.1	1800					
12	29.5	2760.	3.0	1900					
13	27.5	2600.	2.5	2900					
14	28.0	2520.	2.5	2950	210.	195.	100.	1099.	702.
15	29.0	2570.	2.8	2100					
16	28.5	2310.	2.8	2250					
17	28.0	2280.	2.5	2300					
18	24.0	2190.	2.6	2050					
19	28.0	2130.	2.8	1700					
20	25.0	1920.	3.1	2350					

*Start-up date was 3/15/72.

TABLE A57

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 51
(STONE #1809, 1/2 x 0 SIZE CONTAINING 5% BENTONITE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	65.	5.4	2000	150.	141.	327.	1264.	216.
2	72.0	40.	5.5	2050					
3	72.0	25.	5.7	2050					
4	72.0	18.	5.4	2150					
5	72.0	20.	5.4	2150					
6	72.0	13.	5.4	2150					
7	72.0	12.	5.6	2100	40.0	154.	305.	1150.	324.
8	72.0	26.	5.1	1800					
9	72.0	30.	5.5	1850					
10	72.0	22.	5.6	1800					
11	72.0	26.	6.3	1750					
12	72.0	25.	6.0	1900					
13	72.0	10.	6.8	2050					
14	72.0	30.	6.3	1900	40.0	49.9	390.	1075.	< 4.0
15	72.0	15.	5.5	2050					
16	72.0	9.	6.0	2050					
17	72.0	8.	5.6	1950					
18	72.0	85.	6.1	1850					
19	72.0	20.	6.0	1300					
20	72.0	12.	6.5	2150					
21	72.0	12.	6.6	2000	30.0	32.0	415.	1140.	< 4.0
22	72.0	14.	6.7	2100					
23	72.0	15.	6.7	2000					
24	72.0	20.	6.7	2000					
25	72.0	10.	6.7	1900					
26	72.0	15.	6.8	1900					
27	72.0	14.	6.8	1750					
28	72.0	14.	6.6	1800	5.0	42.9	343.	911.	269.
29	72.0	13.	6.6	1800					
30	72.0	10.	6.5	1800					
31	72.0	14.	6.6	1800					
32	72.0	40.	6.7	1250					
33	72.0	52.	6.7	1200					
34	72.0	48.	6.7	1200					
35	72.0	22.	6.5	1650	40.0	64.4	310.	942.	23.0
36	72.0	16.	6.3	1800					
37	72.0	18.	6.5	1950					
38	72.0	14.	6.3	1900					
39	72.0	12.	6.6	1850					
40	72.0	18.	6.7	1850					
41	72.0	9.	6.5	1600					
42	72.0	12.	7.3	1600	4.0	10.0	350.	1364.	< 4.0
43	72.0	8.	6.6	1800					
44	72.0	8.	6.7	1900					
45	72.0	7.	6.7	1800					
46	72.0	5.	6.7	1800					
47	72.0	8.	6.8	1650					
48	72.0	6.	6.4	1700					
49	72.0	5.	6.6	1850	10.0	26.0	388.	1002.	4.0
50	72.0	6.	6.3	1850					
51	72.0	10.	6.4	1750					
52	72.0	6.	6.4	1900					
53	72.0	6.	6.7	1700					

*Start-up date was 3/15/72.

TABLE A58

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 52
(STONE #1809, 1 x 0 SIZE CONTAINING 5% BENTONITE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	35.0	3785.	2.5	2750	190.	198.	169.	1178.	735.
2	25.5	3700.	2.6	2350					
3	24.5	3630.	3.2	1950					
4	25.0	3700.	2.1	2550					
5	26.5	3590.	2.5	2750					
6	28.0	3560.	2.5	2900					
7	26.5	3440.	2.6	2300	190.	201.	147.	1230.	756.
8	28.5	3300.	2.5	2300					
9	27.5	3060.	2.8	2300					
10	27.5	2920.	2.8	2050					
11	28.0	2820.	2.9	1800					
12	28.0	2650.	2.8	1900					
13	29.5	2600.	2.2	3300					
14	28.0	2450.	2.4	3050	200.	201.	77.	1111.	850.
15	28.0	2390.	2.7	2200					
16	29.0	2350.	2.6	2300					
17	29.0	2100.	2.6	2350					
18	29.0	2130.	2.5	2150					
19	30.0	2140.	2.7	1650					
20	31.0	1780.	3.0	2450					

*Start-up date was 3/15/72.

TABLE A59

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 53
(STONE #1809, 1/2 x 0 SIZE CONTAINING 10% FLYASH)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	290.	6.3	2150	80.0	86.9	480.	1292.	5.5
2	72.0	125.	6.1	2000					
3	72.0	100.	5.5	2000					
4	72.0	120.	5.4	1950					
5	72.0	110.	5.6	1900					
6	72.0	111.	5.4	1950					
7	72.0	66.	5.6	1950	50.0	24.5	466.	1180.	14.4
8	72.0	104.	5.3	1800					
9	72.0	85.	5.8	1850					
10	72.0	74.	5.7	1750					
11	72.0	72.	6.4	1750					
12	72.0	75.	6.2	1850					
13	72.0	60.	5.9	1950					
14	72.0	75.	6.3	1800	60.0	18.5	402.	993.	< 4.0
15	72.0	80.	5.6	2000					
16	72.0	90.	6.6	1850					
17	72.0	84.	5.7	1850					
18	72.0	76.	5.8	1700					
19	72.0	130.	5.6	1550					
20	72.0	180.	6.2	2000					
21	72.0	146.	6.5	1800	50.0	100.	348.	1087.	< 4.0
22	72.0	68.	6.8	2000					
23	72.0	55.	7.1	2000					
24	72.0	60.	7.2	1800					
25	72.0	55.	7.2	1900					
26	72.0	40.	7.0	1900					
27	72.0	32.	7.0	1750					
28	72.0	30.	7.0	1750	< 1.0	< 0.03	378.	948.	< 4.0
29	72.0	36.	6.8	1700					
30	72.0	27.	7.1	1800					
31	72.0	26.	7.0	1750					
32	72.0	32.	7.1	1450					
33	72.0	28.	7.2	1400					
34	72.0	24.	7.2	1450					
35	72.0	24.	7.4	1600	6.5	< 0.03	343.	837.	7.7
36	72.0	24.	6.8	1850					
37	72.0	22.	7.1	1900					
38	72.0	20.	6.8	1900					
39	72.0	32.	7.0	1800					
40	72.0	24.	6.8	1850					
41	72.0	25.	6.9	1550					
42	72.0	16.	7.1	1600	< 1.0	0.10	332.	812.	< 4.0
43	72.0	20.	6.9	1750					
44	72.0	18.	7.0	1950					
45	72.0	16.	7.2	1900					
46	72.0	18.	7.1	1850					
47	72.0	36.	7.0	1600					
48	72.0	14.	6.7	1600					
49	72.0	14.	6.9	1800	< 1.0	< 0.03	384.	937.	< 4.0
50	72.0	14.	6.5	1900					
51	72.0	19.	7.0	1800					
52	72.0	18.	6.6	2000					
53	72.0	19.	7.0	1800					

*Start-up date was 3/15/72.

TABLE A60

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 54
(STONE #1809, 1 x 0 SIZE CONTAINING 10% FLYASH)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	435.	5.7	2100	130.	127.	412.	1268.	79.0
2	72.0	280.	6.4	1650					
3	72.0	270.	6.0	1900					
4	72.0	230.	5.8	1900					
5	72.0	300.	5.8	1850					
6	72.0	340.	5.6	1800					
7	72.0	680.	4.6	1700	180.	148.	325.	1180.	205.
8	72.0	152.	5.6	1700					
9	72.0	130.	6.0	1750					
10	72.0	98.	6.0	1700					
11	72.0	52.	6.5	1750					
12	72.0	70.	6.5	1900					
13	72.0	40.	6.3	2050					
14	72.0	60.	6.4	1300	30.0	33.0	389.	1051.	10.8
15	72.0	40.	6.0	2100					
16	72.0	8.	6.7	1750					
17	72.0	10.	6.6	2050					
18	72.0	69.	6.1	1600					
19	72.0	70.	6.1	1550					
20	72.0	60.	6.3	1950					
21	72.0	60.	6.6	1650	90.0	94.4	328.	1115.	36.6
22	72.0	124.	5.6	1750					
23	72.0	85.	6.5	1800					
24	72.0	90.	6.7	1650					
25	72.0	80.	6.8	1600					
26	72.0	80.	6.7	1700					
27	72.0	68.	6.5	1600					
28	72.0	54.	6.5	1650	80.0	102.	277.	904.	134.
29	72.0	72.	6.4	1600					
30	72.0	51.	6.2	1600					
31	72.0	64.	6.3	1650					
32	72.0	72.	6.6	1250					
33	72.0	56.	6.6	1250					
34	72.0	9.	7.5	1700					
35	72.0	10.	7.6	1650	8.5	0.05	358.	914.	< 4.0
36	72.0	20.	7.1	1800					
37	72.0	14.	7.3	1850					
38	72.0	8.	7.0	1850					
39	72.0	18.	7.2	1900					
40	72.0	14.	7.0	1850					
41	72.0	21.	7.0	1650					
42	72.0	8.	7.5	1550	< 1.0	0.13	342.	861.	< 4.0
43	72.0	9.	7.1	1650					
44	72.0	8.	7.2	1800					
45	72.0	8.	7.0	1850					
46	72.0	9.	7.3	1900					
47	72.0	12.	7.3	1800					
48	72.0	8.	6.9	1600					
49	72.0	8.	7.1	1700	< 1.0	0.03	382.	989.	< 4.0
50	72.0	12.	6.8	1800					
51	72.0	20.	7.1	1750					
52	72.0	15.	6.9	1900					
53	72.0	17.	7.1	1800					

*Start-up date was 3/15/72.

TABLE A61

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 55
(STONE #1809, 1/8 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	845.	6.2	2150	110.	106.	475.	1258.	1.8
2	68.0	630.	5.7	1950					
3	72.0	570.	6.1	1950					
4	72.0	530.	6.0	2000					
5	72.0	460.	6.0	2000					
6	72.0	440.	5.8	2000					
7	72.0	460.	5.6	1350	90.0	100.	417.	1160.	18.0
8	72.0	424.	5.7	1650					
9	72.0	390.	6.0	1850					
10	72.0	360.	6.2	1700					
11	72.0	264.	6.4	1650					
12	72.0	230.	6.3	1800					
13	72.0	200.	6.3	2050					
14	72.0	210.	6.4	1900	60.0	54.9	403.	1037.	39.6
15	72.0	170.	6.1	2100					
16	72.0	150.	5.9	1950					
17	72.0	152.	6.5	2000					
18	72.0	122.	6.2	1800					
19	72.0	140.	6.3	1600					
20	72.0	120.	6.7	2100					
21	72.0	90.	6.8	1900	20.0	17.0	430.	1135.	7.2
22	72.0	90.	6.5	2100					
23	72.0	90.	6.7	1950					
24	72.0	80.	6.8	1800					
25	72.0	80.	6.8	1850					
26	72.0	40.	6.7	1850					
27	72.0	58.	6.8	1700					
28	72.0	54.	6.9	1800	1.0	3.5	411.	997.	< 4.0
29	72.0	46.	6.7	1900					
30	72.0	25.	6.9	1900					
31	72.0	47.	6.8	1900					
32	72.0	64.	7.0	1650					
33	72.0	44.	6.8	1650					
34	72.0	36.	7.5	1550					
35	72.0	44.	7.6	1620	2.5	<0.03	343.	788.	< 4.0
36	72.0	52.	7.0	1850					
37	72.0	56.	7.0	1900					
38	72.0	54.	6.9	1900					
39	72.0	70.	6.7	1850					
40	72.0	76.	6.5	1750					
41	72.0	43.	6.8	1650					
42	72.0	60.	7.1	1600	< 1.0	9.0	355.	788.	288.
43	72.0	72.	6.7	1900					
44	72.0	76.	6.7	1900					
45	72.0	67.	6.9	1950					
46	72.0	70.	7.0	1750					
47	72.0	72.	6.9	1700					
48	72.0	62.	6.2	1800					
49	72.0	100.	6.4	1800	33.0	102.	363.	1041.	9.0
50	72.0	112.	6.2	1800					
51	72.0	120.	6.2	1700					
52	72.0	100.	6.2	1800					
53	72.0	100.	6.7	1900					

*Start-up date was 3/15/72.

TABLE A62

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 56
(STONE #1809, 1/4 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	1100.	5.6	2000	160.	145.	376.	1211.	193.
2	72.0	850.	6.1	1550					
3	40.5	790.	6.2	1800					
4	41.0	785.	6.0	1800					
5	72.0	770.	5.8	1850					
6	72.0	800.	5.5	1800					
7	72.0	840.	5.8	1700	170.	157.	280.	1160.	288.
8	72.0	1040.	4.8	1650					
9	72.0	1070.	5.0	1650					
10	72.0	1040.	4.9	1550					
11	72.0	1120.	4.9	1550					
12	72.0	1110.	4.4	1500					
13	72.0	1160.	3.2	1900					
14	72.0	1120.	3.3	1900	180.	166.	197.	1114.	533.
15	72.0	1070.	4.1	1700					
16	72.0	960.	3.7	1750					
17	72.0	940.	3.5	1800					
18	72.0	930.	3.4	1600					
19	72.0	920.	3.7	1500					
20	72.0	920.	3.7	1900					
21	72.0	920.	3.8	1650	180.	166.	185.	1106.	418.
22	72.0	720.	4.1	1900					
23	72.0	765.	3.8	1850					
24	72.0	620.	4.2	1650					
25	72.0	660.	6.5	1400					
26	72.0	480.	5.1	1500					
27	72.0	480.	6.4	1300					
28	72.0	520.	5.0	1650	160.	143.	204.	1003.	326.
29	72.0	520.	4.4	1550					
30	72.0	55.	4.8	1400					
31	72.0	520.	4.7	1500					
32	72.0	232.	6.4	1250					
33	72.0	228.	6.2	1200					
34	72.0	168.	6.8	1250					
35	72.0	248.	5.8	1600	160.	120.	250.	969.	251.
36	72.0	272.	6.6	1600					
37	72.0	400.	4.1	1800					
38	72.0	390.	4.9	1700					
39	72.0	400.	4.7	1600					
40	72.0	380.	4.6	1550					
41	72.0	200.	6.7	1300					
42	72.0	304.	5.5	1450	160.	142.	182.	898.	< 4.0
43	72.0	348.	4.2	1700					
44	72.0	400.	4.0	1650					
45	72.0	410.	4.4	1600					
46	72.0	340.	5.4	1500					
47	72.0	200.	6.5	1200					
48	72.0	280.	3.3	1750					
49	72.0	276.	4.3	1700	160.	142.	228.	1067.	393.
50	72.0	288.	4.0	1550					
51	72.0	268.	2.9	1750					
52	72.0	280.	3.9	1750					
53	72.0	280.	3.9	1650					

*Start-up date was 3/15/72.

TABLE A63

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 57
(STONE #1809, 1/2 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (µmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	31.0	3785.	3.4	1950	200.	195.	440.	1226.	485.
2	30.5	3200.	3.1	1550					
3	34.0	3480.	3.5	1850					
4	36.0	3525.	3.2	1950					
5	37.0	2490.	3.0	2150					
6	32.0	3380.	2.8	2200					
7	39.5	3240.	3.0	1800	190.	199.	200.	1170.	626.
8	41.5	3200.	3.0	1850					
9	40.5	3000.	3.3	1850					
10	40.5	2880.	3.3	1700					
11	40.5	2800.	3.3	1700					
12	40.5	2660.	3.0	1850					
13	42.0	2520.	2.7	2350					
14	43.5	1500.	2.8	2400	200.	200.	145.	1138.	691.
15	45.5	2430.	3.2	1900					
16	46.5	2280.	3.1	1850					
17	46.0	2050.	2.7	2050					
18	47.5	2050.	2.8	1850					
19	49.0	2060.	2.9	1600					
20	50.5	1760.	3.3	2150					

*Start-up date was 3/15/72.

TABLE A64

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 58
(STONE #1809, 1/2 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	41.0	3785.	3.4	1950	190.	191.	259.	1227.	478.
2	39.5	3740.	2.9	2050					
3	40.0	3785.	3.2	1800					
4	41.0	3810.	3.1	2000					
5	44.0	3770.	2.9	2200					
6	47.5	3640.	2.7	2350					
7	50.0	3560.	2.9	1900	200.	196.	200.	1190.	666.
8	50.0	3460.	2.8	1900					
9	52.0	3150.	3.1	1900					
10	50.0	3000.	3.1	1850					
11	46.0	2620.	3.0	1750					
12	48.0	2450.	3.0	1900					
13	50.5	2420.	2.6	2600					
14	56.0	1300.	2.8	2500	200.	194.	137.	1087.	688.
15	60.0	2210.	3.0	2000					
16	61.0	2000.	3.1	1900					
17	62.0	1920.	2.8	2050					
18	64.0	1900.	2.7	1850					
19	65.0	870.	2.9	1550					
20	67.0	1640.	3.2	2200					
21	72.0	1280.	3.2	1400	200.	190.	155.	1097.	490.
22	72.0	820.	3.2	1950					
23	72.0	870.	3.2	2000					
24	72.0	810.	3.3	1900					
25	72.0	740.	6.4	1300					
26	72.0	480.	4.4	1400					
27	72.0	480.	6.0	1200					
28	72.0	440.	3.7	1650	160.	165.	169.	988.	442.
29	72.0	420.	3.7	1600					
30	72.0	370.	4.2	1450					
31	72.0	360.	4.0	1550					
32	72.0	100.	6.4	1250					
33	72.0	56.	6.4	1300					
34	72.0	52.	6.6	1300					
35	72.0	208.	3.9	1650	160.	170.	190.	1035.	449.
36	72.0	204.	3.9	1650					
37	72.0	250.	3.4	1900					
38	72.0	240.	3.8	1700					
39	72.0	210.	4.1	1600					
40	72.0	200.	4.0	1550					
41	72.0	57.	6.7	1300					
42	72.0	136.	5.3	1450	150.	147.	172.	901.	332.
43	72.0	128.	3.9	1700					
44	72.0	124.	4.5	1600					
45	72.0	120.	4.6	1600					
46	72.0	110.	4.9	1450					
47	72.0	108.	6.4	1300					
48	72.0	96.	3.5	1650					
49	72.0	96.	4.1	1650	150.	132.	221.	1051.	368.
50	72.0	96.	3.7	1600					
51	72.0	110.	3.2	1600					
52	72.0	110.	3.4	1700					
53	72.0	100.	3.4	1700					

*Start-up date was 3/15/72.

TABLE A65

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 59
(STONE #1809, 1 x 50 M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	29.0	3735.	4.6	1850	190.	196.	257.	1241.	481.
2	34.5	3500.	3.1	2000					
3	36.0	3785.	3.2	1850					
4	34.0	3910.	3.0	2050					
5	72.5	3820.	2.4	2150					
6	47.0	3680.	2.8	2250					
7	51.0	3580.	2.9	1850	200.	200.	210.	1180.	630.
8	48.5	3320.	3.0	1800					
9	45.5	3020.	3.2	1900					
10	53.0	2820.	3.2	1750					
11	60.5	2800.	3.2	1650					
12	63.0	2570.	3.1	1850					
13	72.0	2420.	2.6	2500					
14	72.0	1970.	2.9	2250	200.	178.	155.	1104.	587.
15	72.0	1900.	3.2	1900					
16	72.0	1460.	3.2	1800					
17	72.0	1380.	3.0	1900					
18	65.0	1180.	2.9	1800					
19	72.0	1020.	3.0	1600					
20	72.0	1040.	3.3	2200					
21	61.0	900.	3.3	1600	200.	192.	158.	1107.	508.
22	72.0	500.	3.3	1950					
23	72.0	845.	3.2	2000					
24	72.0	710.	3.4	2000					
25	72.0	730.	6.1	1250					
26	72.0	515.	4.1	1400					
27	72.0	640.	5.9	1150					
28	72.0	640.	3.2	2000	180.	201.	149.	1034.	545.
29	72.0	720.	3.4	1750					
30	72.0	760.	3.5	1450					
31	72.0	700.	3.2	1650					
32	72.0	413.	6.4	1100					
33	72.0	364.	6.2	1100					
34	72.0	292.	6.4	1100					
35	72.0	600.	3.0	2100	190.	187.	160.	1066.	584.
36	72.0	564.	3.0	1950					
37	72.0	600.	2.7	2450					
38	72.0	560.	2.8	2100					
39	72.0	520.	3.0	1850					
40	72.0	580.	2.9	1900					
41	72.0	250.	6.1	1100					
42	72.0	432.	3.7	1600	180.	179.	125.	904.	449.
43	72.0	510.	2.9	2100					
44	72.0	510.	3.1	1900					
45	72.0	490.	3.2	1800					
46	72.0	490.	3.4	1700					
47	72.0	236.	6.2	1100					
48	72.0	456.	2.5	2300					
49	72.0	408.	2.9	2050	200.	174.	155.	1082.	553.
50	72.0	384.	2.7	1900					
51	72.0	420.	2.3	2300					
52	72.0	420.	2.7	2150					
53	72.0	420.	2.9	2050					

*Start-up date was 3/15/72.

TABLE A66

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 60
(STONE #1809, 1 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	32.5	3785.	3.2	1900	200.	191.	245.	1216.	471.
2	23.0	3600.	5.8	2100					
3	22.0	3480.	2.2	2000					
4	22.0	3810.	2.2	2400					
5	23.0	3580.	2.7	2400					
6	23.0	3440.	2.5	2550					
7	22.5	3340.	2.6	2100	200.	197.	177.	1170.	742.
8	23.0	3220.	2.5	2000					
9	21.0	2920.	2.9	2050					
10	21.0	2760.	2.8	2100					
11	21.0	2720.	2.8	1850					
12	72.0	2570.	2.8	2050					
13	21.5	2480.	2.4	2950					
14	20.5	2430.	2.6	2800	200.	201.	113.	1125.	763.
15	20.5	2340.	2.7	2100					
16	19.5	2240.	3.0	1950					
17	19.5	2000.	2.8	2150					
18	19.0	2060.	2.5	1950					
19	19.0	2040.	2.8	1600					
20	18.0	1460.	3.1	2250					

*Start-up date was 3/15/72.

TABLE A67

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 61
(STONE #1355, 1/8 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	85.	6.2	2250	50.0	51.9	515.	1276.	21.6
2	72.0	60.	6.3	2050					
3	72.0	75.	5.8	2100					
4	72.0	83.	5.4	2000					
5	72.0	90.	5.5	1950					
6	72.0	78.	5.4	1950					
7	72.0	96.	5.4	2050	< 1.0	109.	435.	1137.	25.2
8	72.0	150.	5.2	1800					
9	72.0	140.	5.6	1850					
10	72.0	136.	5.7	1800					
11	72.0	130.	6.1	1750					
12	72.0	160.	5.9	1800					
13	72.0	134.	5.8	2050					
14	72.0	150.	6.1	1900	180.	102.	383.	1026.	21.6
15	72.0	130.	5.5	2050					
16	72.0	130.	5.9	1900					
17	72.0	122.	6.1	2000					
18	72.0	116.	5.7	1800					
19	72.0	120.	5.8	1550					
20	72.0	112.	6.4	2100					
21	72.0	120.	5.9	1550	50.0	84.0	365.	1004.	10.8
22	72.0	104.	6.2	2000					
23	72.0	100.	6.1	1900					
24	72.0	90.	6.3	1650					
25	72.0	100.	6.4	1800					
26	72.0	80.	6.1	1800					
27	72.0	80.	6.4	1650					
28	72.0	90.	6.1	1700	80.0	107.	331.	973.	46.0
29	72.0	96.	6.4	1700					
30	72.0	93.	6.1	1650					
31	72.0	100.	6.0	1750					
32	72.0	50.	6.7	1350					
33	72.0	40.	6.7	1350					
34	72.0	36.	6.6	1350					
35	72.0	84.	6.2	1600	60.0	95.0	323.	912.	7.7
36	72.0	84.	5.9	1700					
37	72.0	74.	6.3	1900					
38	72.0	84.	5.9	1800					
39	72.0	76.	6.2	1850					
40	72.0	74.	6.0	1700					
41	72.0	40.	6.3	1400					
42	72.0	68.	6.2	1600	30.0	68.9	322.	888.	< 4.0
43	72.0	68.	5.9	1650					
44	72.0	72.	6.0	1850					
45	72.0	66.	5.7	1850					
46	72.0	68.	5.8	1750					
47	72.0	40.	6.5	1400					
48	72.0	68.	5.8	1850					
49	72.0	64.	5.9	1800	80.0	116.	345.	1018.	6.0
50	72.0	62.	5.8	1800					
51	72.0	66.	5.8	1650					
52	72.0	69.	5.5	2000					
53	72.0	65.	5.5	1850					

*Start-up date was 3/15/72.

TABLE A68

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 62
(STONE #1355, 1/4 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (µmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	525.	5.9	2200	110.	102.	506.	1259.	< 4.0
2	72.0	310.	3.0	2050					
3	72.0	300.	6.0	2000					
4	72.0	290.	5.8	2050					
5	72.0	160.	5.9	1950					
6	72.0	146.	5.8	1950					
7	72.0	126.	5.8	2000	40.0	44.9	424.	1118.	< 4.0
8	72.0	242.	5.6	1900					
9	72.0	270.	6.0	1850					
10	72.0	216.	6.1	1800					
11	72.0	184.	6.3	1750					
12	72.0	180.	6.2	1850					
13	72.0	156.	6.1	2100					
14	72.0	160.	6.3	1850	100.	65.9	395.	1037.	< 4.0
15	72.0	160.	6.1	2050					
16	72.0	140.	5.6	1850					
17	72.0	134.	6.0	1900					
18	72.0	128.	6.1	1800					
19	72.0	140.	6.2	1650					
20	72.0	124.	6.5	2000					
21	72.0	120.	6.5	1450	40.0	61.9	388.	1038.	< 4.0
22	72.0	120.	6.5	2000					
23	72.0	120.	6.8	1850					
24	72.0	100.	6.6	1800					
25	72.0	100.	6.7	1850					
26	72.0	80.	6.5	1900					
27	72.0	80.	6.6	1750					
28	72.0	80.	6.4	1850	30.0	44.9	400.	993.	15.4
29	72.0	96.	6.4	1750					
30	72.0	100.	6.3	1700					
31	72.0	104.	6.3	1800					
32	72.0	64.	6.8	1450					
33	72.0	56.	6.8	1400					
34	72.0	48.	7.0	1450					
35	72.0	72.	6.8	1700	5.0	19.9	365.	881.	9.6
36	72.0	76.	6.5	1800					
37	72.0	83.	6.4	1950					
38	72.0	80.	6.3	1900					
39	72.0	54.	6.2	1750					
40	72.0	88.	6.6	1800					
41	72.0	40.	6.7	1500					
42	72.0	48.	6.9	1650	< 1.0	3.5	75.	871.	< 4.0
43	72.0	52.	6.5	1900					
44	72.0	60.	6.5	1950					
45	72.0	49.	6.5	1950					
46	72.0	50.	5.9	1850					
47	72.0	40.	6.8	1550					
48	72.0	44.	6.2	1650					
49	72.0	42.	6.4	1900	2.0	2.5	440.	1035.	< 4.0
50	72.0	44.	6.1	1900					
51	72.0	50.	6.3	1850					
52	72.0	46.	6.1	2050					
53	72.0	52.	6.3	1900					

*Start-up date was 3/15/72.

