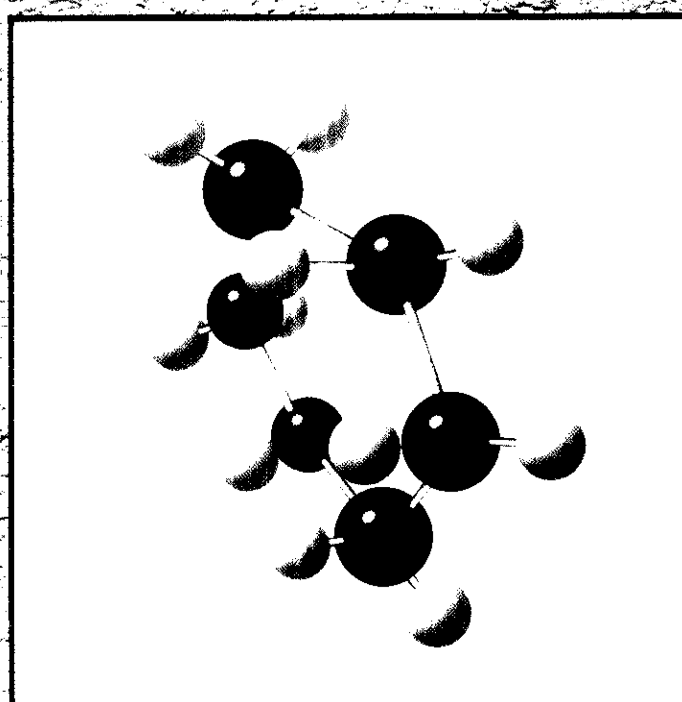

# Hycal

ENERGY RESEARCH LABORATORIES LTD.

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# ANDERSON - PIERSON
# FORMATION DAMAGE STUDY

Prepared For

Anderson Exploration Ltd.

Prepared By

Hycal Energy Research Laboratories Ltd.

June 21, 1996

95-189-F

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## TABLE OF CONTENTS

# TABLE OF CONTENTS

## List of Tables

# List of Figures

# SUMMARY

## SUMMARY

At the request of Anderson Exploration, Hycal Energy Research Laboratories Ltd. conducted a formation damage study. In this study, tests were conducted to evaluate the permeability reduction due to fines migration and the sensitivity of the core to injection brine.

These tests were conducted using core material from the Spearfish formation in the Pierson area. The displacement tests were conducted while simulating the reservoir conditions of 40°C and an applied net overburden pressure at 15940 kPa and by utilizing supplied dead oil and formation and injection brines as displacing fluids. Major results of the study are summarized as follows:

**Fluid Sensitivity Test**

A fluid sensitivity test was conducted to investigate the potential of the core material to exhibit permeability impairment as a result of exposure to Blairmore water. Results of the fluid sensitivity test are summarized in the following table:

| | **Core #23** |
|---|---|
| Initial Permeability To Formation Brine (mD) | 10.78 |
| Fluid To Be Tested | Blairmore Water |
| Final Permeability To Test Fluid (mD) | 5.56 |
| % Change In Permeability | -48 |

**Fines Migration Test**

An experiment was conducted to determine if permeability impairment in the core material would occur as a result of increasing interstitial velocity in the pore space. The major results of the test are summarized in the following table:

| | **Core #19** |
|---|---|
| Baseline Permeability (mD) | 0.193 |
| Critical Interstitial Velocity (m/d) | 73.73 |
| Maximum Interstitial Velocity Tested (m/d) | 1966 |
| Permeability After Maximum Interstitial Velocity (mD) | 0.123 |
| % Change in Permeability | -36.3 |

# INTRODUCTION

## INTRODUCTION

At the request of Jik Chan of Anderson Exploration, Hycal conducted a formation damage study using reservoir core material from the Spearfish formation in the Pierson area. The purpose of this study was to investigate change in permeability due to increasing injection velocity and determine permeability reduction caused by injection of Blairmore water. This report describes the experimental equipment and procedures used. The summary of this report is designed to provide an abridged overview of all experimental data while the "Results and Discussion" section provides a detailed discussion of the experiments and the results obtained. The "Conclusions" section provides the pertinent findings of these data with reference to specific mechanisms and phenomena exhibited during the experimental process.

## DESCRIPTION OF EQUIPMENT

## DESCRIPTION OF EQUIPMENT

### General Displacement Test Equipment

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

#### Core Mounting

The core sample to be tested is placed in a 3.81 cm ID flexible confining sleeve. The ductility of the sleeve allows a confining external overburden pressure to be transferred to the core in a radial and axial mode to simulate reservoir pressure. The core, mounted within the sleeve, is placed inside a 7.5 cm ID steel core holder that can simulate reservoir pressures of up to 68.9 MPa. This pressure is applied by filling the annular space between the core sleeve and the core holder with non-damaging saline brine. The water is then compressed with a hydraulic pump to obtain the desired overburden pressure. The core holder ends each contain two ports to facilitate fluid displacement and pressure measurements at each end of the core.

#### Conventional Core Flow Heads

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

Pressure Measurement

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

Temperature Control

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

Filtration

All injection fluids are filtered to 0.5 microns before use to remove any potentially plugging suspended particles (unless unfiltered fluids are requested). An in-line 0.5 micron filter is also present directly before the core as a backup filtration system (removable if unfiltered fluids are desired).