TABLE A69

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 63
(STONE #1355, 1/2 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	39.0	3785.	3.3	1900	200.	178.	251.	1263.	444.
2	45.5	3730.	4.5	1550					
3	52.0	3740.	3.5	1750					
4	33.0	3620.	3.3	1900					
5	23.0	3230.	3.1	2000					
6	72.0	1920.	3.3	1850					
7	72.0	1440.	3.3	1800	180.	185.	195.	1179.	292.
8	72.0	2100.	3.0	1800					
9	72.0	1050.	3.8	1700					
10	72.0	1300.	4.0	1550					
11	72.0	820.	3.7	1500					
12	72.0	750.	3.7	1650					
13	72.0	740.	3.2	1850					
14	72.0	680.	3.4	1850	70.0	176.	187.	1077.	479.
15	72.0	620.	4.0	1750					
16	72.0	550.	3.4	1750					
17	72.0	540.	3.5	1750					
18	72.0	500.	3.5	1650					
19	72.0	480.	3.5	1400					
20	72.0	460.	4.2	2000					
21	72.0	440.	4.2	1600	190.	166.	190.	1050.	422.
22	72.0	360.	4.1	1800					
23	72.0	370.	4.1	1800					
24	72.0	330.	5.0	1600					
25	72.0	310.	6.1	1450					
26	72.0	225.	5.1	1550					
27	72.0	220.	5.9	1300					
28	72.0	208.	4.9	1550	160.	140.	191.	968.	319.
29	72.0	176.	4.9	1650					
30	72.0	190.	4.8	1450					
31	72.0	164.	5.1	1550					
32	72.0	76.	6.6	1300					
33	72.0	48.	6.5	1350					
34	72.0	36.	6.7	1300					
35	72.0	152.	4.9	1550	170.	156.	200.	950.	373.
36	72.0	148.	5.0	1650					
37	72.0	160.	4.7	1750					
38	72.0	142.	5.0	1650					
39	72.0	224.	4.8	1550					
40	72.0	212.	4.7	1500					
41	72.0	73.	6.4	1250					
42	72.0	168.	5.2	1450	160.	147.	172.	904.	351.
43	72.0	164.	4.7	1650					
44	72.0	160.	5.2	1600					
45	72.0	150.	5.6	1600					
46	72.0	150.	5.8	1550					
47	72.0	84.	6.5	1250					
48	72.0	140.	4.6	1650					
49	72.0	132.	4.7	1650	170.	135.	222.	1064.	339.
50	72.0	128.	4.6	1600					
51	72.0	126.	4.2	1550					
52	72.0	135.	4.3	1700					
53	72.0	128.	4.4	1650					

*Start-up date was 3/15/72.

TABLE A70

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 64
(STONE #1355, 1/2 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	1470.	5.1	1950	170.	166.	352.	1240.	282.
2	72.0	1500.	2.8	2200					
3	72.0	1830.	4.6	1700					
4	72.0	2800.	3.6	1800					
5	70.0	2820.	3.3	1900					
6	72.0	2560.	2.9	1950					
7	72.0	1480.	3.4	1750	190.	191.	210.	1154.	623.
8	72.0	1800.	3.1	1750					
9	72.0	1280.	3.7	1700					
10	72.0	800.	3.7	1650					
11	72.0	1140.	3.5	1550					
12	72.0	1125.	3.4	1800					
13	72.0	1060.	3.1	1900					
14	72.0	940.	3.2	2000	190.	188.	175.	1099.	547.
15	72.0	900.	3.5	1800					
16	72.0	800.	3.4	1800					
17	72.0	760.	3.3	1800					
18	72.0	730.	3.2	1650					
19	72.0	700.	3.2	1400					
20	72.0	660.	3.7	1900					
21	72.0	600.	3.9	1550	200.	179.	180.	1035.	442.
22	72.0	360.	4.4	1800					
23	72.0	325.	4.4	1700					
24	72.0	270.	5.0	1550					
25	72.0	240.	6.0	1500					
26	72.0	170.	5.1	1550					
27	72.0	180.	6.0	1350					
28	72.0	192.	5.0	1550	150.	137.	219.	955.	269.
29	72.0	166.	5.2	1650					
30	72.0	90.	5.4	1500					
31	72.0	140.	5.5	1600					
32	72.0	62.	6.5	1400					
33	72.0	52.	6.3	1450					
34	72.0	40.	6.8	1400					
35	72.0	112.	5.8	1500	120.	124.	240.	911.	246.
36	72.0	120.	4.9	1650					
37	72.0	140.	4.7	1750					
38	72.0	124.	4.7	1650					
39	72.0	192.	4.7	1550					
40	72.0	184.	4.2	1500					
41	72.0	55.	6.3	1300					
42	72.0	140.	4.9	1450	160.	162.	170.	901.	345.
43	72.0	148.	3.8	1700					
44	72.0	144.	4.7	1600					
45	72.0	134.	4.8	1600					
46	72.0	130.	5.0	1500					
47	72.0	68.	6.4	1300					
48	72.0	128.	3.3	1750					
49	72.0	116.	4.0	1700	160.	190.	217.	1054.	381.
50	72.0	120.	4.1	1600					
51	72.0	120.	3.2	1600					
52	72.0	124.	3.6	1700					
53	72.0	124.	3.4	1700					

*Start-up date was 3/15/72.

TABLE A71

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 65
(STONE #1355, 1 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	21.0	3300.	3.3	1950	90.0	148.	250.	1175.	485.
2	22.0	3070.	3.4	1550					
3	23.0	2770.	3.2	1950					
4	24.0	2620.	3.0	2000					
5	24.0	2280.	2.8	2200					
6	28.0	2340.	2.7	2250					
7	28.5	2330.	2.6	2200	200.	219.	186.	1193.	769.
8	31.0	2240.	2.7	1950					
9	27.0	2160.	3.1	1950					
10	32.0	1650.	3.0	1900					
11	31.5	2430.	2.9	1850					
12	33.5	2480.	2.9	2100					
13	35.0	2360.	2.6	2450					
14	72.0	2200.	2.7	2600	210.	194.	132.	1122.	594.
15	43.0	2120.	3.0	1950					
16	43.5	2120.	3.0	1950					
17	46.0	2000.	2.7	2100					
18	47.0	1990.	2.6	2050					
19	48.0	1890.	2.9	1150					
20	46.0	1660.	3.1	2250					

*Start-up date was 3/15/72.

TABLE A72

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 66
(STONE #1355, 1 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	62.0	2340.	4.6	1850	170.	179.	287.	1239.	380.
2	50.0	2160.	3.7	1550					
3	49.0	2140.	3.6	1750					
4	46.0	2150.	3.2	1900					
5	48.0	2000.	3.0	2050					
6	48.5	2200.	2.8	2150					
7	48.5	1800.	2.8	2000	200.	192.	205.	1169.	695.
8	50.0	1700.	2.9	1700					
9	72.0	2740.	2.9	1900					
10	72.0	1660.	3.1	1750					
11	72.0	2400.	3.0	1700					
12	72.0	2010.	2.9	1900					
13	72.0	1800.	2.8	2250					
14	72.0	1510.	2.8	2300	200.	191.	152.	1116.	608.
15	72.0	1320.	3.2	1900					
16	72.0	1150.	3.2	1850					
17	72.0	1060.	3.0	1950					
18	72.0	930.	2.8	1900					
19	72.0	870.	2.9	1350					
20	72.0	800.	3.4	2100					
21	72.0	720.	3.5	1650	200.	180.	165.	1050.	511.
22	72.0	560.	3.7	1850					
23	72.0	420.	3.7	1800					
24	72.0	300.	4.8	1600					
25	72.0	330.	5.6	1400					
26	72.0	235.	4.6	1550					
27	72.0	240.	5.4	1300					
28	72.0	220.	4.8	1600	150.	147.	200.	960.	349.
29	72.0	208.	5.0	1550					
30	72.0	210.	4.6	1550					
31	72.0	188.	4.8	1550					
32	72.0	80.	6.4	1300					
33	72.0	52.	6.1	1300					
34	72.0	44.	6.6	1300					
35	72.0	140.	4.8	1500	160.	157.	200.	954.	361.
36	72.0	160.	4.5	1650					
37	72.0	158.	4.4	1700					
38	72.0	152.	4.5	1650					
39	72.0	192.	4.6	1550					
40	72.0	204.	4.1	1500					
41	72.0	100.	6.3	1250					
42	72.0	180.	4.7	1450	170.	158.	160.	890.	406.
43	72.0	196.	3.6	1750					
44	72.0	188.	4.3	1600					
45	72.0	180.	4.4	1700					
46	72.0	170.	4.7	1450					
47	72.0	104.	6.0	1200					
48	72.0	168.	3.1	1800					
49	72.0	154.	3.4	1800	150.	142.	217.	1013.	446.
50	72.0	156.	3.3	1650					
51	72.0	156.	2.9	1750					
52	72.0	160.	3.3	1750					
53	72.0	154.	3.4	1750					

*Start-up date was 3/15/72.

TABLE A73

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 67
(STONE #1337, 1/8 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	25.	6.4	2100	8.0	11.0	266.	1169.	< 4.0
2	57.0	10.	8.0	2100					
3	57.0	10.	5.9	2100					
4	72.0	12.	5.9	2050					
5	59.0	15.	5.7	2050					
6	54.0	10.	5.5	2050					
7	41.0	7.	5.7	2000	< 1.0	0.28	320.	1199.	< 4.0
8	40.0	12.	5.5	2000					
9	39.0	20.	5.8	1900					
10	42.0	10.	5.8	1800					
11	42.0	8.	6.7	1750					
12	42.5	25.	6.5	1900					
13	50.0	15.	5.8	1950					
14	48.0	35.	6.2	1850	< 1.0	0.90	440.	1037.	25.2
15	48.0	20.	5.7	1900					
16	72.0	15.	6.3	1900					
17	72.0	22.	6.1	1850					
18	72.0	28.	5.9	1700					
19	72.0	30.	5.8	1250					
20	72.0	36.	6.4	2000					
21	72.0	36.	6.2	1600	30.0		278.	1056.	10.8
22	72.0	32.	6.8	1950					
23	72.0	35.	6.1	1800					
24	72.0	55.	6.2	1750					
25	72.0	30.	6.3	1800					
26	72.0	30.	6.2	1750					
27	72.0	28.	6.4	1650					
28	72.0	60.	6.1	1650	30.0	45.0	216.	948.	154.
29	72.0	28.	6.5	1700					
30	72.0	25.	6.2	1650					
31	72.0	28.	6.1	1700					
32	66.0	28.	7.0	1300					
33	72.0	0.							
34	72.0	28.	7.3	1350					
35	68.0	28.	6.5	1650	1.0	6.8	228.	860.	< 4.0
36	62.0	24.	6.4	1850					
37	72.0	22.	6.2	1800					
38	72.0	22.	6.4	1850					
39	72.0	26.	6.2	1750					
40	72.0	24.	6.6	1750					
41	72.0	29.	6.7	1300					
42	60.0	26.	6.4	1500	< 1.0	23.0	200.	826.	< 4.0
43	58.0	24.	5.8	1800					
44	56.0	24.	6.0	1800					
45	72.0	26.	5.9	1800					
46	72.0	19.	5.6	1650					
47	54.5	24.	6.5	1350					
48	54.0	20.	5.7	1700					
49	52.0	18.	5.8	1750	8.0	25.0	220.	1025.	9.0
50	52.0	18.	5.9	1800					
51	72.0	26.	6.0	1600					
52	54.0	24.	5.5	1900					
53	52.0	22.	5.5	1650					

*Start-up date was 3/15/72.

TABLE A74

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 68
(STONE #1337, 1/4 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	180.	5.9	2050	80.0	75.4	302.	1178.	< 4.0
2	72.0	200.	5.6	1600					
3	72.0	225.	6.1	1850					
4	53.0	200.	6.2	1900					
5	61.0	50.	6.0	1900					
6	50.0	140.	6.0	1900					
7	55.0	125.	5.9	1900	30.0	29.5	235.	1072.	< 4.0
8	72.0	164.	5.8	1700					
9	72.0	80.	6.1	1750					
10	72.0	54.	6.2	1700					
11	72.0	70.	6.4	1700					
12	72.0	70.	6.6	1800					
13	72.0	70.	6.1	2000					
14	59.0	50.	6.5	1750	< 1.0	127.	420.	1037.	10.8
15	72.0	40.	6.2	1950					
16	72.0	40.	6.6	1950					
17	67.0	41.	6.3	1900					
18	72.0	38.	6.3	1700					
19	72.0	40.	6.4	1650					
20	72.0	34.	6.8	2100					
21	72.0	15.	6.8	1700	< 1.0	< 0.03	248.	1146.	< 4.0
22	35.0	16.	6.5	2150					
23	40.0	20.	6.7	1950					
24	48.0	15.	6.6	2000					
25	47.0	15.	6.8	1900					
26	49.5	20.	6.7	1800					
27	57.0	16.	6.7	1750					
28	72.0	16.	6.6	1650	1.0	< 0.03	216.	944.	< 4.0
29	47.0	12.	6.8	1750					
30	33.0	11.	6.9	1750					
31	36.0	12.	6.5	1750					
32	42.0	12.	7.4	1650					
33	72.0	0.							
34	52.0	12.	7.6	1550					
35	72.0	16.	6.8	1550	< 1.0	< 0.03	203.	823.	< 4.0
36	72.0	20.	6.7	1700					
37	72.0	21.	6.8	1750					
38	72.0	18.	6.8	1750					
39	72.0	20.	6.7	1750					
40	72.0	18.	7.0	1700					
41	49.0	10.	7.0	1500					
42	68.0	14.	6.7	1450	< 1.0	< 0.03	195.	816.	< 4.0
43	53.0	22.	6.2	1650					
44	43.0	15.	6.4	1850					
45	44.0	10.	6.4	1800					
46	36.0	8.	6.3	1750					
47	57.0	12.	6.7	1500					
48	52.0	8.	6.1	1500					
49	58.0	7.	6.3	1750	< 1.0	< 0.03	235.	1018.	< 4.0
50	55.0	8.	6.3	1800					
51	72.0	12.	7.1	1700					
52	72.0	0.	6.0	1850					
53	72.0	0.							

*Start-up date was 3/15/72.

TABLE A75

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 69
(STONE #1337, 1/2 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	31.0	3785.	3.0	2100	200.	189.	158.	1089.	432.
2	27.0	3640.	1.8	5800					
3	24.0	3630.	3.5	1850					
4	25.0	3620.	3.6	1750					
5	24.5	3650.	3.2	1900					
6	26.0	3540.	3.1	1950					
7	25.5	3400.	3.1	1850	200.	192.	155.	1162.	554.
8	26.0	3340.	3.4	1650					
9	27.0	3020.	3.9	1700					
10	24.0	2880.	4.1	1500					
11	25.0	2820.	3.6	1550					
12	22.5	2590.	3.8	1600					
13	25.0	2480.	3.5	1800					
14	26.0	247.	3.5	1850	210.	193.	120.	1095.	500.
15	25.0	2400.	3.9	1700					
16	24.0	2230.	3.8	1650					
17	24.5	2200.	3.6	1750					
18	25.0	2130.	3.5	1600					
19	25.0	2100.	4.9	1450					
20	24.0	1760.	4.4	1800					

*Start-up date was 3/15/72.

TABLE A76

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 70
(STONE #1337, 1/2 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	72.0	320.	5.1	1900	170.	165.	204.	1185.	310.
2	72.0	245.	1.7	5850					
3	72.0	240.	4.8	1750					
4	72.0	240.	4.8	1800					
5	72.0	230.	4.6	1800					
6	72.0	260.	4.6	1750					
7	72.0	158.	4.5	1700	180.	175.	171.	1100.	367.
8	72.0	480.	4.4	1600					
9	72.0	560.	4.5	1650					
10	72.0	560.	4.5	1450					
11	72.0	520.	4.3	1500					
12	72.0	600.	4.3	1600					
13	72.0	1120.	2.9	2050					
14	59.0	2410.	3.1	2000	200.	194.	107.	1092.	585.
15	37.0	2320.	3.4	1800					
16	31.5	2200.	0.0	1750					
17	28.0	2120.	3.0	1900					
18	24.5	2140.	2.9	1800					
19	24.0	2050.	3.4	1450					
20	21.0	1800.	3.6	1950					

*Start-up date was 3/15/72.

TABLE A77

FLOW AND EFFLUENT COMPOSITION DATA FOR TEST VESSEL NO. 71 (STONE #1337, 1 x 50M SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	22.0	3785.	2.8	2100	200.	191.	135.	1092.	600.
2	18.0	3440.	1.6	5950					
3	15.0	3500.	3.1	1800					
4	13.0	3420.	3.1	1950					
5	72.0	3360.	2.8	2200					
6	72.0	3260.	2.7	2250					
7	9.0	3160.	2.6	2050	200.	195.	137.	1162.	511.
8	10.5	3080.	2.8	1850					
9	9.5	2780.	3.2	1850					
10	10.0	2680.	3.5	1650					
11	9.0	2590.	3.2	1650					
12	8.5	2390.	3.2	1750					
13	8.0	2340.	3.3	1900					
14	9.0	2480.	3.0	2050	200.	196.	115.	1111.	615.
15	9.5	2230.	3.4	1800					
16	10.0	2150.	3.5	1700					
17	10.5	1980.	3.2	1800					
18	9.0	1990.	3.0	1750					
19	10.0	2000.	3.6	1450					
20	10.0	1740.	3.8	1900					

*Start-up date was 3/15/72.

TABLE A78

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 72
(STONE #1337, 1 x 0 SIZE)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
1	27.0	3785.	2.9	2150	200.	191.	145.	1078.	622.
2	20.5	3290.	1.5	7330					
3	16.0	3230.	3.0	2100					
4	15.0	3380.	3.0	1950					
5	13.5	3150.	2.8	2200					
6	35.5	3010.	2.7	2300					
7	10.5	2900.	2.6	2150	190.	195.	134.	1198.	648.
8	11.5	3100.	2.7	1950					
9	10.5	2940.	3.1	1900					
10	6.0	1900.	3.8	1550					
11	9.0	1880.	3.2	1750					
12	8.0	1750.	3.2	1750					
13	8.0	1740.	2.9	2150					
14	8.0	1660.	3.0	2100	210.	195.	105.	1097.	645.
15	8.0	1530.	3.2	1800					
16	7.5	1540.	3.3	1700					
17	8.0	700.	3.1	1900					
18	7.0	1390.	3.0	1700					
19	7.0	1340.	3.4	1500					
20	7.0	1220.	3.6	1950					

*Start-up date was 3/15/72.

TABLE A79

COMPARISON OF PARTICLE SIZE DISTRIBUTIONS
BEFORE AND AFTER 50 DAYS OF MINE WATER PERCOLATION
MATERIAL NO. 1809

(PERCENT OF MATERIAL SMALLER BY WEIGHT)

Sieve Size	1/2 x 0				1/4 x 0		1/8 x 0	
	Before	After			Before	After	Before	After
	---	Ferric	Ferrous	Ferric-Ferrous	---	Ferric-Ferrous	---	Ferric-Ferrous
		TV 10	TV 38	TV 34		TV 32		TV 31
1 1/2	---	---	---	---	---	---	---	---
3/4	100.0	100.0	100.0	100.0	---	---	---	---
3/8	84.0	91.7	90.6	81.2	100.0	100.0	---	---
4	42.5	64.9	62.1	49.8	88.3	84.1	100.0	100.0
8	24.9	44.4	40.4	30.0	58.1	47.7	65.9	67.8
16	14.2	30.1	26.0	19.9	34.2	26.0	33.3	37.4
30	8.1	21.1	17.2	14.2	19.5	14.4	16.6	19.2
50	4.8	15.9	12.3	11.3	10.9	8.7	9.0	11.0
100	2.9	12.6	9.4	9.5	6.1	5.8	5.5	7.5
200	1.9	10.7	7.9	8.5	3.9	4.5	3.9	5.8

NOTE: TV indicates test vessel.

TABLE A80

COMPARISON OF PARTICLE SIZE DISTRIBUTIONS
BEFORE AND AFTER 100 DAYS OF MINE WATER PERCOLATION
MATERIAL NO. 1355

(PERCENT OF MATERIAL SMALLER BY WEIGHT)

Sieve Size	1 x 0		1/4 x 0		1/8 x 0	
	Before	After Ferric-Ferrous TV 42	Before	After Ferric-Ferrous TV 38	Before	After Ferric-Ferrous TV 37
1 1/2	100.0	100.0	---	---	---	---
3/4	87.6	88.6	---	---	---	---
3/8	65.6	77.1	100.0	100.0	---	---
4	35.5	47.5	77.6	82.7	100.0	100.0
8	20.4	32.1	42.0	48.5	84.5	75.7
16	11.8	24.1	23.8	30.9	51.6	51.8
30	6.6	19.4	15.4	21.2	32.6	35.4
50	4.0	15.9	10.6	15.1	20.5	25.3
100	2.7	12.3	7.7	10.4	13.1	18.6
200	1.9	9.4	5.6	7.1	8.5	13.7

NOTE: TV indicates test vessel.

TABLE A81

Specimens Tested in Lab Cycle II

Test Vessel	Description	Approximate Relative Density (%)	Actual Density (LB/FT^3)
73	5% Portland cement	30	105
74	5% Calcium sulfate hemihydrate	30	105
75	5% Sodium silicate	30	105
76	2X original fines content	30	105
77	2X original fines content	60	116
78	3X original fines content	30	105
79	3X original fines content	60	116
80	5% $Fe_2(SO_4)_3$ + 15% Na_2SO_4 zone	30	105
81	3/8 x 0 stone	30	105
82	3/8 x 0 stone	60	116
83*	3/8 x 0 stone	0	98
84*	3/8 x 0 stone	30	105

NOTE:

* Tested on South Pittsburgh City water
Others tested on ferric/ferrous water

TABLE A82

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 73
(5% PORTLAND CEMENT, 30% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
30 min.	72	155							
3 hr.	72	120							
8 hr.	72	96	12.4						
1	72	82	11.8	8800	1.0	1.0		1211.	4.0
3	72	100	11.9	5700					
6	72	70	11.7	3950					
8	72	52	11.5	3000					
10	72	40	11.5	2650					
13	72	32	11.2	1950					
15	72	22	11.5	2300					
17	72	20	10.1	2300					
20	72	12	10.7	1950					
22	72	8	10.0	2100					
24	72	8	10.2	2250	1.0	1.0	600.	1319.	4.0
27	72	6	10.5	1850					
29	72	4	10.7	2400					
31	72	4	10.7	2650					
34	72	3	10.8	2450					
36	72	3	10.8	2350					
38	72	3	10.9	2600					
41	72	4	10.7	2550					
43	72	6	10.5	2500					
45	72	6	10.2	2500					
48	72	10	9.5	2450					
50	72	16	8.9	2400	1.0	1.0	588.	1566.	4.0

*Start-up date was 8/15/72.

TABLE A83

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 74
(5% CALCIUM SULFATE HEMIHYDRATE, 30% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
30 min.	72	240							
3 hr.	72	154							
8 hr.	72	150	7.4						
1	72	126	6.9	2900	18.8			1599.	12.0
3	72	258	7.2	2850					
6	72	138	7.6	2750					
8	72	180	7.2	2650					
10	72	108	8.3	2700					
13	72	40	8.5	2100					
15	72	23	7.7	2600					
17	72	24	7.2	2450					
20	72	14	7.6	2350					
22	72	12	7.7	1900					
24	72	10	7.5	2450	1.0	2.0	672.	1550	11.4
27	72	8	8.1	2150					
29	72	8	8.4	2700					
31	72	8	8.3	2600					
34	72	6	7.5	2700					
36	72	5	7.2	2700					
38	72	6	7.6	2600					
41	72	12	8.0	2650					
45	72	20	7.6	2500					
48	72	32	7.3	2800					
50	72	52	7.1	2200	19.0	21.0	656	1501	4.0

*Start-up date was 8/15/72.

TABLE A84

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 75
(5% SODIUM SILICATE, 30% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
30 min	72	104							
3 hr.	72	136							
8 hr.	72	144	9.9						
1	72	148	6.7	2850	4.0	5.0		1653.	4.0
3	72	206	7.2	2400					
6	72	235	7.1	2800					
8	72	176	7.3	2500					
10	72	100	7.5	1950					
13	72	44	7.6	1700					
15	72	22	7.6	2300					
17	72	75	7.0	2350					
20	72	24	7.5	1950					
22	72	23	7.5	1900					
24	72	20	7.0	2300	1.0	1.0	596.	1518.	7.6
27	72	12	7.7	2050					
29	72	12	8.1	2600					
31	72	16	7.9	2550					
34	72	20	7.5	2400					
36	72	17	7.6	2550					
38	72	18	7.5	2750					
41	72	12	8.0	2500					
43	72	12	8.0	2800					
45	72	26	7.5	2700					
48	72	24	7.4	2700					
50	72	16	7.4	2750	1.0	1.0	612.	1441.	4.0

*Start-up date was 8/15/72.

TABLE A85

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 76
(2X ORIGINAL FINES, 30% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
30 min.	72	64							
3 hr.	72	80							
8 hr.	72	70	7.5						
1	72	64	6.6	3000	1.9	1.5		1609.	12.0
3	72	64	7.2	2400					
6	72	56	7.3	2900					
8	72	52	7.5	2200					
10	72	43	6.7	2000					
13	72	18	7.5	1750					
15	72	12	6.9	2200					
17	72	16	7.0	2300					
20	72	8	7.5	2000					
22	72	6	7.4	1950					
24	72	6	7.3	2350	1.0	1.0	620.	1461.	4.0
27	72	4	7.6	1950					
29	72	4	7.5	2650					
31	72	4	7.9	2400					
34	72	3	7.9	2600					
36	72	2	7.8	2650					
38	72	2	8.0	2450					
41	72	26	8.0	2550					
43	72	4	8.0	2550					
45	72	2	7.9	2600					
48	72	2	7.8	2700					
50	72	2	7.9	2500	1.0	1.0	632	1502.	4.0

*Start-up date was 8/15/72.

TABLE A86

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 77
(2X ORIGINAL FINES, 60% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l	HOT PHT. ACIDITY (mg/l)
30 min.	72	0							
3 hr.	72	35							
8 hr.	72	30	7.7						
1	72	24	7.0	2850	1.0	1.0		1773.	11.2
3	72	21	7.4	2300					
6	72	20	7.5	2750					
8	72	24	7.7	2350					
10	72	36	7.3	1950					
13	72	16	7.6	1750					
15	72	10	7.3	2150					
17	72	12	7.3	2350					
20	72	6	7.7	1850					
22	72	4	7.7	1900					
24	72	4	7.5	2300	1.0	1.0	580.	1416.	4.0
27	72	3	7.9	1750					
29	72	2	7.4	2350					
31	72	2	8.0	2450					
34	72	1	8.0	2400					
36	72	1	7.7	2800					
38	72	1	7.4	2550					
41	72	4	8.0	2400					
43	72	3	8.0	2600					
45	72	2	8.0	2650					
48	72	1	7.9	2600					
50	72	1	8.0	2550	1.0	1.0	628.	1472.	4.0

*Start-up date was 8/15/72.

TABLE A87

FLOW AND EFFLUENT COMPOSITION DATA FOR TEST VESSEL NO. 78 (3X ORIGINAL FINES, 30% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
30 min.	72	0							
3 hr.	72	0							
8 hr.	72	0							
1	72	0							
3	72	0							
6	72	1.6	7.3	4050					
8	72	1.0	8.7	3150					
10	72	2.2	8.4	3150					
13	72	2.8	7.0	1900					
15	72	2.6	7.3	1800					
17	72	2.0	8.0	1650					
20	72	2.0	7.8	1850					
22	72	1.5	8.0	1850					
24	72	2.0	7.7	2200	1.0	1.0	472.	1323.	4.0
27	72	2.0	8.0	1750					
29	72	2.0	7.9	2400					
31	72	2.0	8.0	2400					
34	72	1.0	8.0	2450					
36	72	1.0	8.1	2350					
38	72	1.0	8.1	2500					
41	72	2.0	8.2	2400					
43	72	2.0	8.1	2450					
45	72	1.0	8.0	2450					
48	72	1.0	8.1	2300					
50	72	1.0	8.0	2450	1.0	1.0	576.	1375.	4.0

*Start-up date was 8/15/72.

TABLE A88

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 79
(3X ORIGINAL FINES, 60% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
30 min.	72	0							
3 hr.	72	0							
8 hr.	72	0							
1	72	0							
3	72	0							
6	72	0							
8	72	0							
10	72	0							
13	72	0							
15	72	0							
17	72	0							
20	72	0							
22	72	0							
24	72	0							
27	72	0							
29	72	0							
31	72	0							
34	72	0							
36	72	0							
38	72	0							
41	72	0							
43	72	0							
45	72	0							
48	72	0							
50	72	0							

*Start-up date was 8/15/72.

TABLE A89

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 80
("ZONED" PLUG, 30% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
30 min.	72	62							
3 hr.	72	236							
8 hr.	72	196	6.8						
1	72	130	6.5	3000	15.0	17.5		1707.	4.0
3	72	181	7.1	2800					
6	72	300	7.0	2850					
8	72	208	7.2	2500					
10	72	72	7.2	2550					
13	72	34	6.9	2050					
15	72	26	7.1	2450					
17	72	29	7.2	2300					
20	72	20	7.4	1850					
22	72	16	7.3	1950					
24	72	16	7.1	2300	1.0	1.0	608.	1482.	4.0
27	72	15	7.0	2100					
29	72	12	7.5	2550					
31	72	12	7.5	2500					
34	72	13	7.3	2650					
36	72	12	7.4	2600					
38	72	14	7.3	2600					
41	72	16	7.5	2750					
43	72	24	7.4	2800					
45	72	24	7.3	2750					
48	72	2	7.4	2550					
50	72	20	7.3	2650	3.0	3.0	636.	1476.	4.0

*Start-up date was 8/15/72.

TABLE A90

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 81
(3/8 x 0 STONE, 30% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT ACIDITY (mg/l)
30 min.	72	406							
3 hr.	72	360							
8 hr.	72	280	6.8						
1	72	170	6.5	2900	18.8	18.8		1665	4.0
3	72	160	6.5	2400					
6	72	176	6.9	2600					
8	72	136	7.1	2250					
10	72	80	7.0	2000					
13	72	17	7.1	1900					
15	72	12	7.3	2100					
17	72	12	7.3	2300					
20	72	8	7.5	1800					
22	72	6	7.7	1900					
24	72	4	7.3	2250	<1.0	<1.0	612.	1456.	<4.0
27	72	4	7.8	2050					
29	72	4	7.8	2650					
31	72	4	6.4	2450					
34	72	2	8.0	2700					
36	72	2	7.9	2600					
38	72	2	7.9	2500					
41	72	4	7.8	2650					
43	72	4	7.9	2600					
45	72	2	7.8	2700					
48	72	2	7.7	2650					
50	72	2	8.0	2550	<1.0	<1.0	660.	1518.	<4.0

*Start-up date was 8/15/72.

TABLE A91

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 82
(3/8 x 0 STONE, 60% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
30 min.	72	44							
3 hr.	72	116							
8 hr.	72	104	7.0						
1	72	96	6.8	2800	<1.0	<1.0		1639	<4.0
33	72	78	7.2	2250					
6	72	120	7.0	2700					
8	72	104	6.7	2200					
10	72	35	7.4	1900					
13	72	9	7.4	1600					
15	72	9	6.2	1950					
17	72	6	7.8	2200					
20	72	4	7.6	1750					
22	72	5	7.7	1800					
24	72	4	7.1	2100	<1.0	<1.0	532	1504	<4.0
27	72	4	8.0	1700					
29	72	4	8.0	2500					
31	72	4	6.8	400					
34	72	1	7.9	2500					
36	72	1	8.0	2300					
38	72	1	8.1	2400					
41	72	3	8.0	2350					
43	72	2	8.1	2500					
45	72	2	8.0	2450					
48	72	2	7.9	2500					
50	72	2	8.0	2300	<1.0	<1.0	584	1509	<4.0

*Start-up date was 8/15/72.

TABLE A92

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 83
(3/8 x 0 STONE, 0% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
30 min.	72	600							
3 hr.	72	530							
8 hr.	72	480	7.4						
1	72	400	8.4	600	<1.0	<1.0		223.	<4.0
3	72	464	8.4	700					
6	72	456	8.1	800					
8	72	328	7.3	800					
10	72	1400		600					
13	72	2000	8.1	700					
15	72	1880	6.8	800					
17	72	1960	7.8	800					
20	72	1720	8.0	650					
22	72	1800	8.2	600					
24	72	1480	7.3	900	<1.0	<1.0	40.	242.	7.6
27	72	1400	8.5	600					
29	72	1340	8.4	700					
31	72	1220	7.2	700					
34	72	1180	8.1	600					
36	72	1100	8.7	750					
38	72	1100	8.6	750					
41	72	1100	8.3	850					
43	72	1080	8.4	900					
45	72	1060	8.3	850					
48	72	1040	8.3	800					
50	72	1000	7.7	900	<1.0	<1.0	104.	247.	<4.0

* Start-up date was 8/15/72.

TABLE A93

FLOW AND EFFLUENT COMPOSITION DATA
FOR TEST VESSEL NO. 84
(3/8 x 0 STONE, 30% DR)

DAYS AFTER START-UP*	HEAD (in)	FLOW (ml/min)	pH	SP. COND. (μmho)	FERROUS IRON (mg/l)	TOTAL IRON (mg/l)	CALCIUM (mg/l)	SULFATE (mg/l)	HOT PHT. ACIDITY (mg/l)
30 min.	72	420							
3 hr.	72	370							
8 hr.	72	310	8.4						
1	72	232	8.4	600	<1.0	<1.0		228.	<4.0
3	72	300	8.4	700					
6	72	324	8.2	700					
8	72	280	7.7	750					
10	72	840		600					
13	72	1240	8.8	650					
15	72	1160	7.3	700					
17	72	1160	8.8	600					
20	72	1080	8.0	600					
22	72	1000	8.6	550					
24	72	960	7.1	700	<1.0	<1.0	44.	247.	7.6
27	72	960	8.5	500					
29	72	800	8.6	600					
31	72	800	7.5	600					
34	72	740	8.5	750					
36	72	760	8.6	650					
38	72	720	7.5	800					
41	72	680	8.5	800					
43	72	700	8.5	800					
45	72	700	8.3	750					
48	72	640	8.3	750					
50	72	640	7.8	850	<1.0	<1.0	92.	328.	<4.0

*Start-up date was 8/15/72.

TABLE A94
COMPARISON OF PARTICLE SIZE DISTRIBUTION
BEFORE AND AFTER 50 DAYS OF FERRIC-FERROUS MINE WATER PERCOLATION
VARYING QUANTITIES OF FINES AND DENSITIES IN TEST VESSELS
MATERIAL NO. 1809
(Percent of Material Smaller by Weight)

Sieve Size	Natural (a)	Natural[a]			2 x Fines[b]			3 x Fines[c]		
		Before	After DR[d]=30% TV[e] 81	After DR[d]=60% TV[e] 82	Before	After DR[d]=30% TV[e] 76	After DR[d]=60% TV[e] 77	Before	After DR[d]=30% TV[e] 78	After DR[d]=60% TV[e] 79
3/8	100	100	100	100	100	100	100	100	100	100
4	99.7	99.7	99.8	100	99.0	98.7	99.6	99.5	100	99.8
8	69.7	69.7	71.5	69.3	59.6	63.5	61.0	85.4	83.1	84.2
16	42.7	42.7	46.5	43.6	40.8	42.6	41.5	68.5	67.3	66.2
30	26.0	26.0	27.2	24.7	31.4	32.8	33.1	56.5	56.1	55.7
50	15.8	15.8	16.8	15.4	26.0	27.2	28.2	48.2	47.5	48.3
100	10.1	10.1	11.5	10.9	17.4	19.2	18.9	32.6	34.0	35.0
200	6.9	6.9	8.7	8.6	11.6	14..	16.5	21.1	24.9	25.6

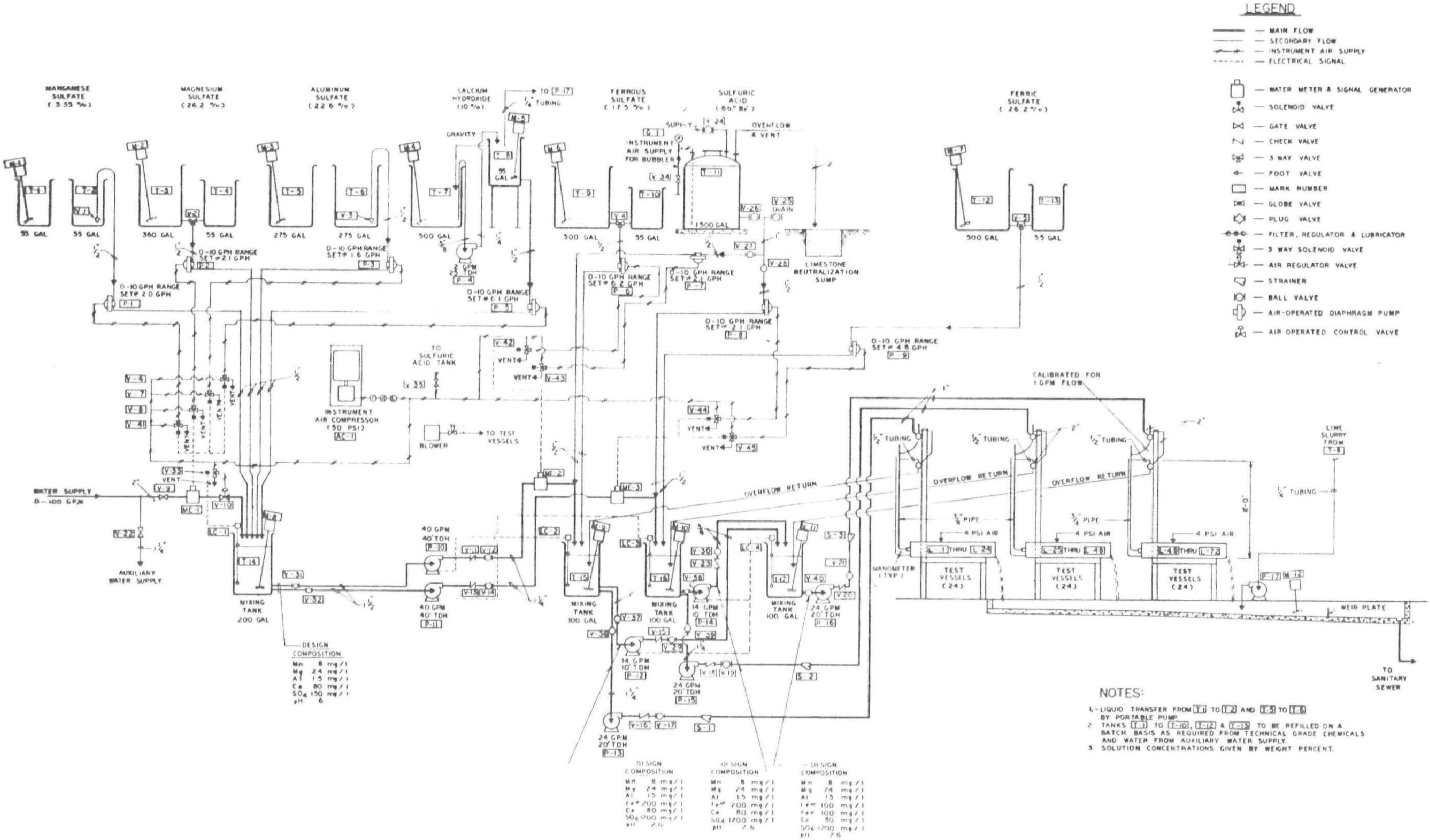
(a) Natural - as obtained from stone quarry.
(b) 2 x Fines - Approximately double percent of fines as measured by No. 50 Sieve.
(c) 3 x Fines - As above, but three times fines.
(d) DR - Relative Density
(e) TV - Test Vessel.

TABLE A95
COMPARISON OF PARTICLE SIZE DISTRIBUTIONS
BEFORE AND AFTER 50 DAYS OF FERRIC-FERROUS MINE WATER PERCOLATION
MATERIAL NO. 1809 WITH ADDITIVES
(PERCENT OF MATERIAL SMALLER BY WEIGHT)

Sieve Size	Natural	5% Cement		5% Calcium Sulfate		5% Sodium Sulfate		Zoned	
		Before	DR[a]=30% TV[b] 73	Before	DR[a]=30% TV[b] 74	Before	DR[a]=30% TV[b] 75	Before	DR[a]=30% TV[b] 80
3/8	100	100	100	100	100	100	100	100	100
4	99.7	100	99.5	99.5	99.6	99.4	99.5	99.7	100
8	69.7	72.2	51.5	58.6	68.6	70.4	65.6	69.7	60.1
16	42.7	47.5	39.4	35.0	42.0	46.6	40.1	42.7	35.8
30	26.0	31.2	35.8	22.6	26.3	24.5	25.6	26.0	21.6
50	15.8	21.0	22.7	15.8	17.5	13.4	17.3	15.8	14.0
100	10.1	14.9	14.0	11.0	12.8	7.8	12.4	10.1	10.2

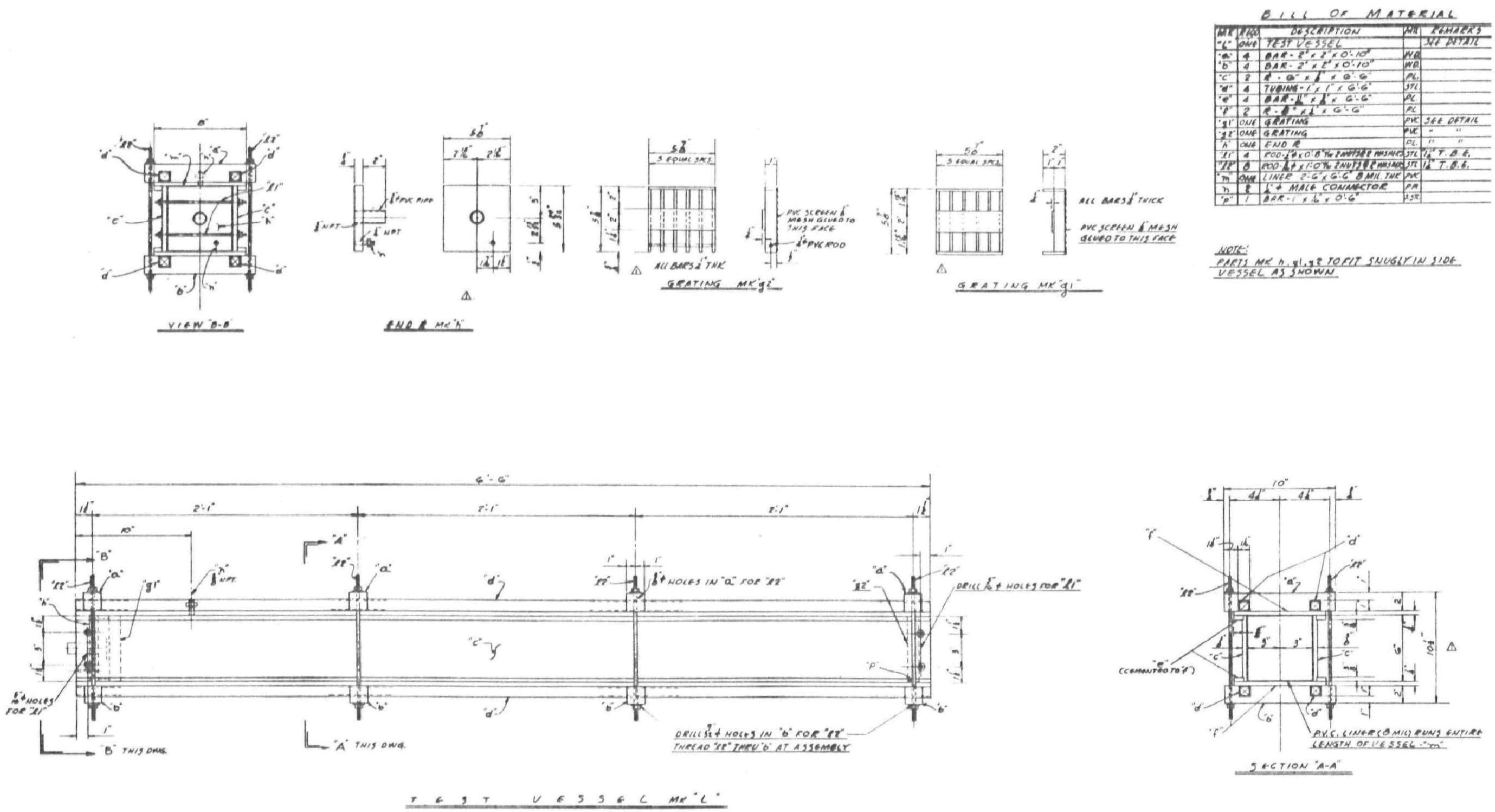
(a) DR - Relative Density.

(b) TV - Test Vessel.



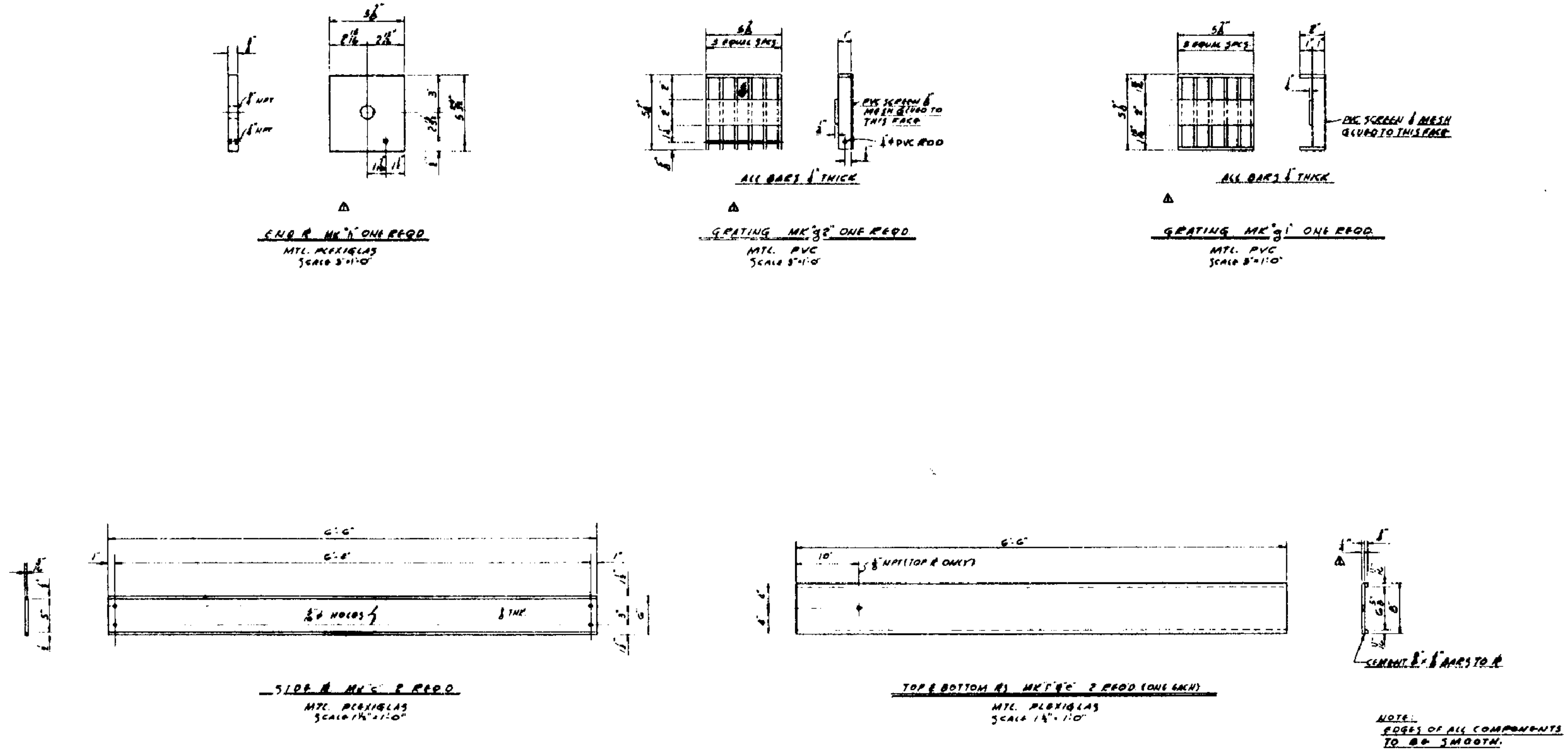
PROCESS FLOW DIAGRAM

FIGURE A1



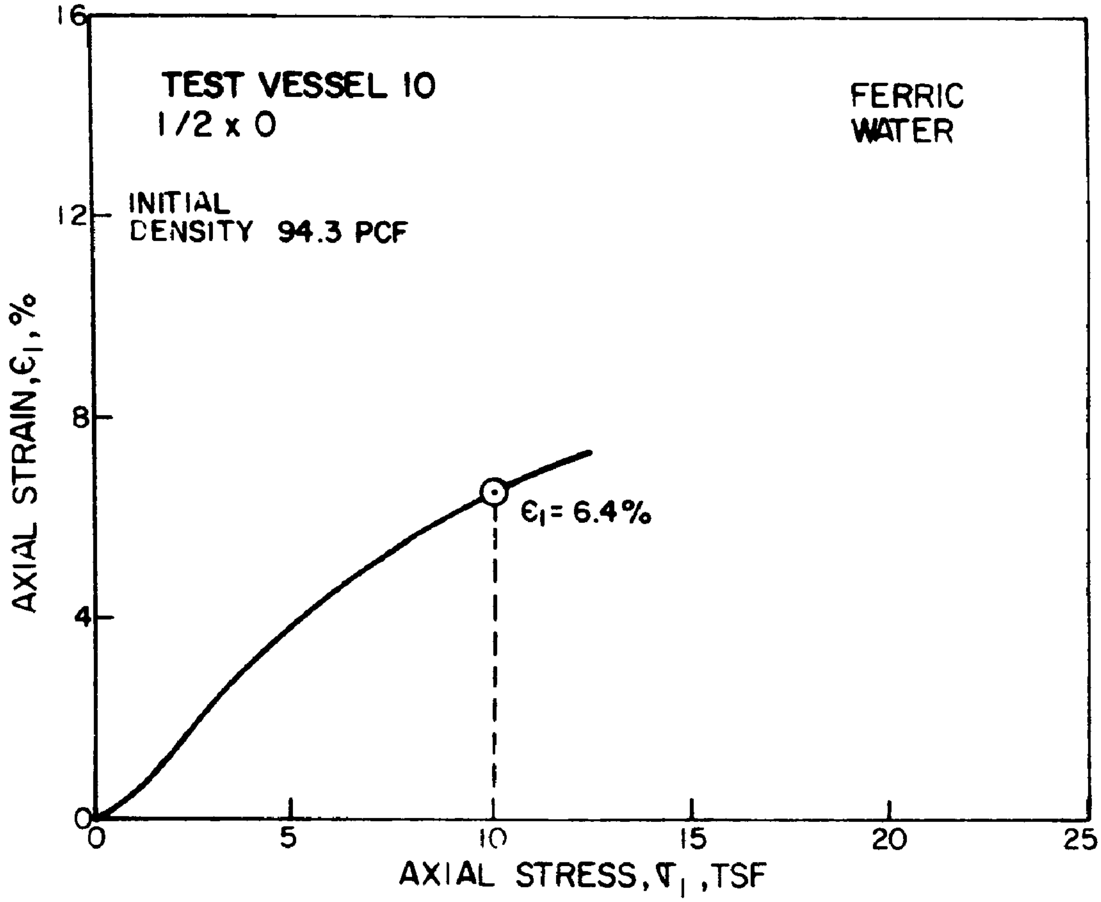
TEST VESSEL DETAIL

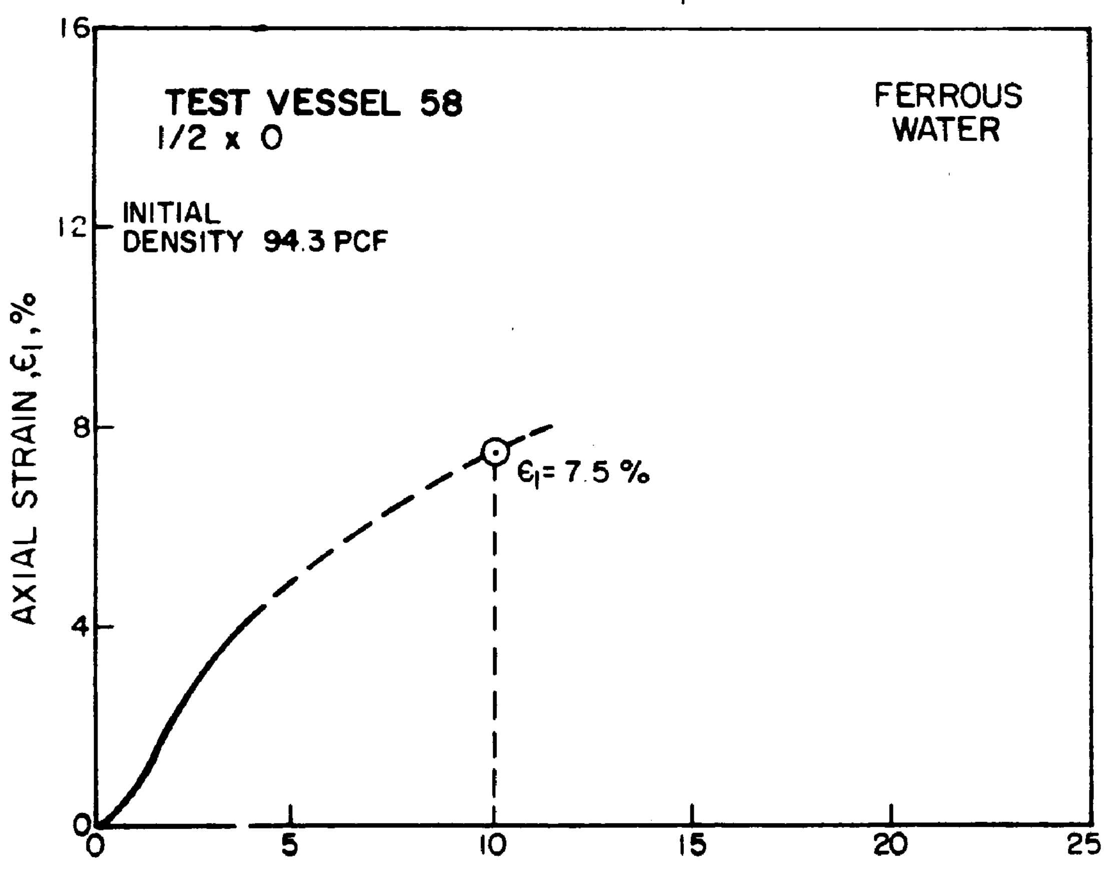
FIGURE A2



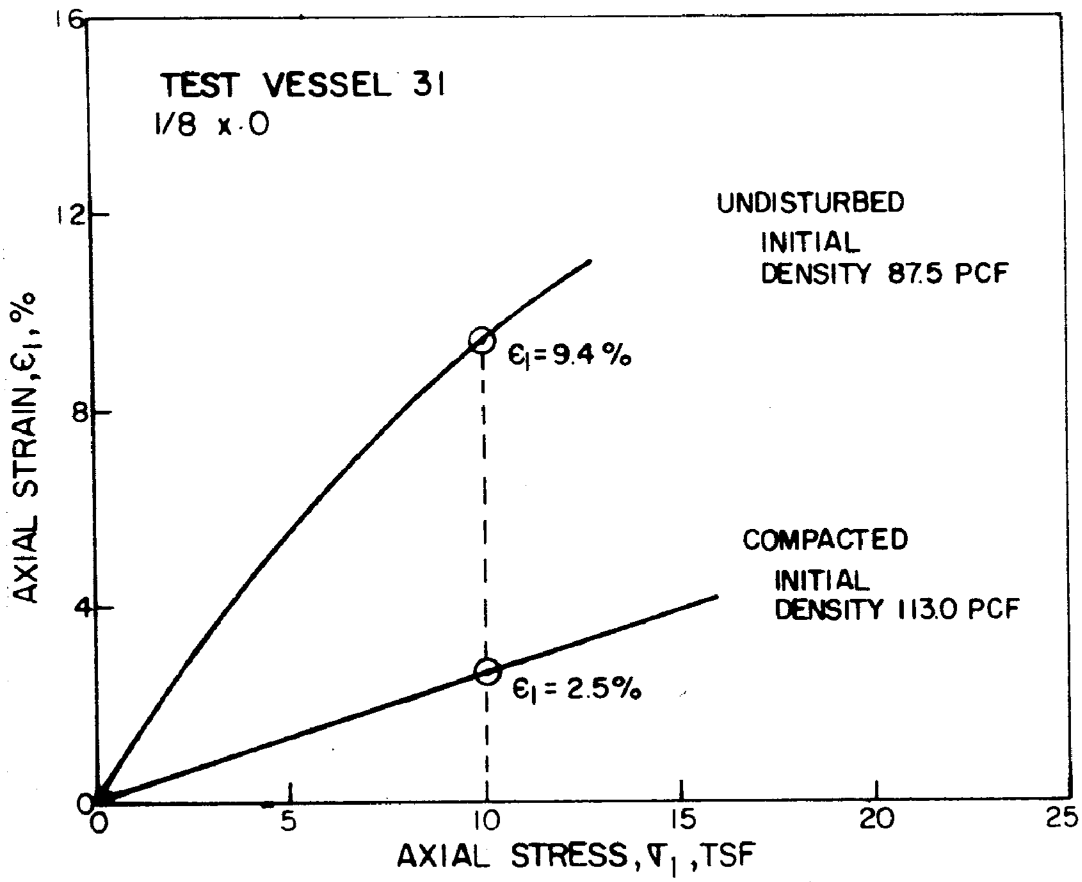
TEST VESSEL DETAILS

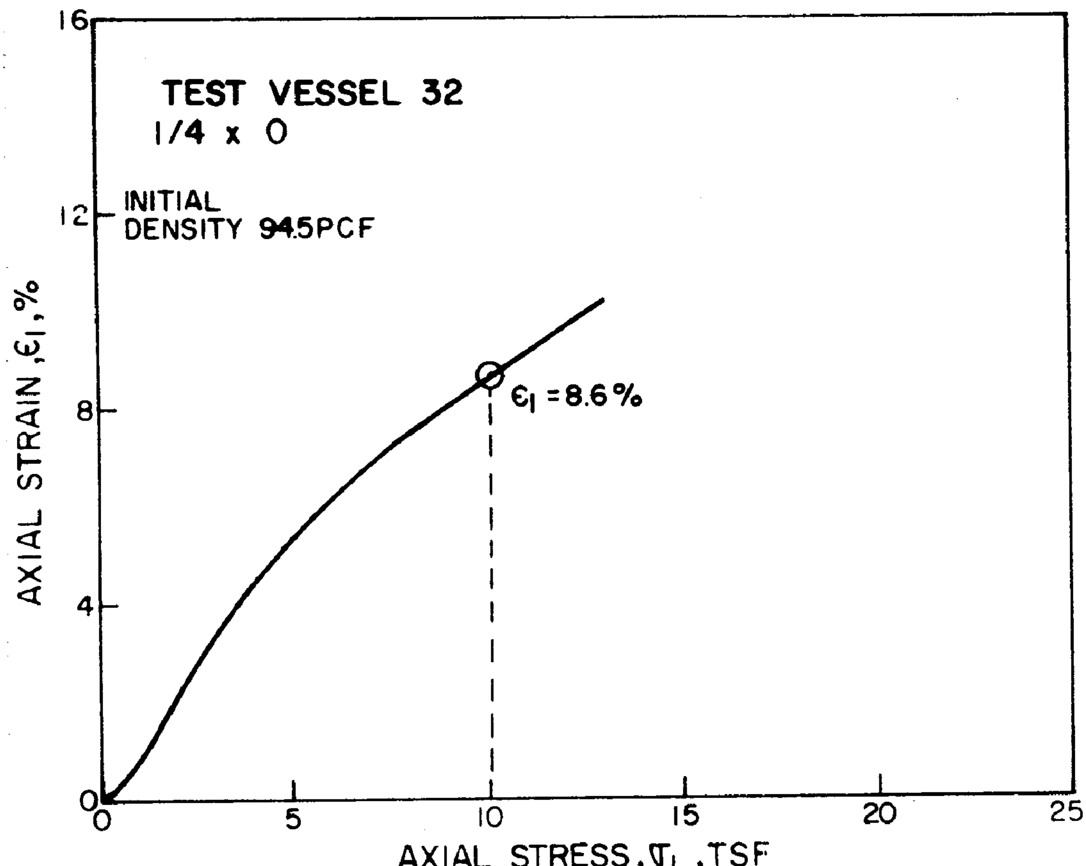
FIGURE A3



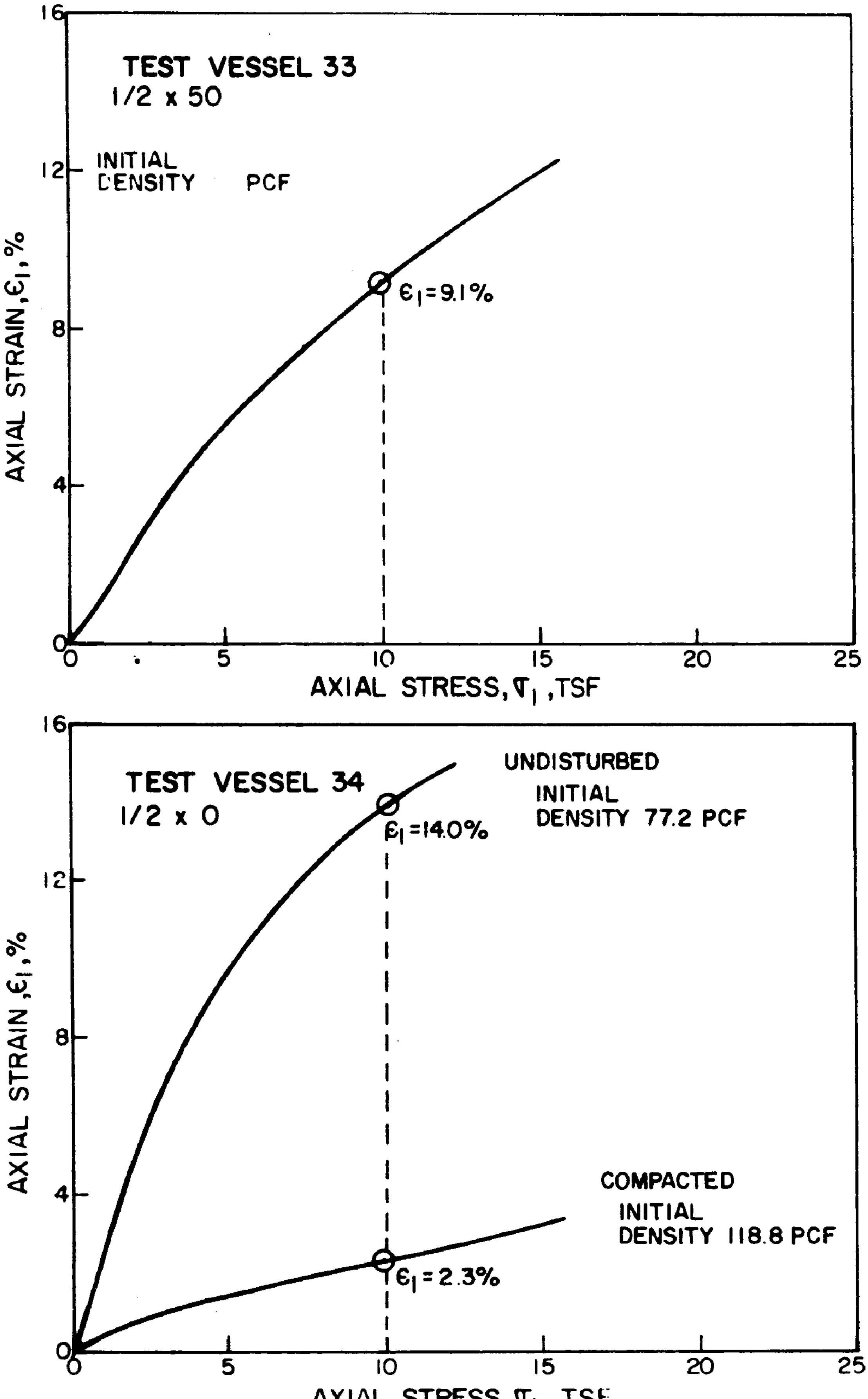


ONE DIMENSIONAL COMPRESSION TEST RESULTS
FIGURE A4

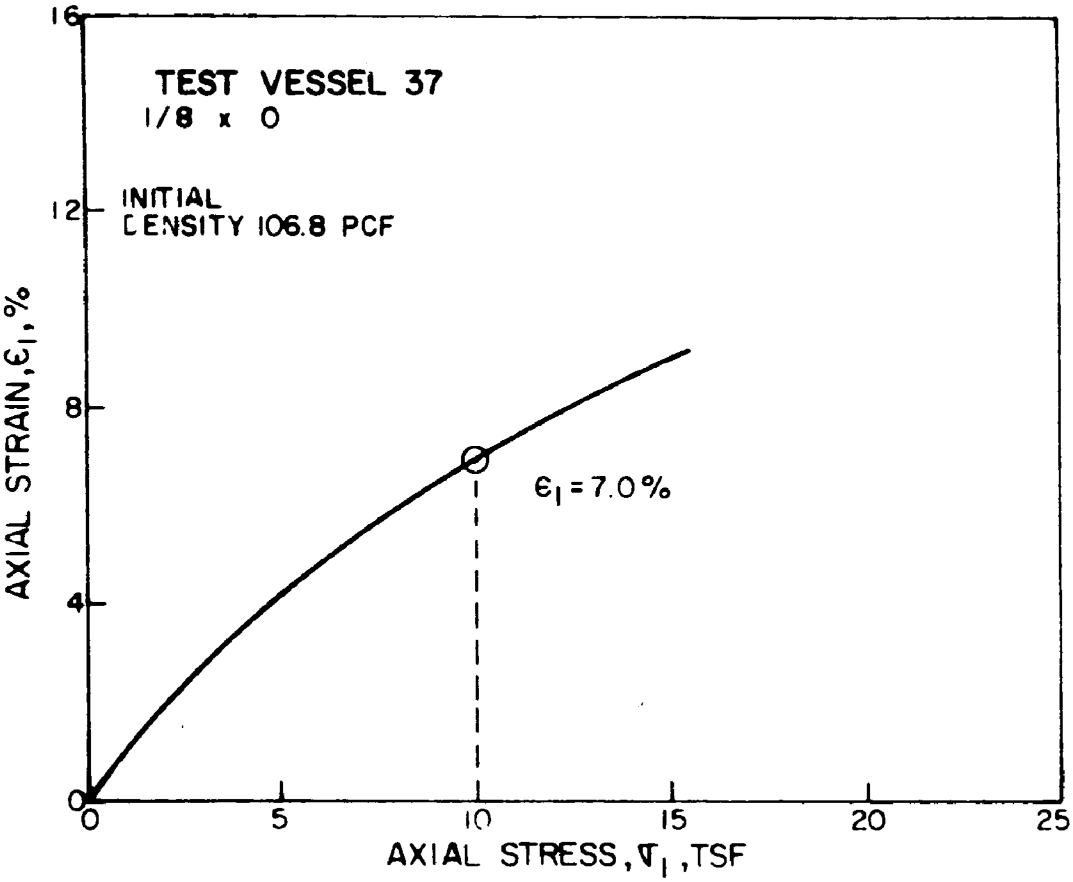


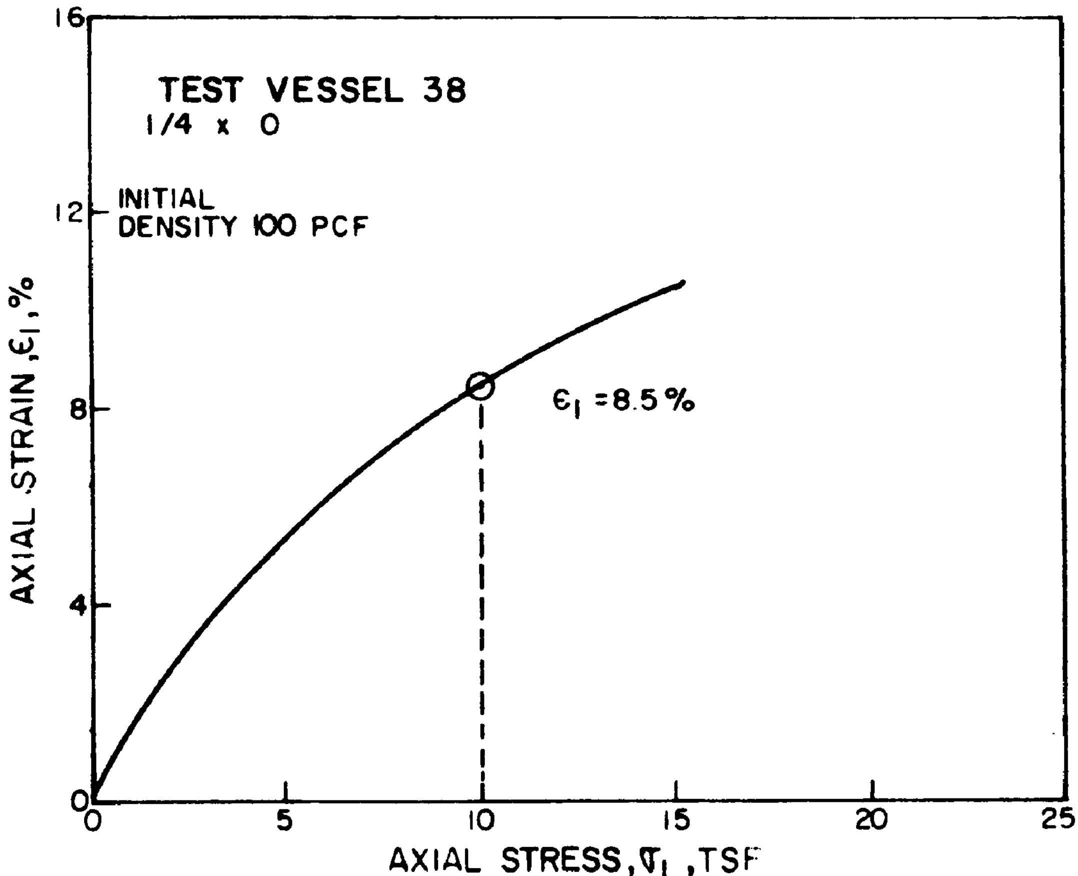


ONE DIMENSIONAL COMPRESSION TEST RESULTS
FIGURE A5

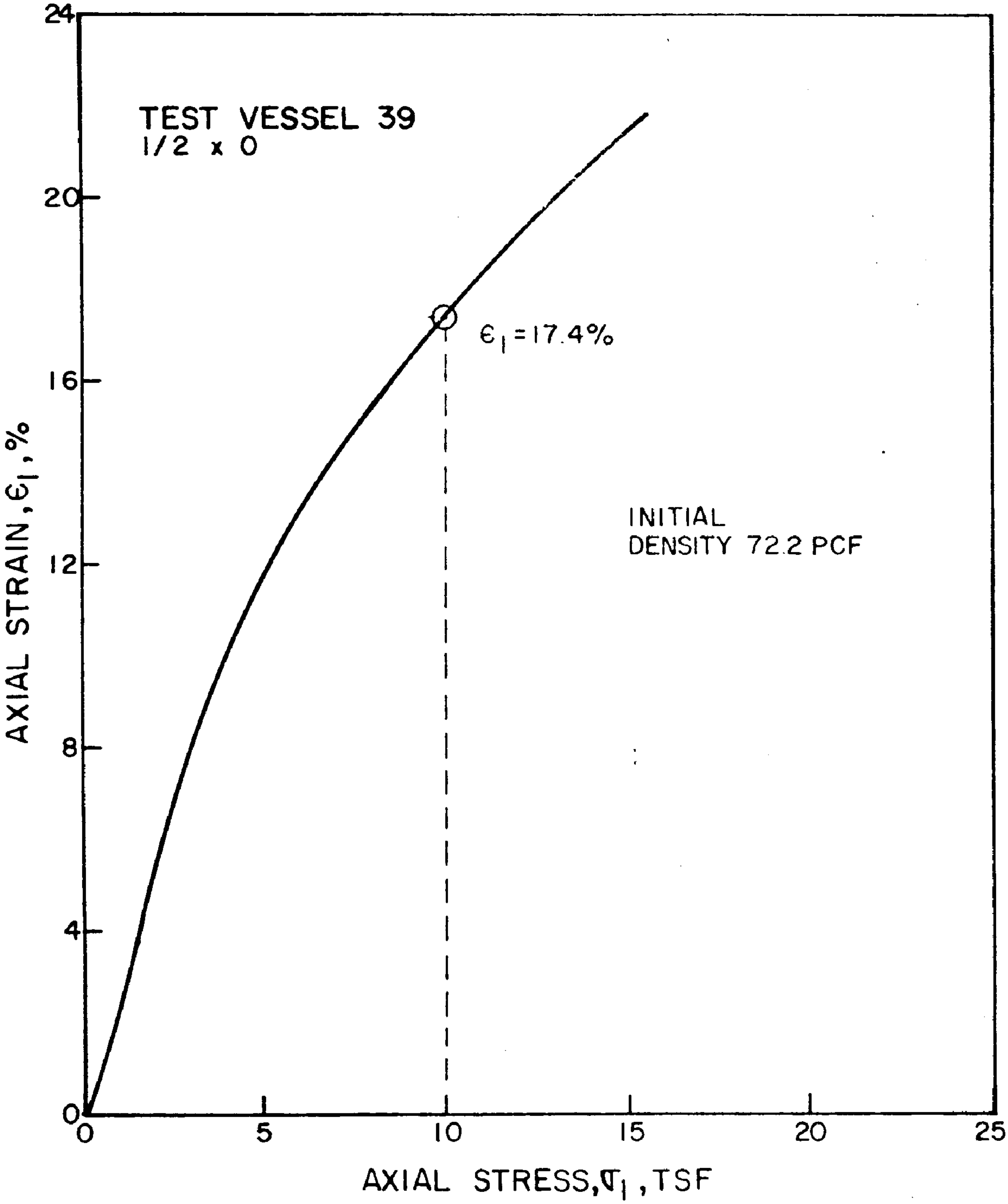


ONE DIMENSIONAL COMPRESSION TEST RESULTS
FIGURE A6



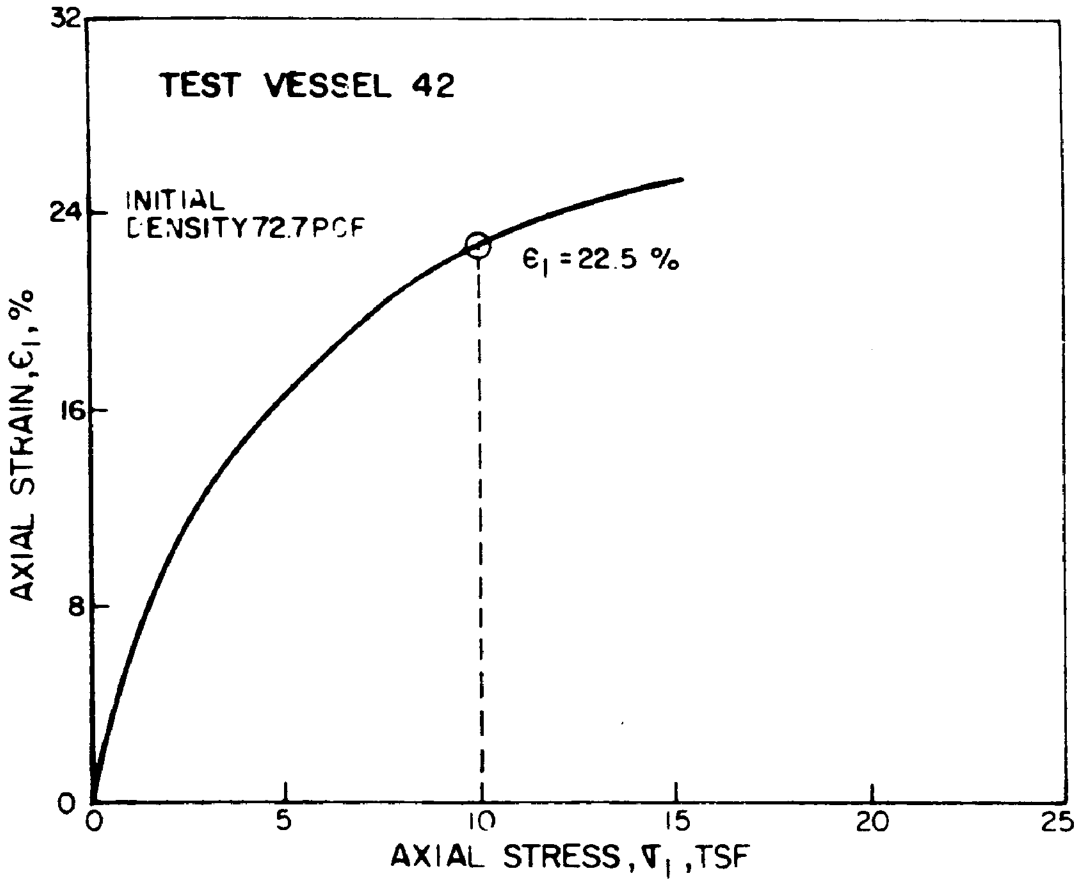


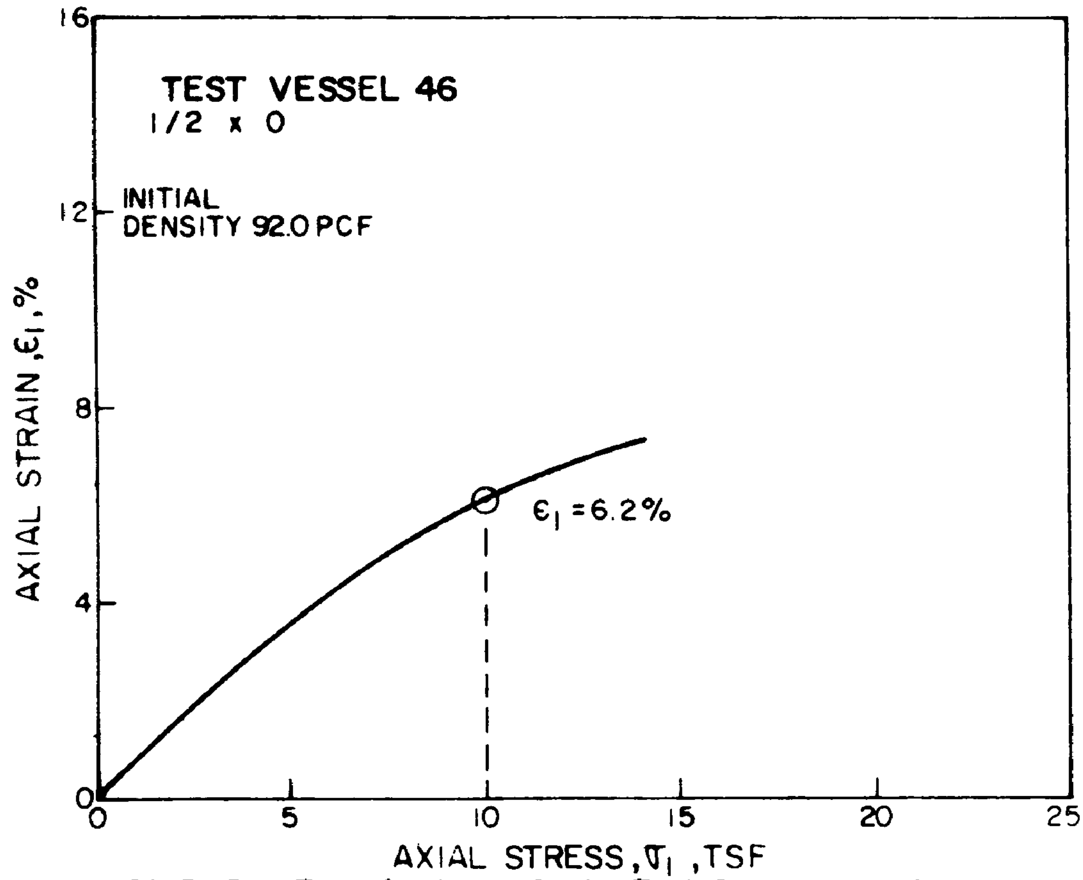
ONE DIMENSIONAL COMPRESSION TEST RESULTS
FIGURE A7



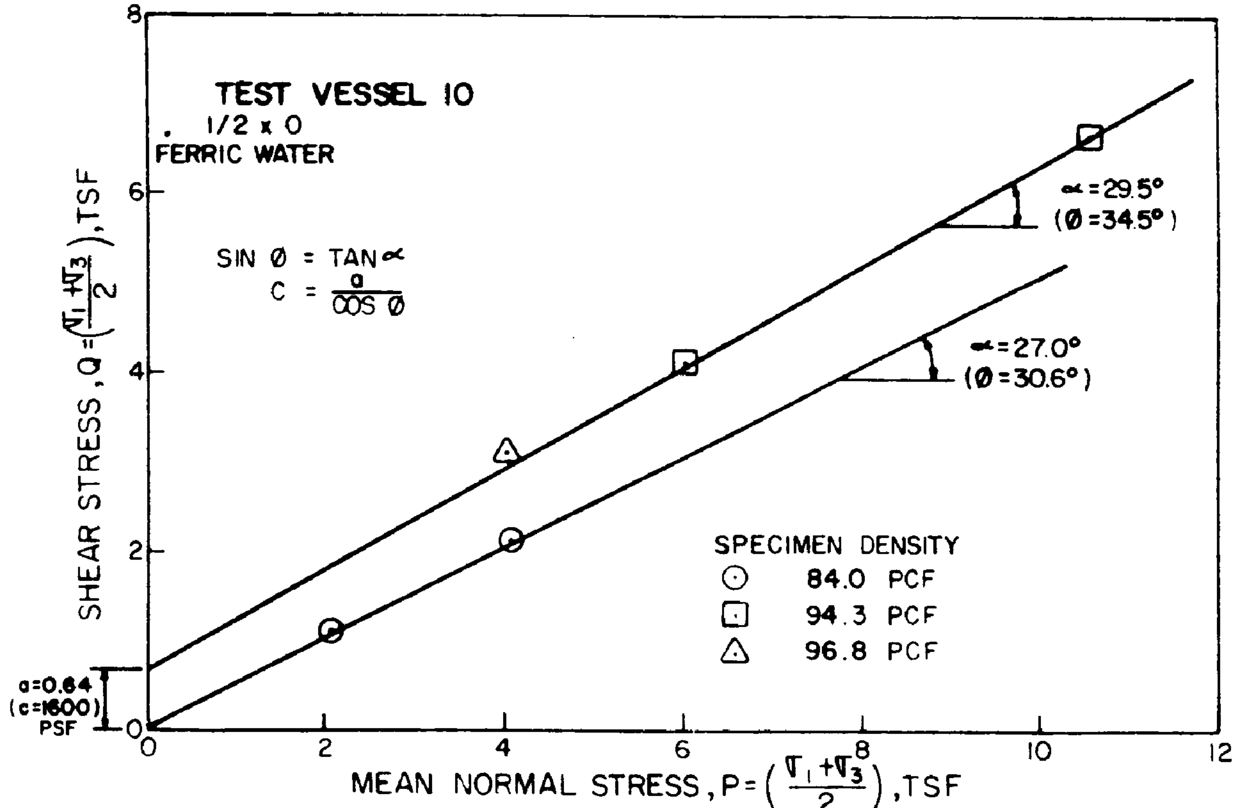
ONE DIMENSIONAL COMPRESSION TEST RESULTS

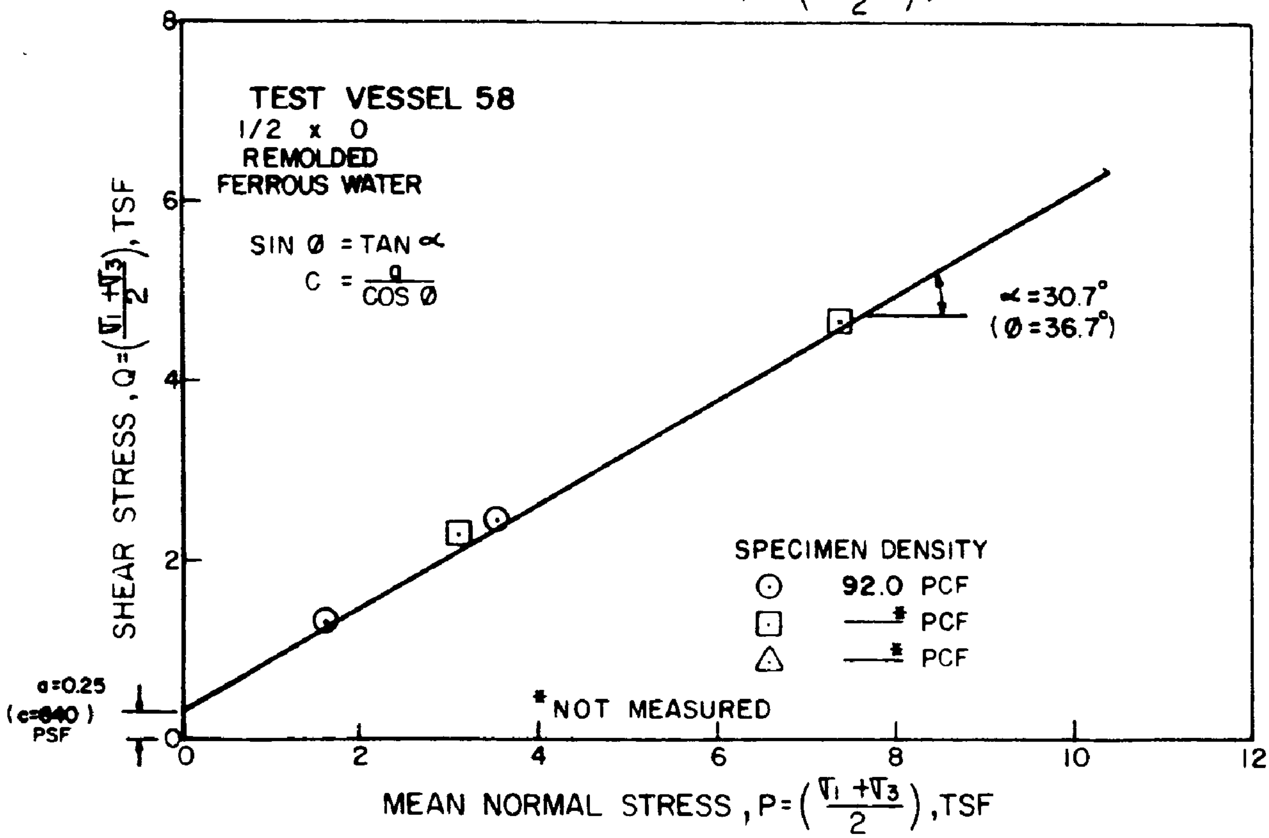
FIGURE A8





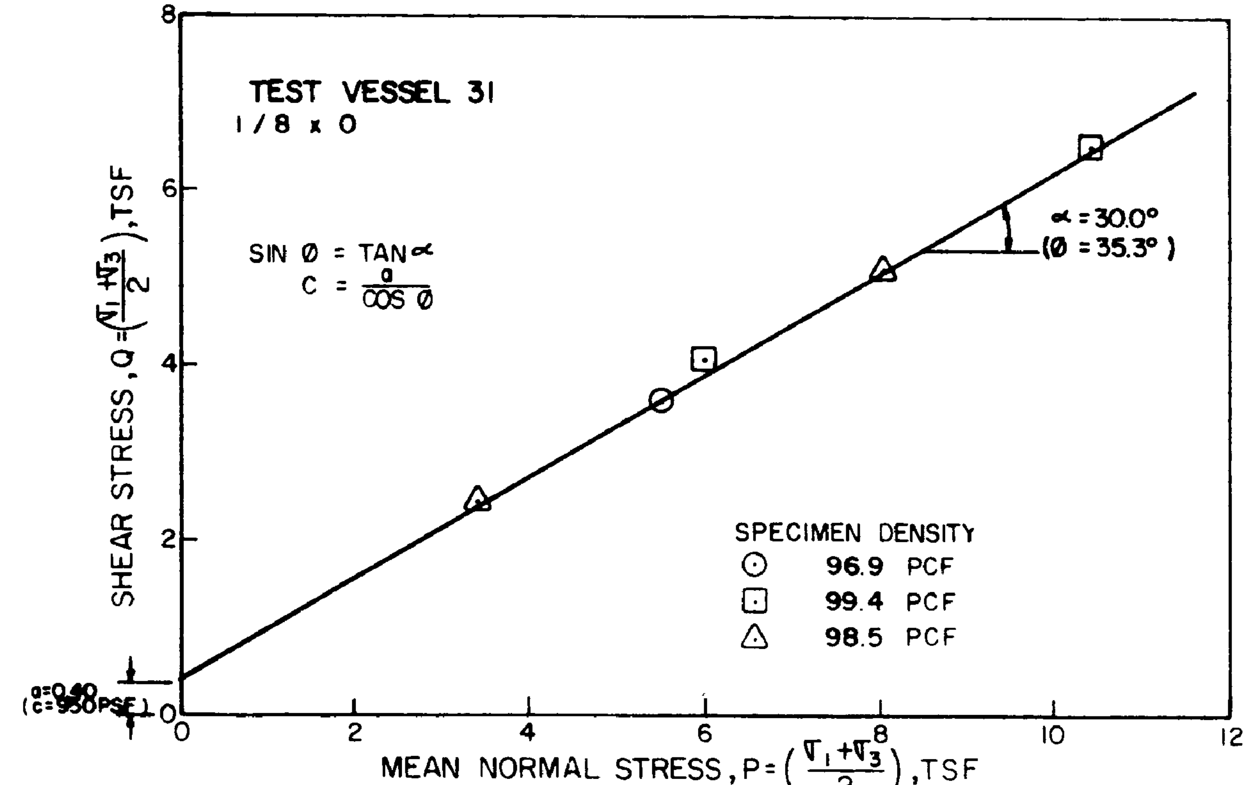
ONE DIMENSIONAL COMPRESSION TEST RESULTS
FIGURE A9

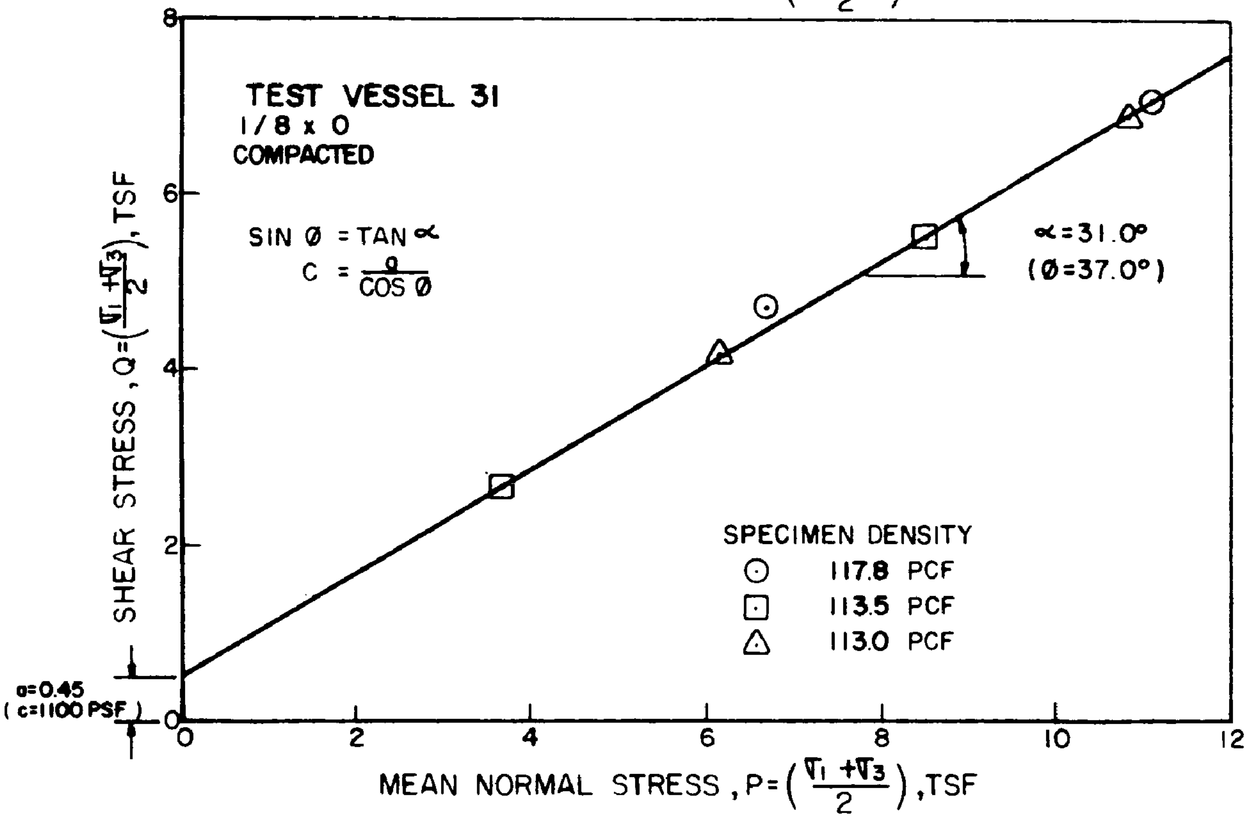




CCNSOLIDATED DRAINED TRIAXIAL TEST RESULTS

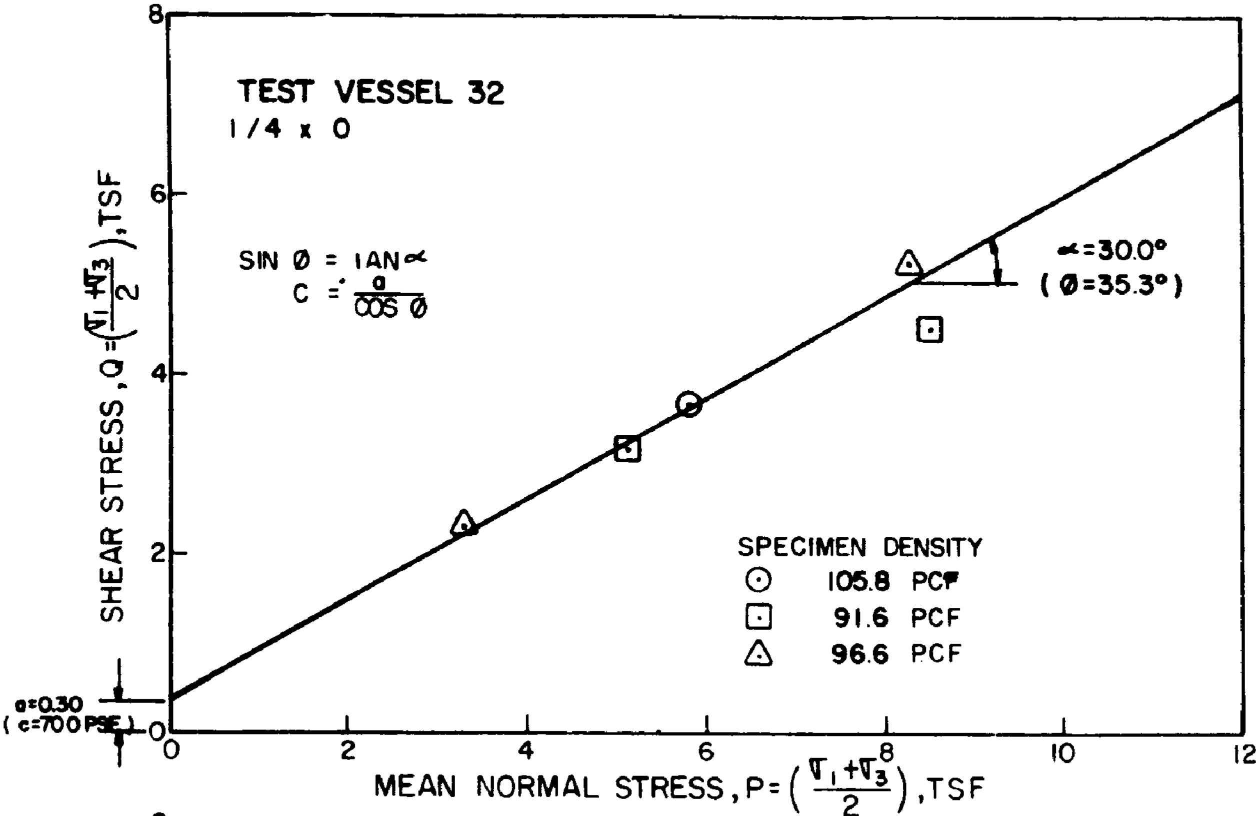
FIGURE A10

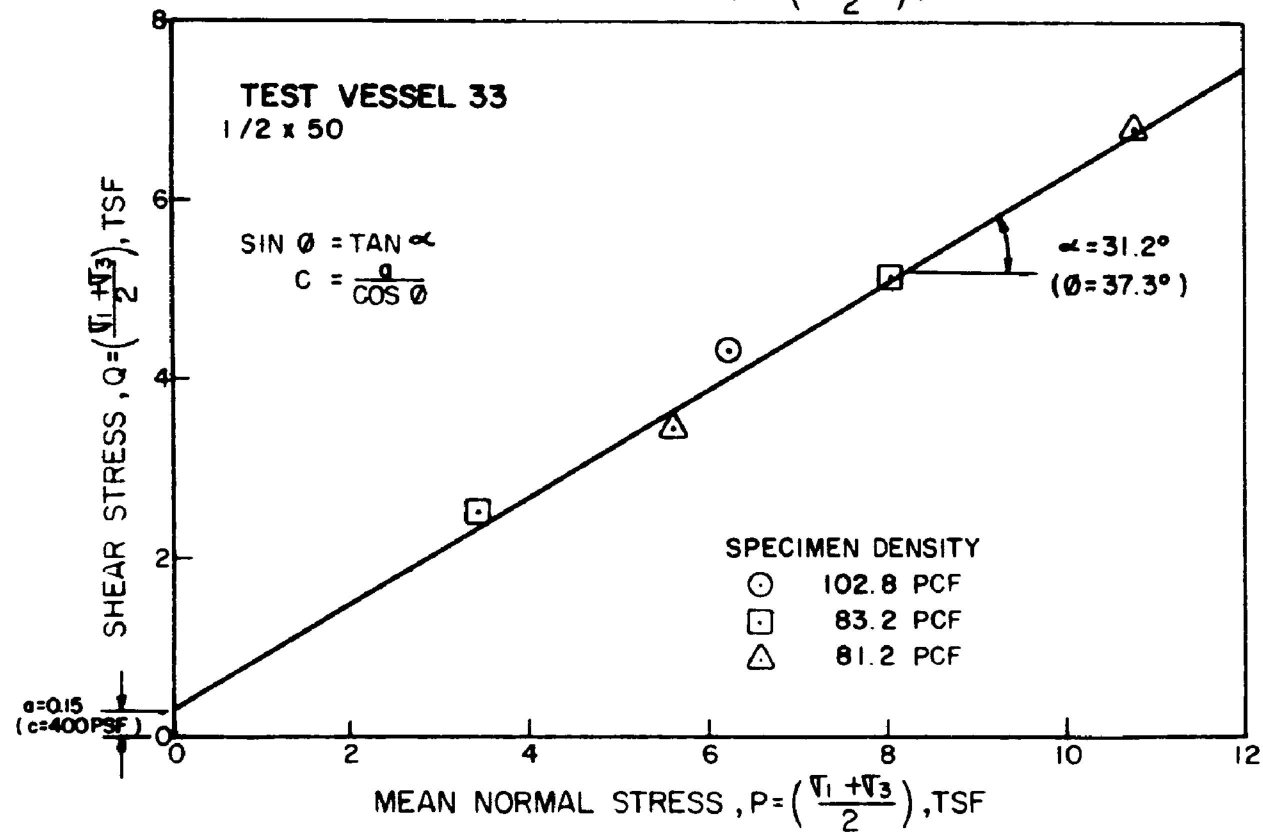




CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS

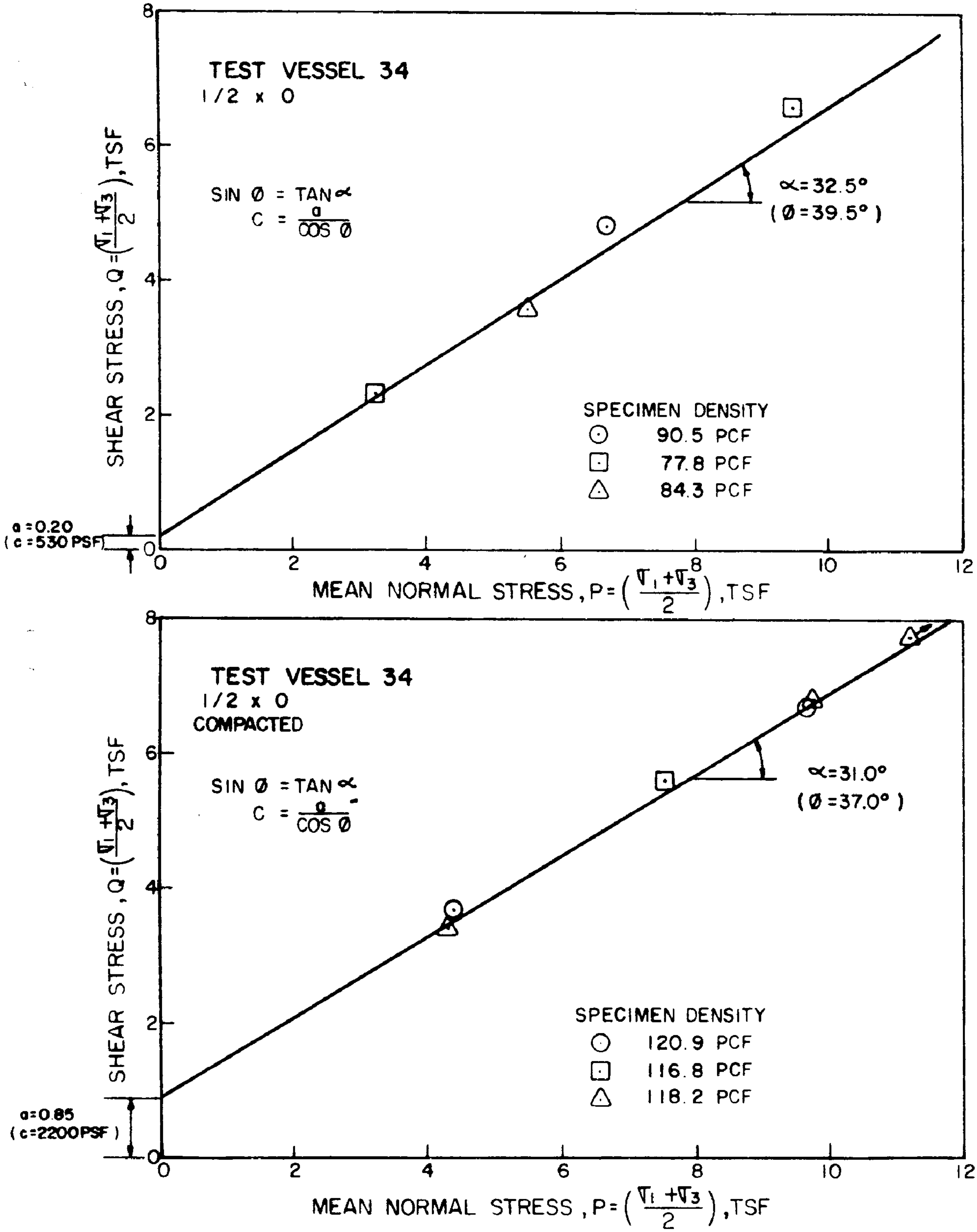
FIGURE A11





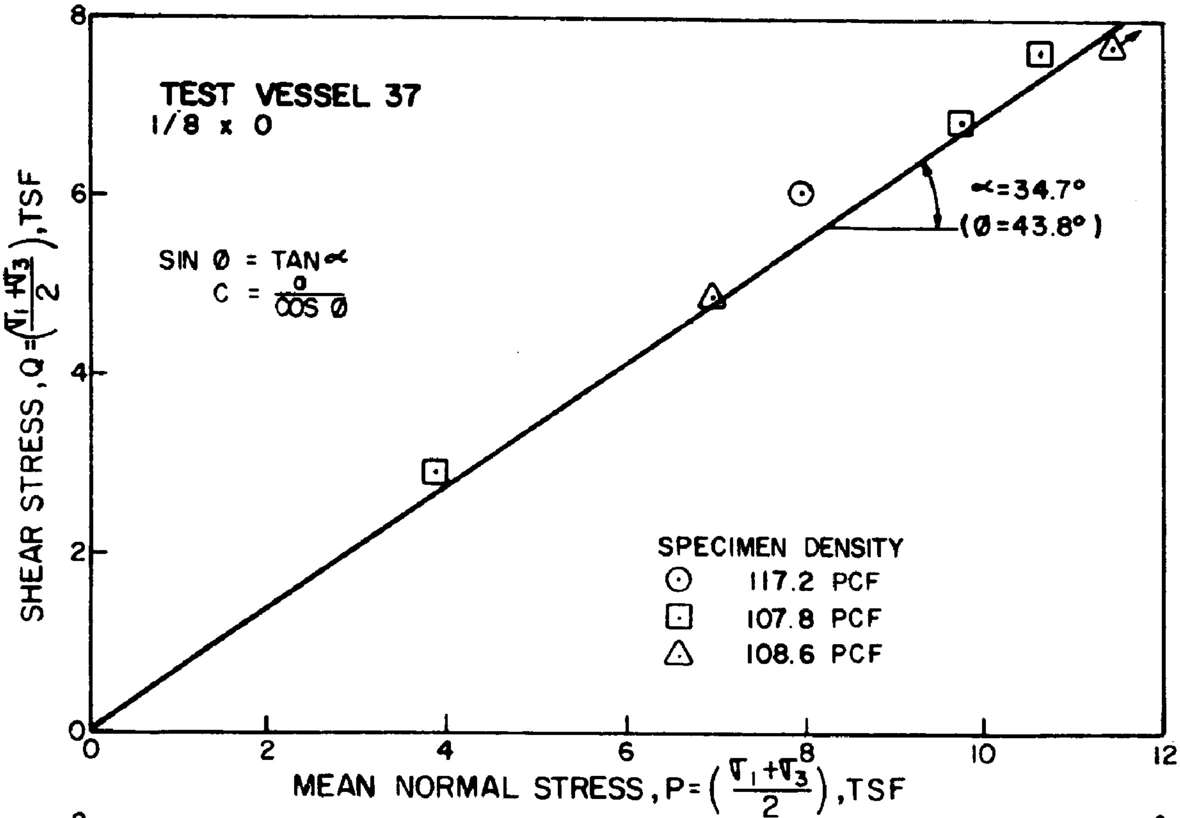
CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS

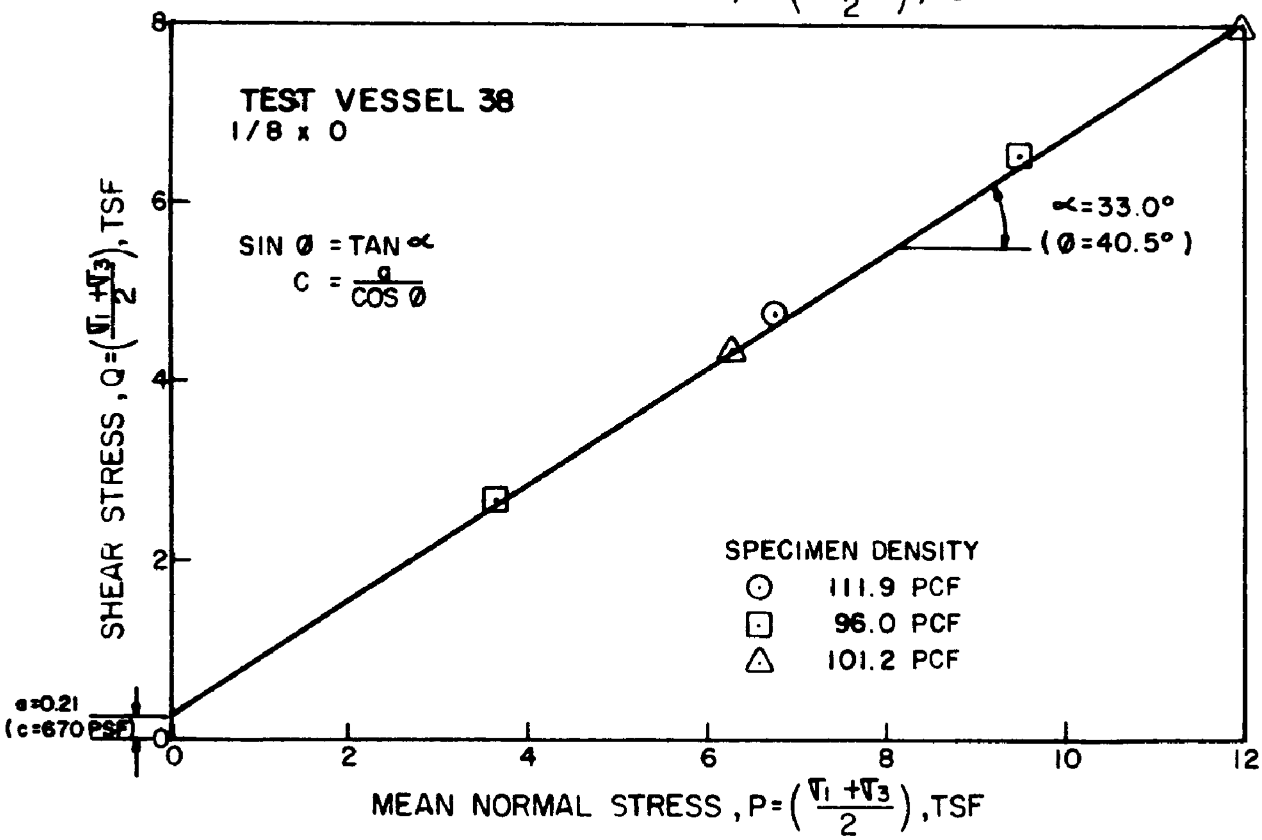
FIGURE A12



CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS

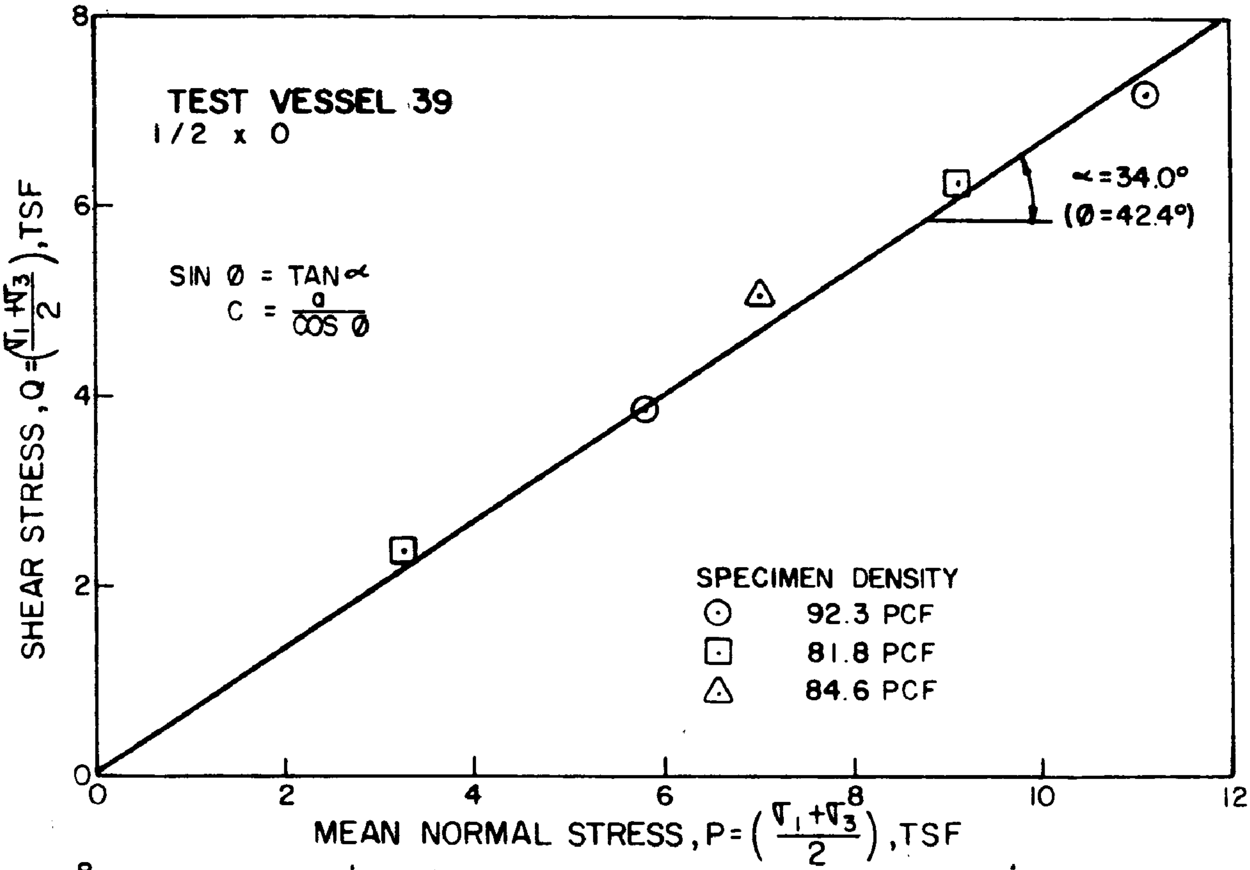
FIGURE A13

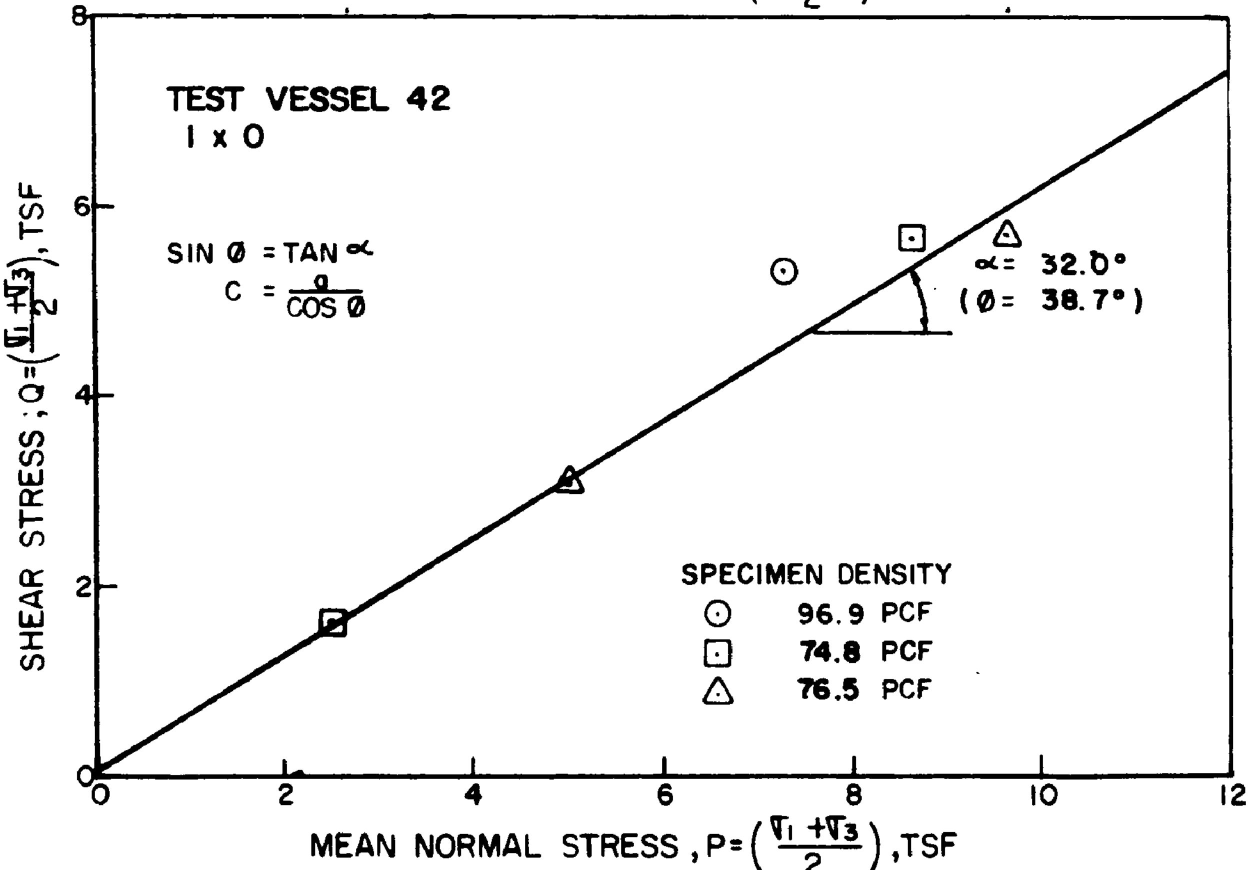




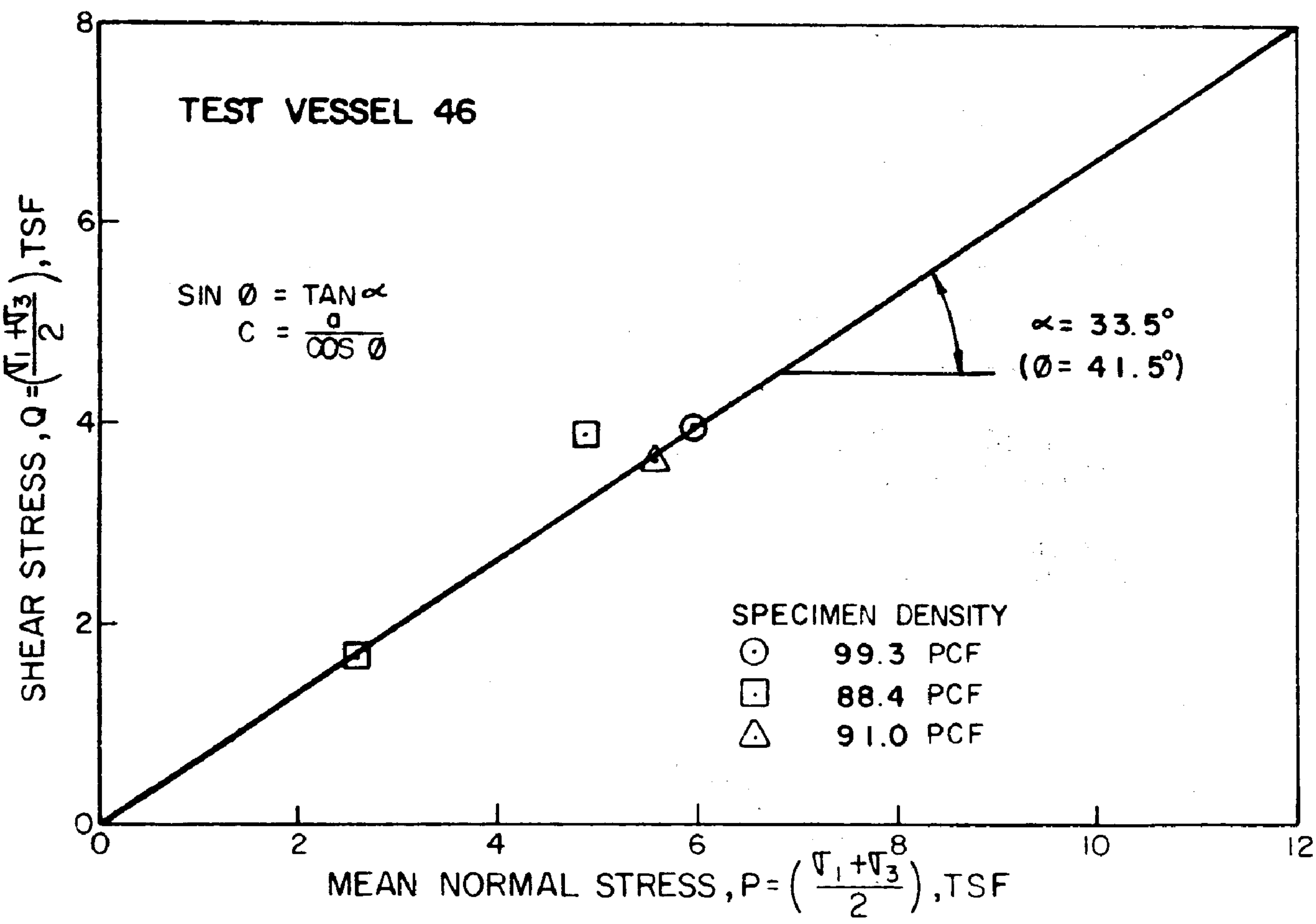
CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS

FIGURE A14



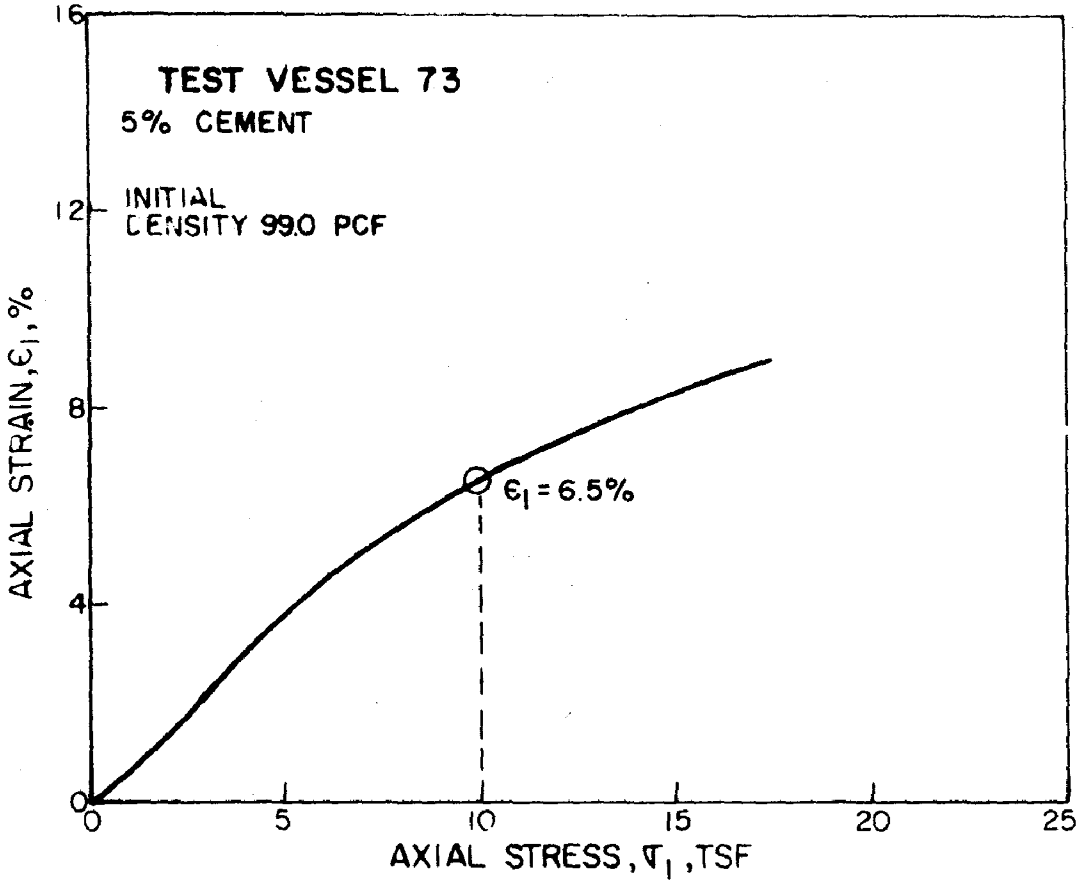


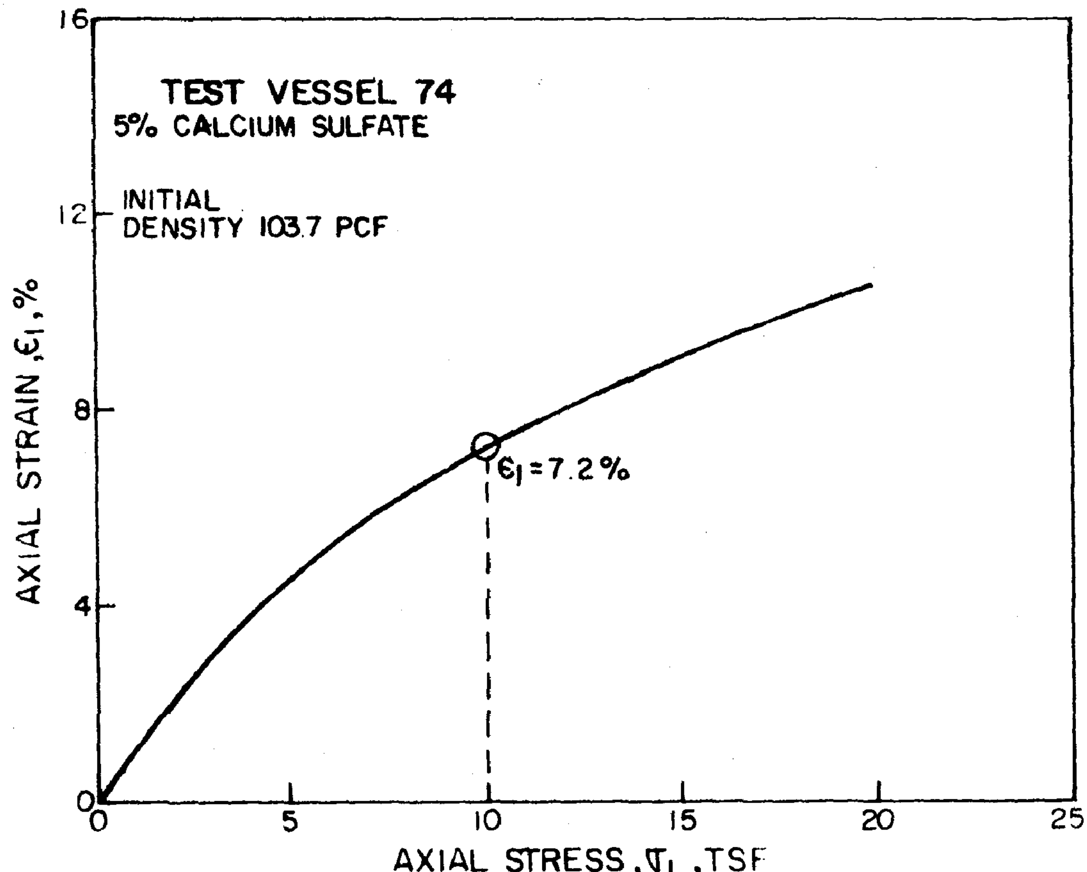
CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS
FIGURE A15



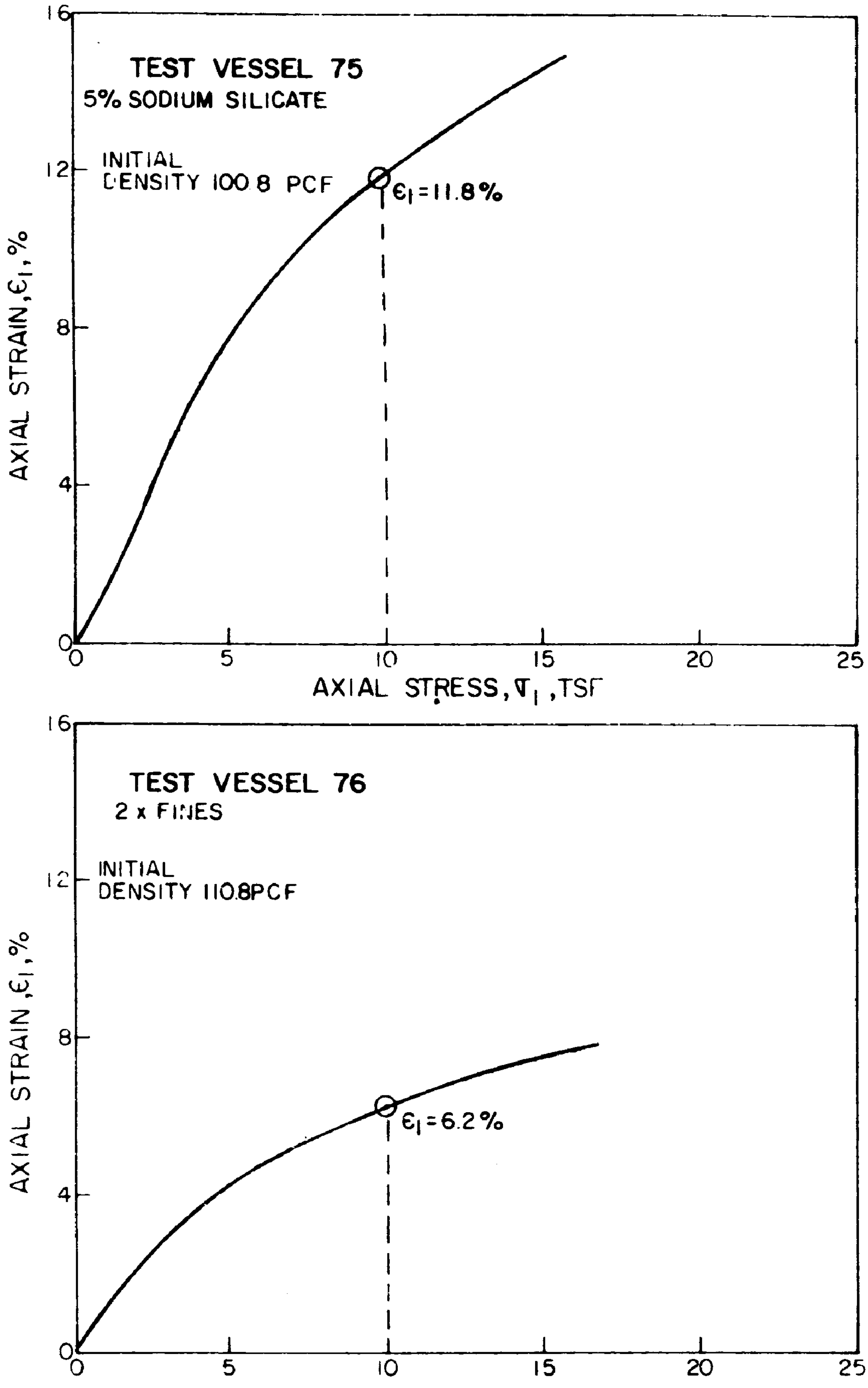
CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS

FIGURE A16

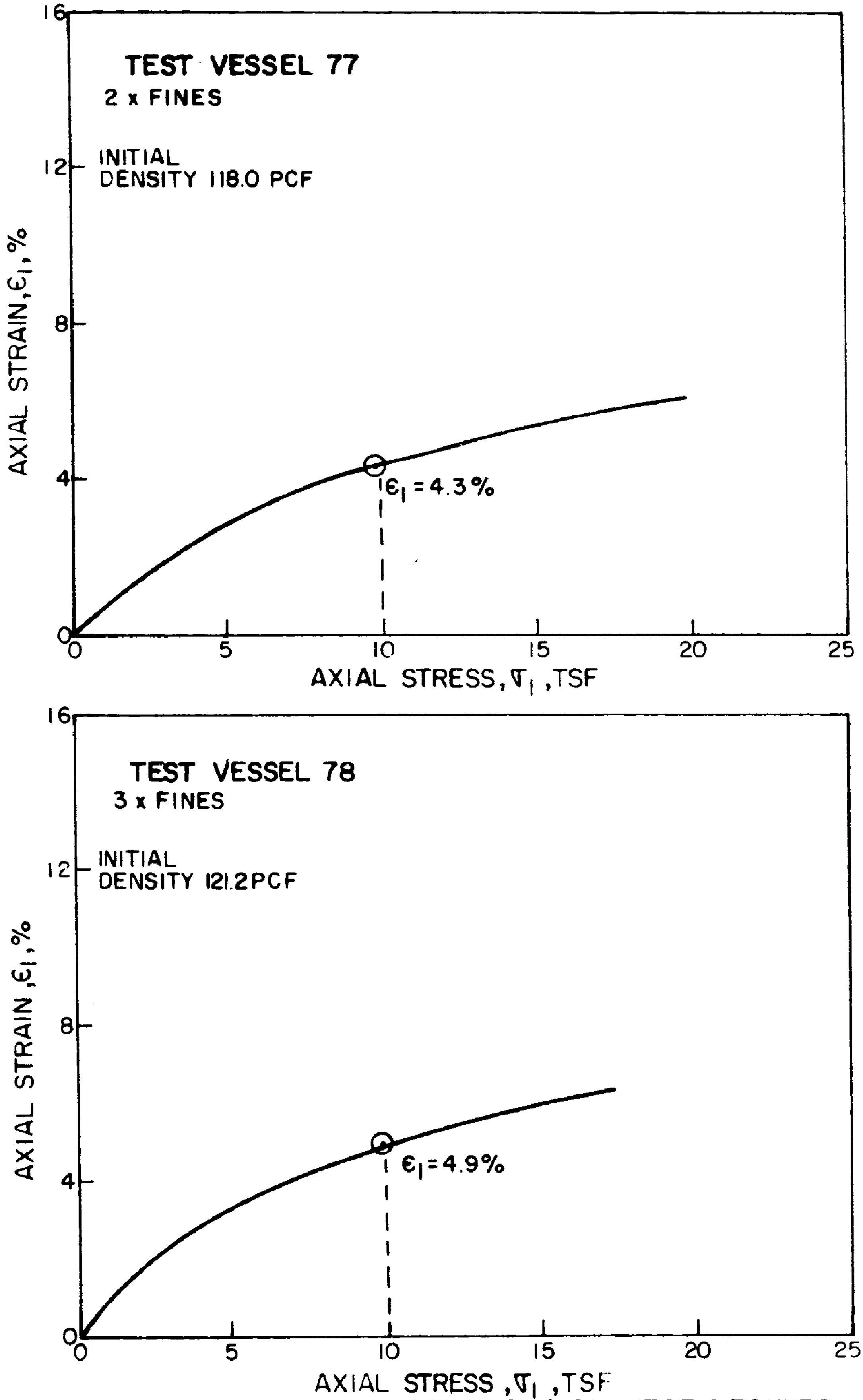




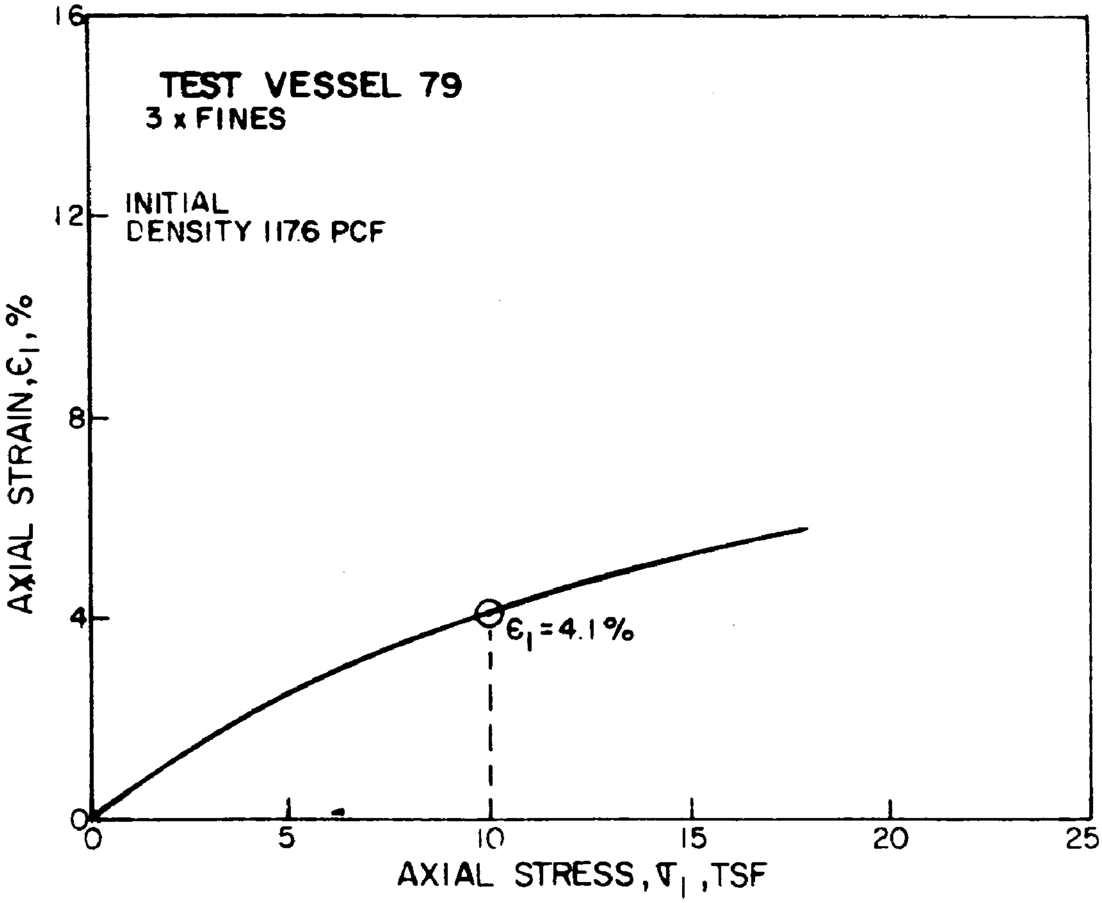
ONE DIMENSIONAL COMPRESSION TEST RESULTS
FIGURE A17

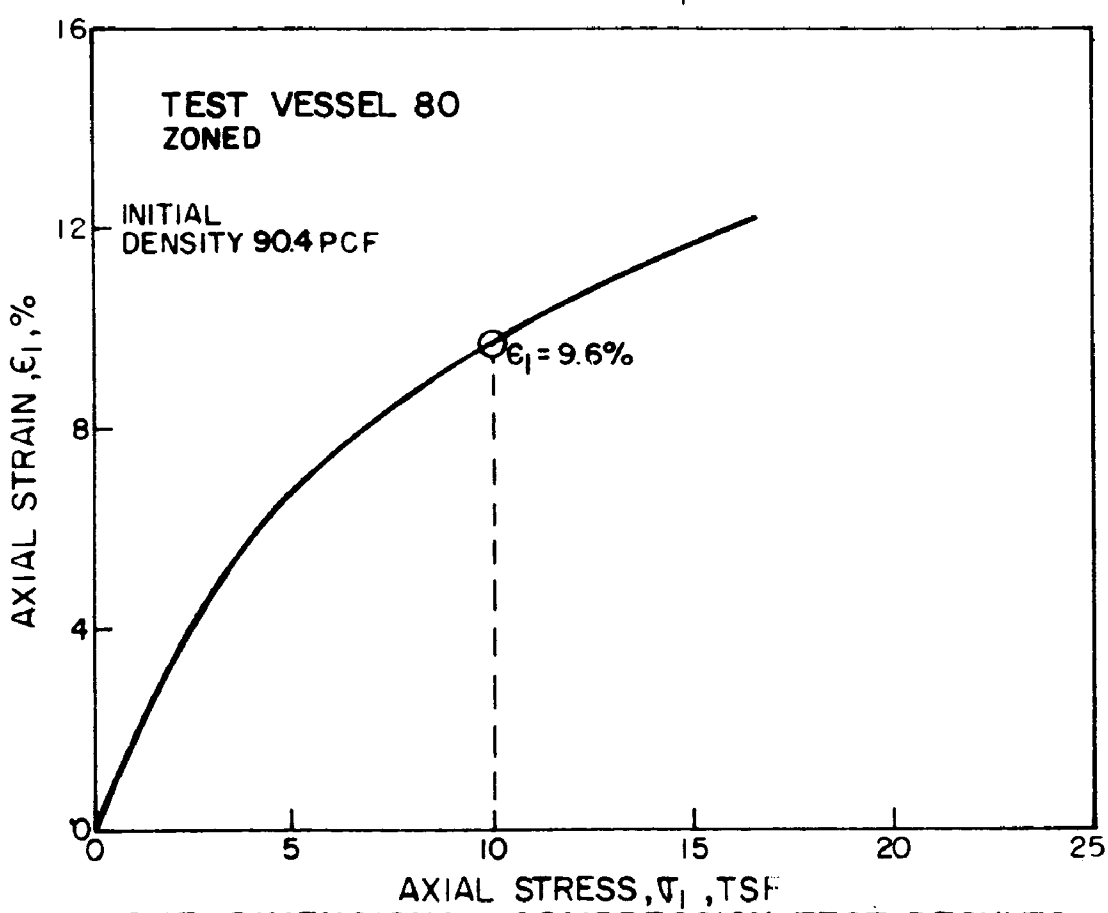


ONE DIMENSIONAL COMPRESSION TEST RESULTS
FIGURE A18

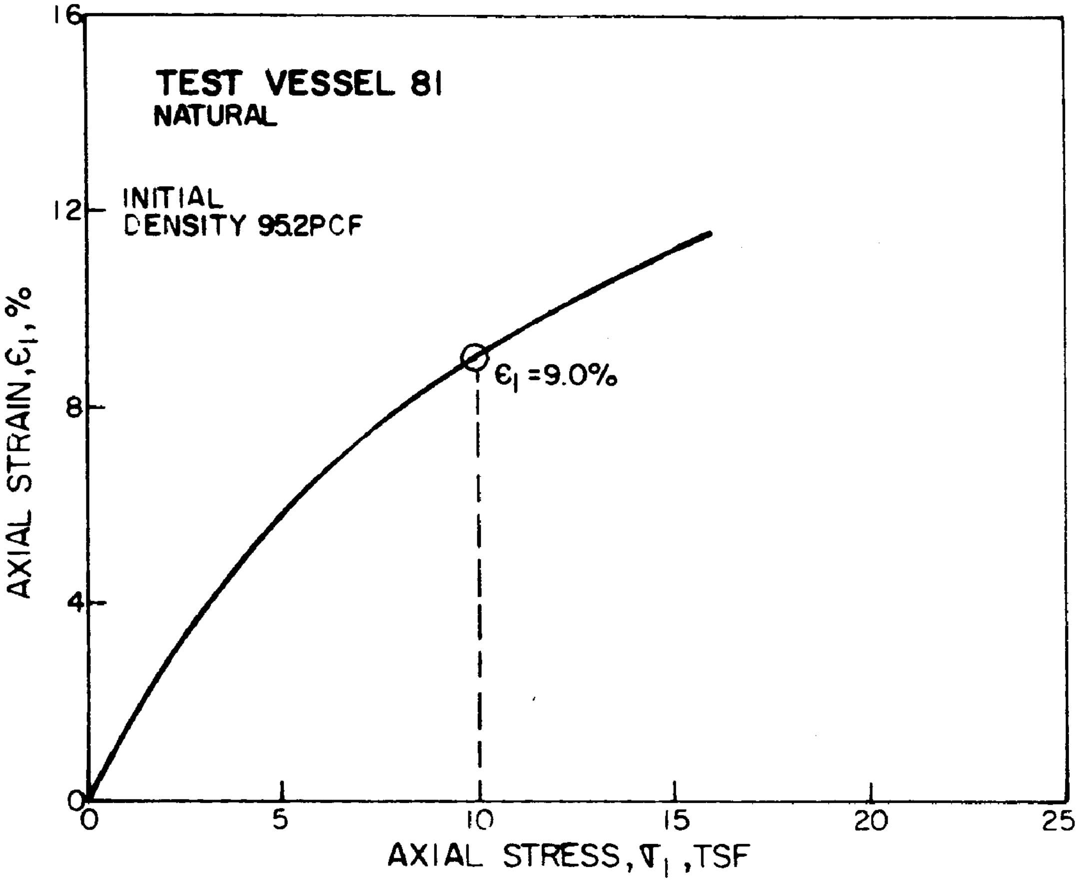


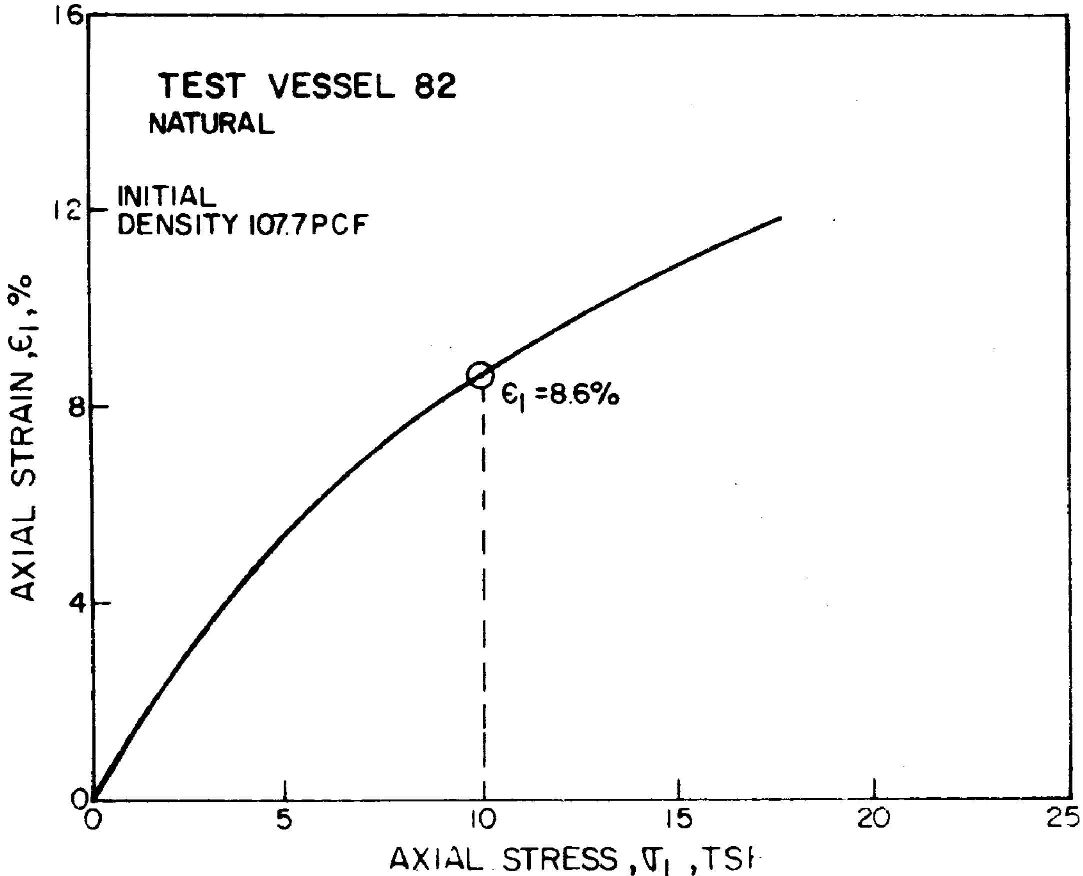
ONE DIMENSIONAL COMPRESSION TEST RESULTS
FIGURE A19



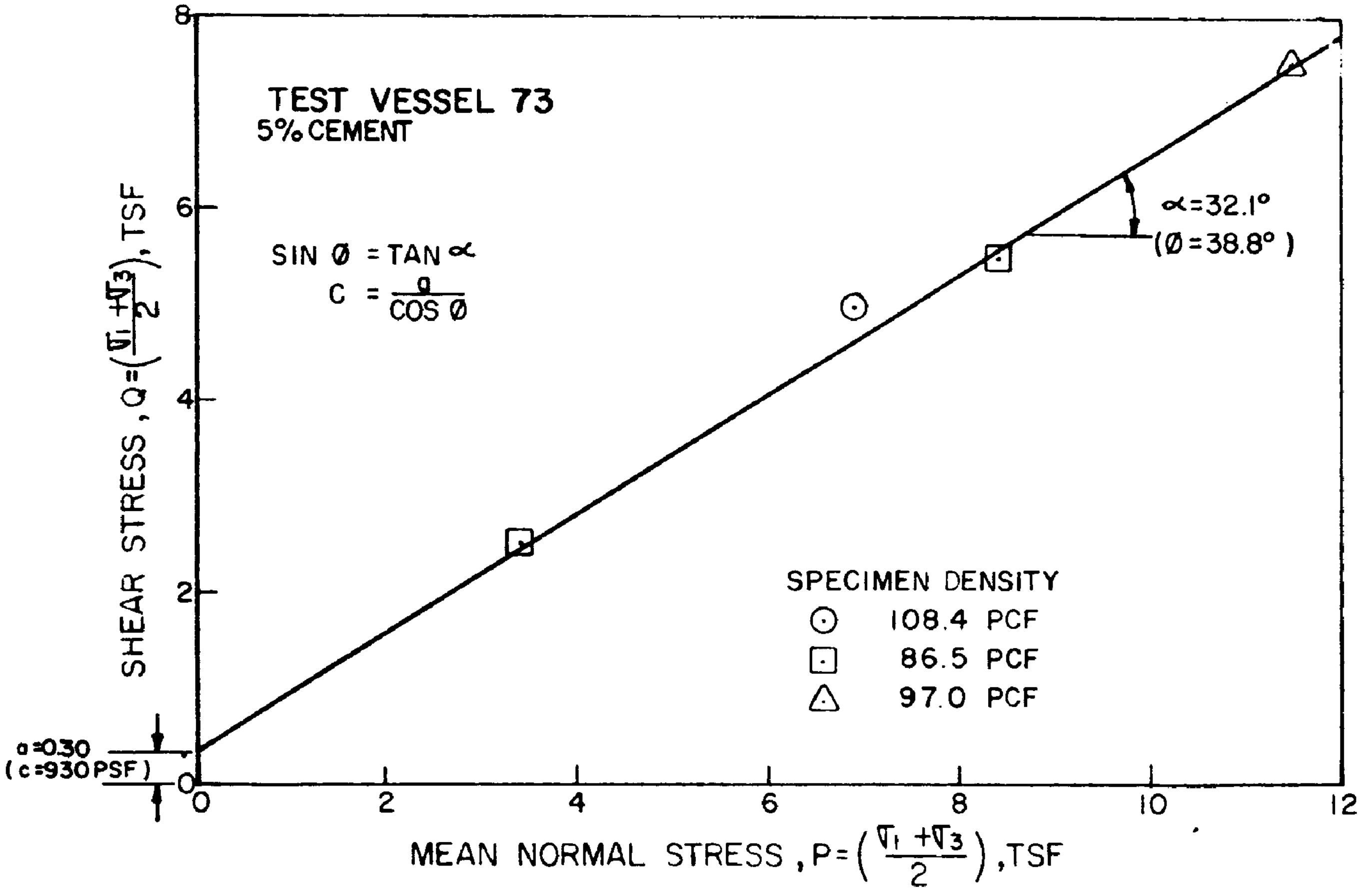


ONE DIMENSIONAL COMPRESSION TEST RESULTS
FIGURE A20



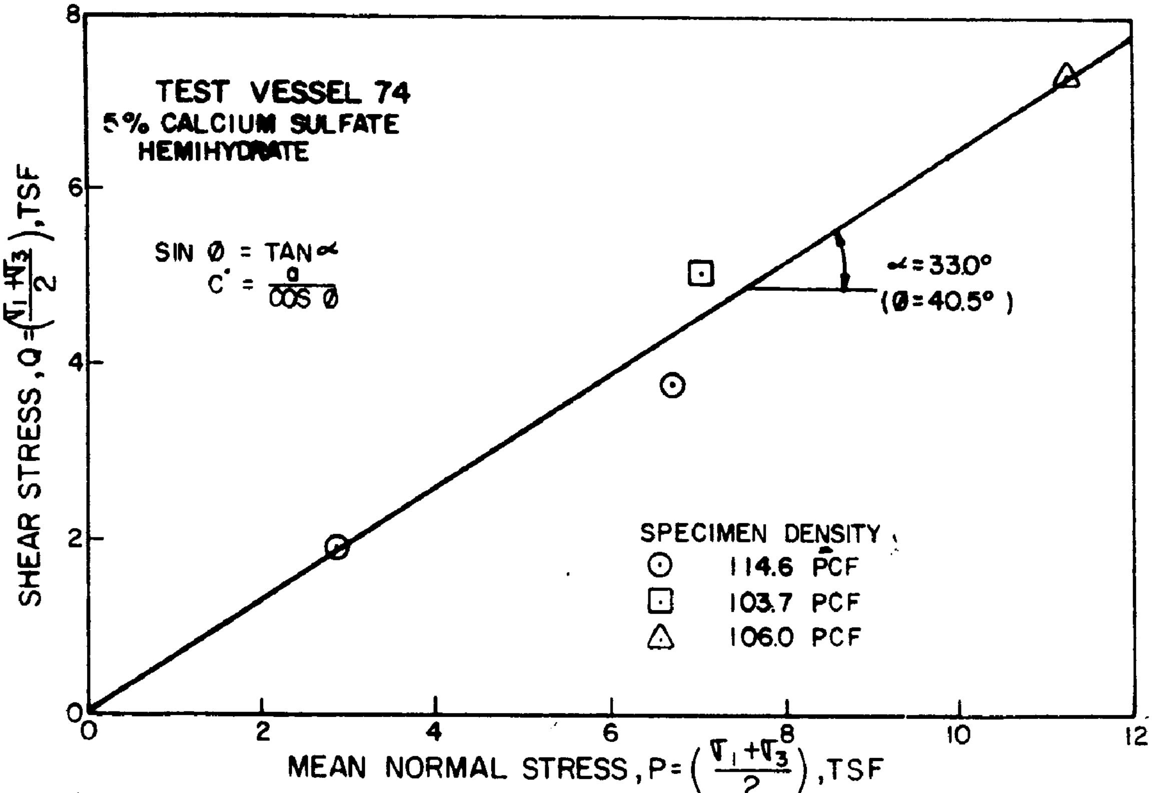


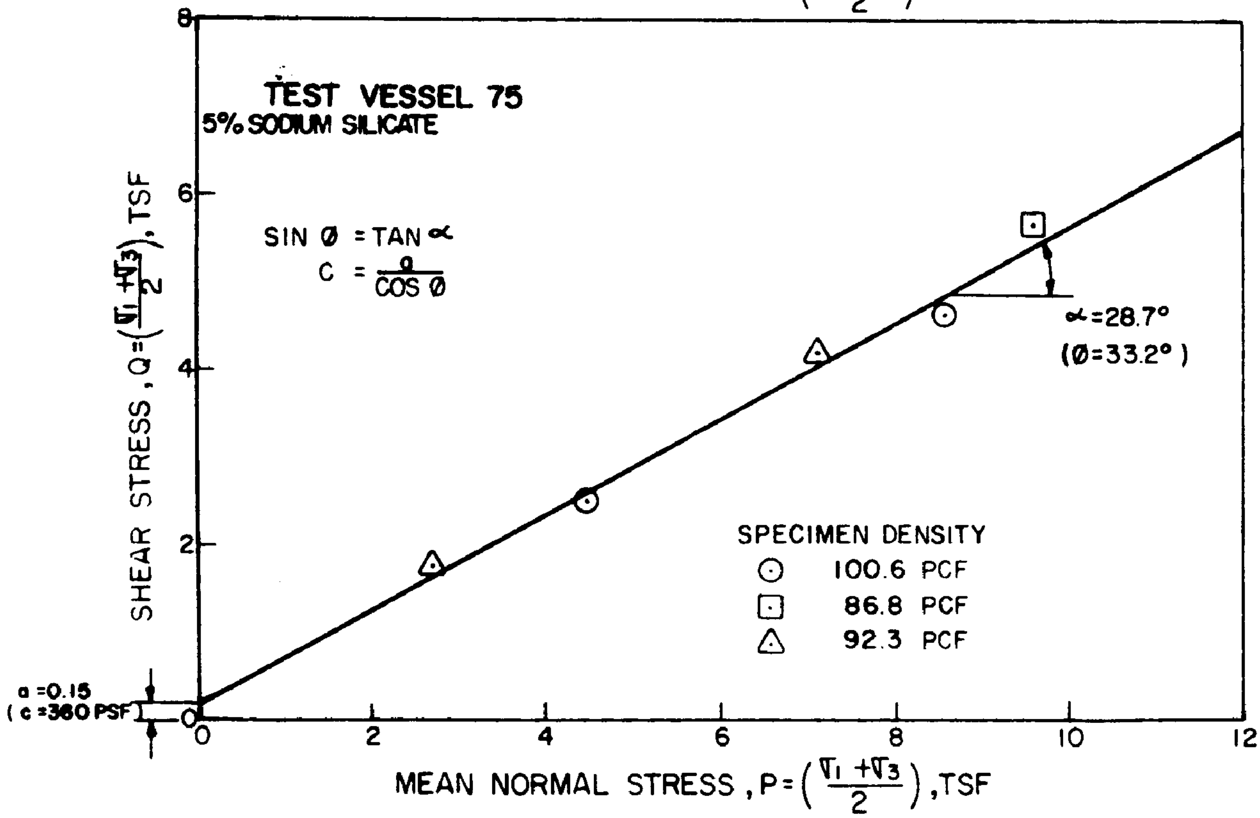
ONE DIMENSIONAL COMPRESSION TEST RESULTS
FIGURE A21



CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS

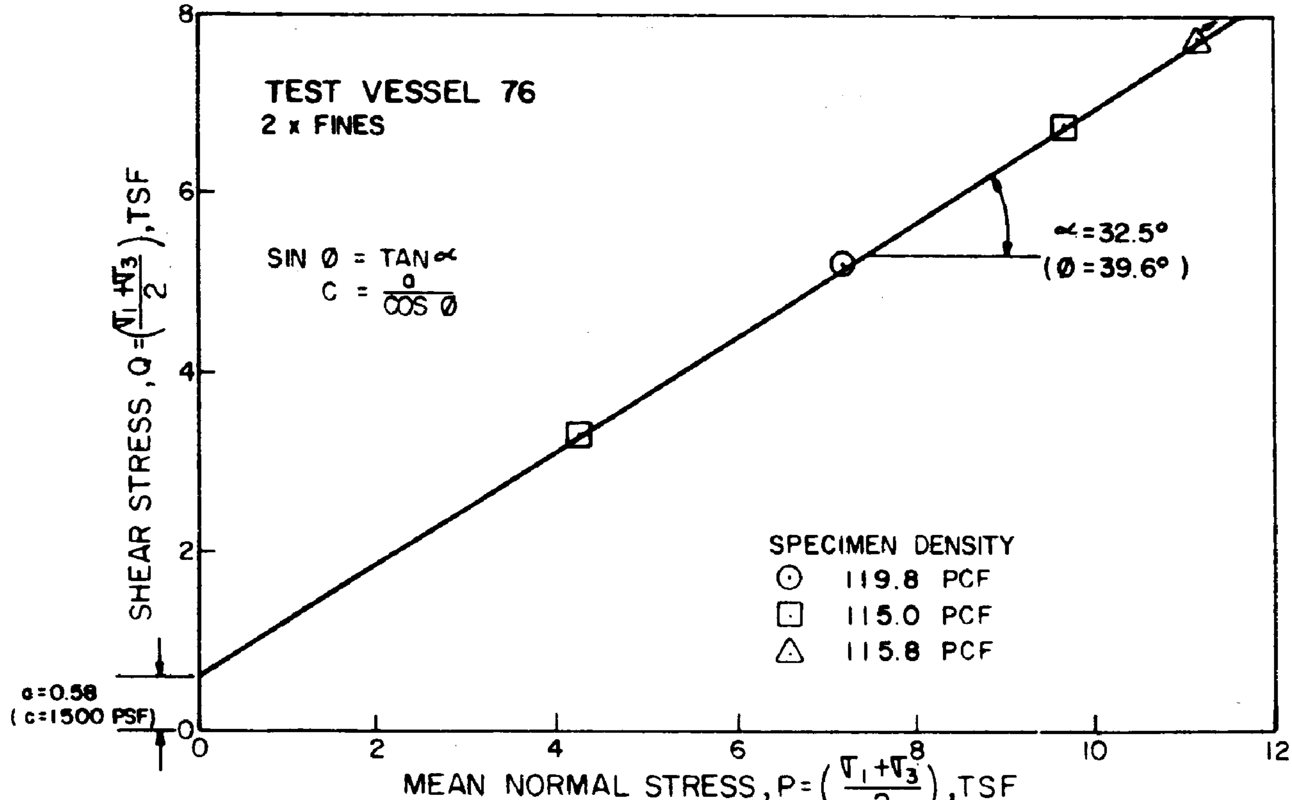
FIGURE A22

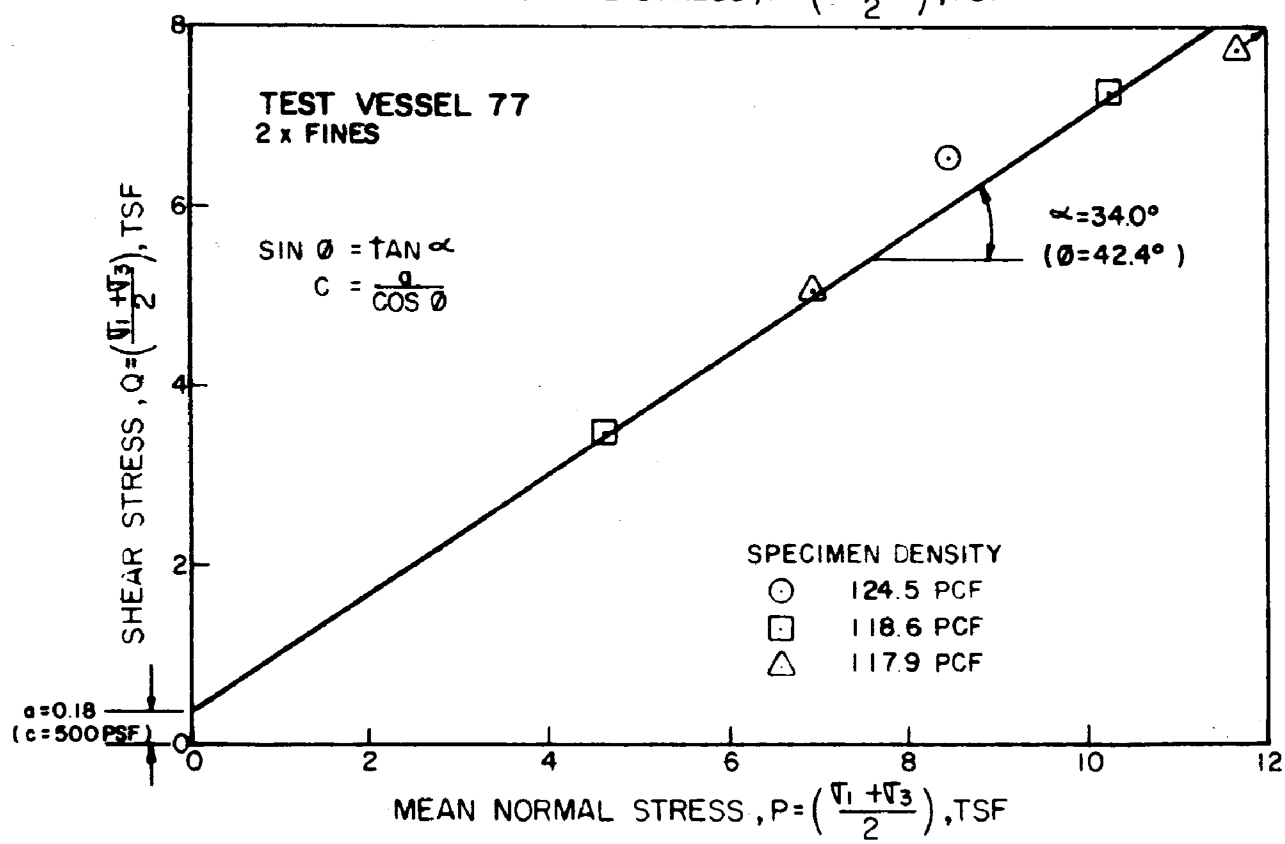




CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS

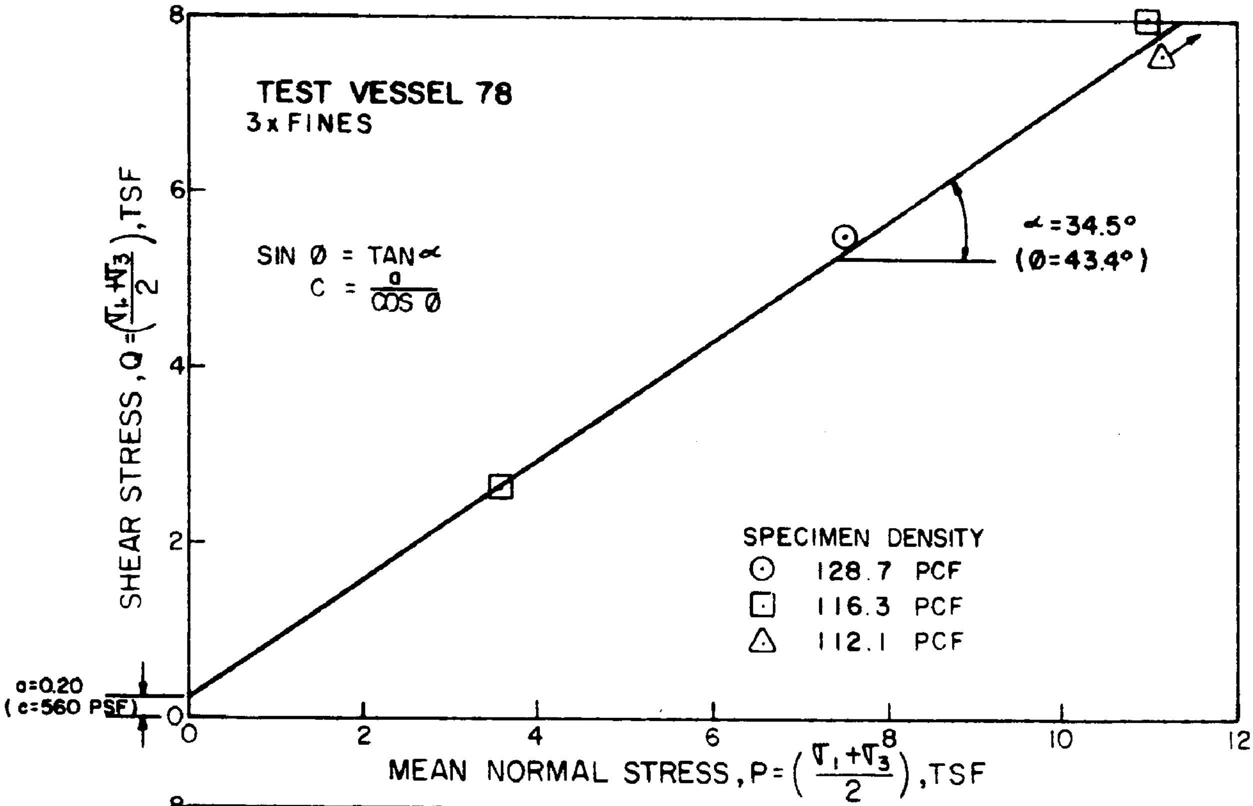
FIGURE A23

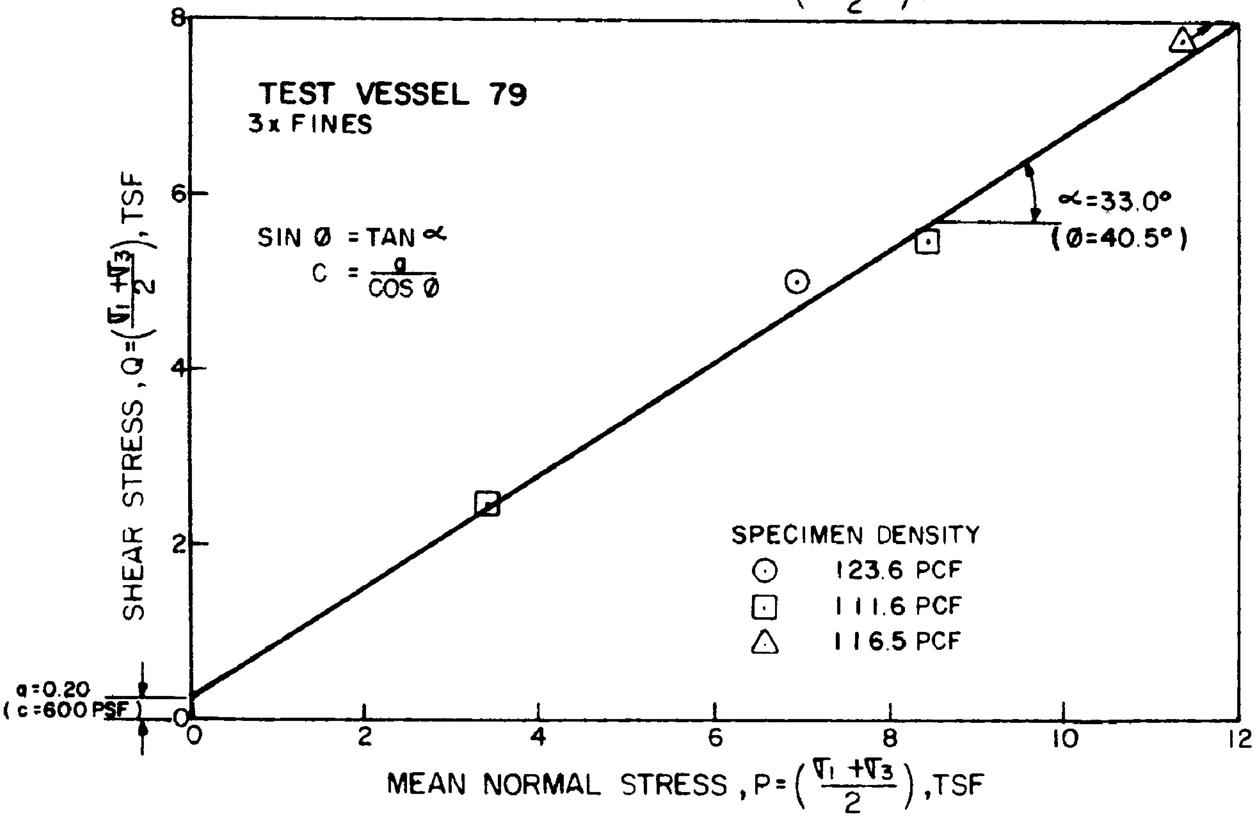




CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS

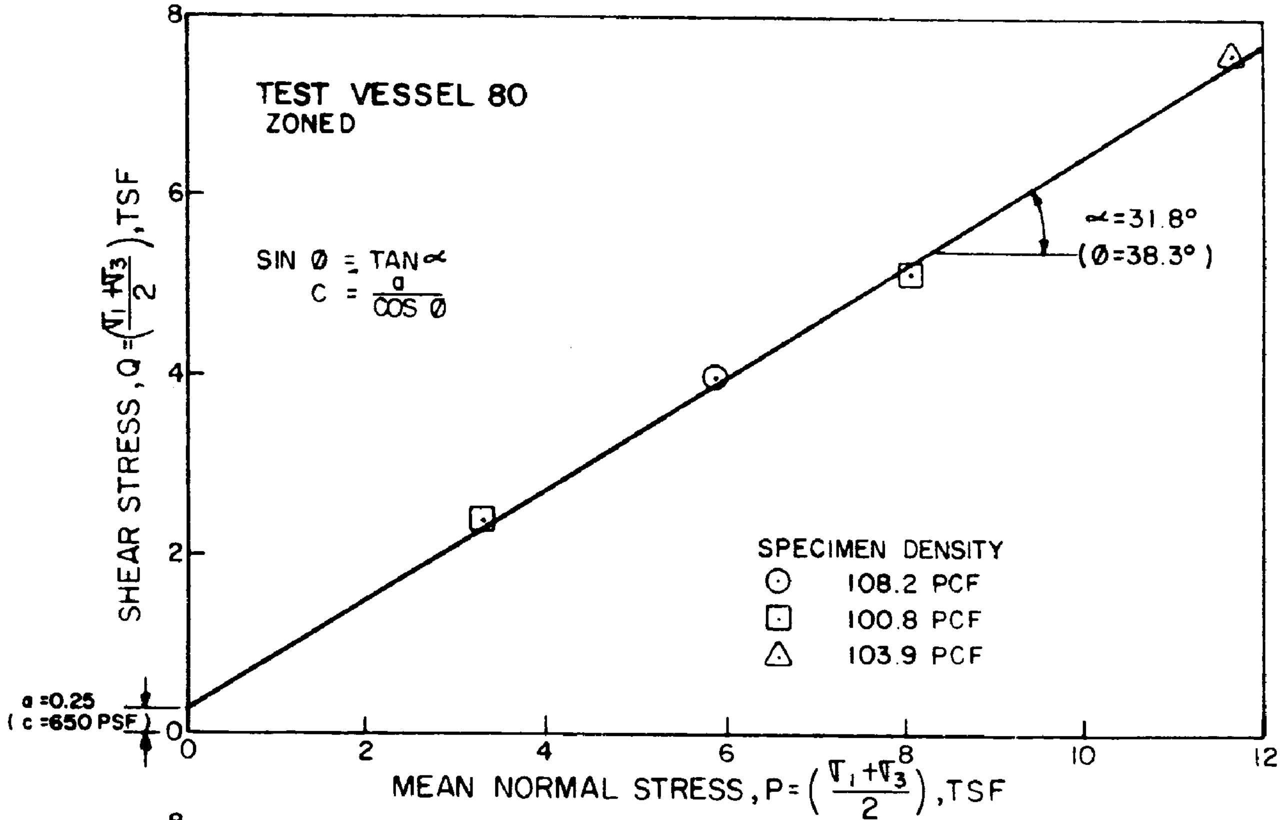
FIGURE A24

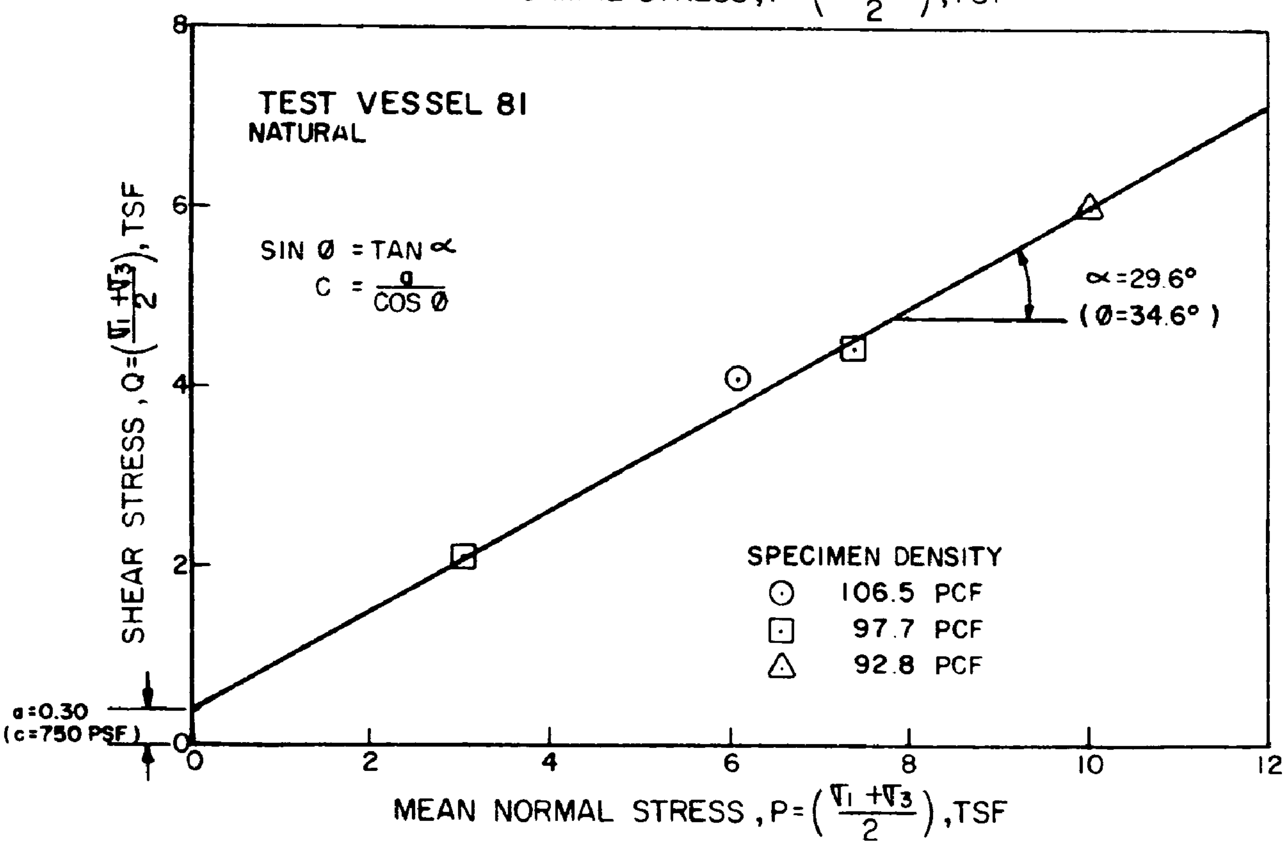




CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS

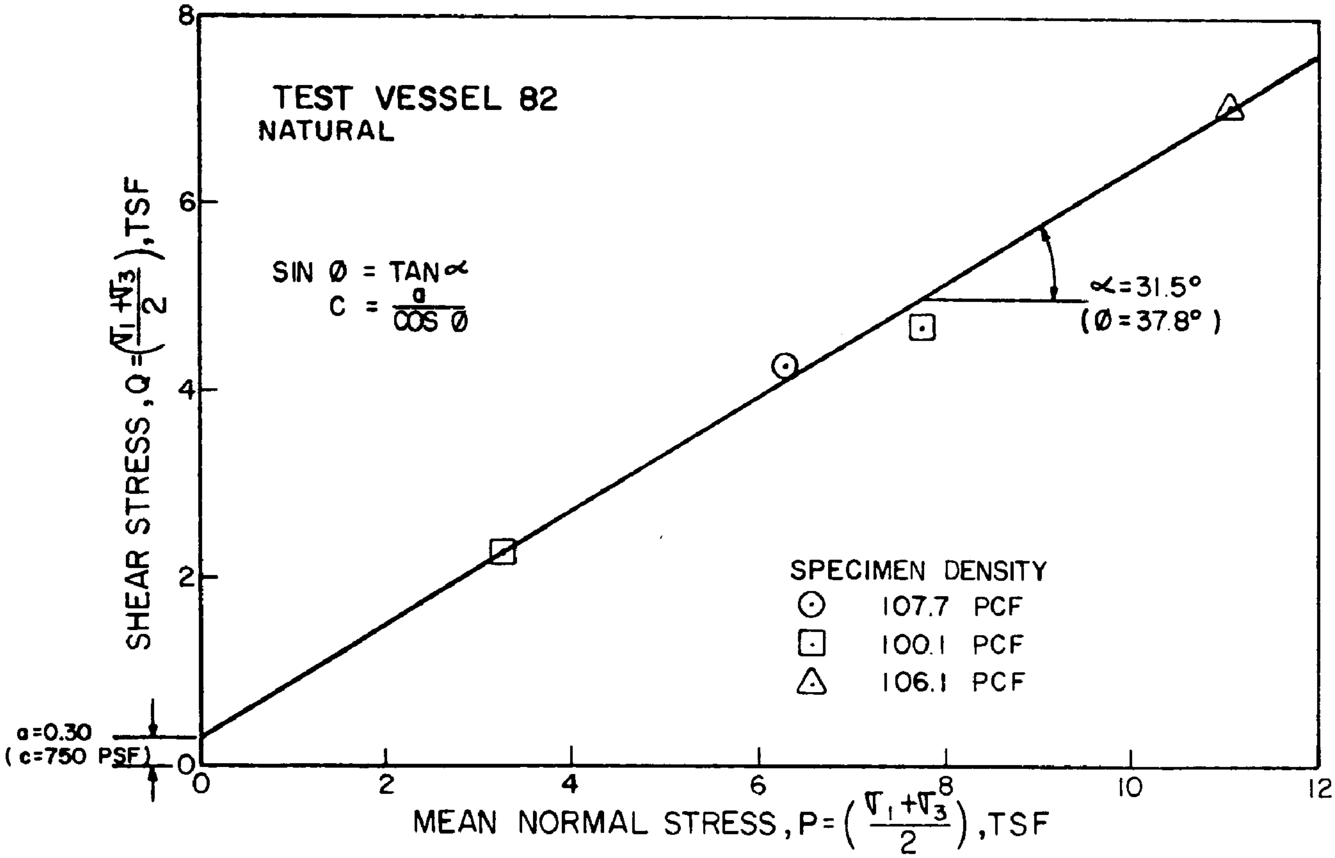
FIGURE A25





CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS

FIGURE A26



CONSOLIDATED DRAINED TRIAXIAL TEST RESULTS

FIGURE A27

1 Accession Number	2 Subject Field & Group	
	05G	**SELECTED WATER RESOURCES ABSTRACTS** INPUT TRANSACTION FORM

5 *Organization*

NUS Corporation, Cyrus Wm. Rice Division; Pittsburgh, Pa.
E. D'Appolonia Consulting Engineers, Inc.; Pittsburgh, Pa.

6 *Title*

LABORATORY STUDY OF SELF-SEALING LIMESTONE PLUGS FOR MINE OPENINGS

10 *Author(s)*

Penrose, Ray G., Jr.
Holubec, Igor

16 *Project Designation*

EPA, WQO Project No. 14016 JBU, Contract No. 68-01-0135

21 *Note*

22 *Citation*

Environmental Protection Agency
Report Number EPA-670/2-73-081

23 *Descriptors (Starred First)*

*limestones, *acid mine water, *laboratory tests, *pilot plants neutralization

25 *Identifiers (Starred First)*

*mine seals

27 *Abstract*

Laboratory studies of self-sealing limestone plugs for mine openings were conducted to determine the optimum limestone material for such a treatment and sealant technique.

Conducting a thorough study of the performance of such plugs required pilot plant operations utilizing synthetic solutions representative of anticipated acid mine waters, aggregate additives to improve plug performance, and several basic types of limestone which were varied interms of size gradation and placement density. The types of limestone used were selected from results of a previous neutralization study; synthetic mine waters were prepared to EPA formulations for ferric, ferrous, and ferrous/ferric solutions; and percentage admixture of bentonite, flyash and air-cooled blast furnace slag additives were used with the aggregate.

Experimental results indicated that permeability, compressibility and strength of a limestone plug are primarily a function of the particle size distribution and density. Plug performance was most effective with high limestone placement density and smaller gradation of stone. Ferric waters were controlled most effectively. Additive effects were less significant throughout the tests.

Further tests were conducted on the effects of particle size distribution variations and placement density and other additives to cement particles into an effective plug. (Loos - NUS)

Abstractor	Institution
Robert A. Loos	NUS Corporation - Cyrus Wm. Rice Division

WR:102 (REV. JULY 1969)
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