Fluid Displacement

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

## EXPERIMENTAL PROCEDURE

## EXPERIMENTAL PROCEDURE

### Core Handling and Preparation

Full diameter core material obtained from Manitoba Energy Mines was utilized as the test matrix for the study. The core material was taken from the 1017.30 to 1019.60 m interval of well 4-15-2-29 W1M in the Pierson area.

A total of 4 plugs were drilled from the full diameter core samples to obtain small plug samples with a maximum diameter of 3.80 cm. All small plugs were drilled using 3% KCl as a lubricating fluid to minimize the potential for damage of in situ clay mineralogy and prevent any other damage to the core during drilling.

Routine air permeability and helium expansion porosity were conducted on the samples to aid in the selection of representative core material for testing. Table 1 summarizes the routine analysis for the samples. Sufficient volumes of oil and both formation and injection brines were supplied by Anderson to act as displacing fluids for the test series.

### Wettability Restoration

Core samples used in this study were in a non-preserved state, and a wettability restoration procedure was utilized to attempt to restore the rock wettability to original in-situ conditions. Since all reservoirs initially exist in a water-wet state, with oil migration occurring into the reservoir following deposition and hydration, the restoration procedure is conducted to simulate the actual field scenario.

The cores to be restored are mounted in lead sleeves, evacuated and then saturated with formation brine (hydration stage). This brine is circulated in the core for one week to re-establish an ionic equilibrium condition and to rehydrate any desiccated in-situ clays. This brine circulation is followed by the displacement of supplied unoxidized dead crude oil (migration stage) at reservoir temperature for a recommended period of six weeks (1100 hours) as discussed in the literature. At the beginning of each week a fresh supply of oil is circulated through the core followed by a static interval to allow the wettability transformation reaction to occur (if the tendency exists).

This wettability restoration procedure is important if the rock has a natural tendency to become less water-wet (i.e. neutral to oil-wet) as normal extraction procedures tend to remove the polar and asphaltic components which cause an oil-wetted pore surface to be established. The long term exposure of the virgin unoxidized crude generally allows an equilibrium concentration of these polar and asphaltic constituents to be re-adsorbed on the rock surface allowing the samples to revert to their natural in-situ wettability. Restoring the correct wettability condition is significant to experimentation because the wetting phase contacting the rock matrix acts as the conduit (or barrier) between invading fluids and rock mineralogy thereby controlling the propensity for rock-fluid interactions. Wettability can also have a profound influence on the efficiency of immiscible displacement processes.

**Sensitivity Test**

The core material to be tested was mounted using the equipment outlined in the "Description of Equipment" section of the report. Core samples were subjected to the reservoir temperature of 40°C and a net overburden stress of 15940 kPag. The laboratory net overburden stress was Poisson's ratio corrected to account for the tri-axial stress condition exerted on the sample in the core holder. This ensures that field stress load conditions are simulated to yield representative rock compression and realistic absolute permeability values.

The following fluid sensitivity procedure was utilized to obtain the experimental results for the study.

Fluid Sensitivity Procedure

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

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

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

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

5. Depressure core, dismantle, and store the core immersed in injection water for possible future petrographic analysis.

**Fines Migration Test**

The core material was subjected to specified reservoir conditions of temperature and net overburden confining stress to obtain representative state for the displacement series. The following fines migration procedure was used to determine the propensity for migration of pore space particulates in a high shear environment.

Fines Migration Procedure

1. Mount the core in a flexible sleeve. Apply the specified net overburden pressure and heat the core to reservoir temperature.

2. Flood the core with filtered non-damaging formation water.

3. Displace filtered formation water through the core at a base rate velocity and determine the initial stabilized permeability of the core material.

4. Increase the injection rate and displace formation water to achieve steady state pressure differential. Reduce the rate to base rate velocity and measure the stabilized permeability

of the core and calculate any change in the baseline permeability caused by the elevated flow rate.

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

# RESULTS AND DISCUSSION

## RESULTS AND DISCUSSION

Hycal Energy Research Laboratories completed a formation damage study to determine permeability impairment resulting from fluid sensitivity and fines migration. Core samples were selected from 4-15-2-29 W1M in the Pierson area, using 3% KCl brine, four plugs were drilled for use in the study. Major results of the study are as follows:

1. Core sample #23 ($k_{air}$ = 4.35 $\phi$ = 6.7%) was used to determine the sensitivity to supplied Blairmore water. The test was conducted by establishing flow of formation water through the core material and measuring stabilized permeability as a function of throughput (10.78 mD). Displacement was then switched to the proposed injection water, and permeability was tracked continuously to determine whether any change in permeability occurred as a result of the injection water exposure.

   Following the switch to Blairmore brine, the permeability was significantly reduced by 48.5% to 5.56 mD, and this change occurred relatively quickly following the switch to the injection water phase. This type of change is normally associated with an adverse reaction of in-situ clay material as a result of exposure to a fresher aqueous phase. Degradation of the permeability is characteristic of a deflocculation type of clay damage process (i.e. resulting from destabilization of kaolinite clay), however this may also be a mass transfer related process resulting from swelling of smectitic clays.

   There is some discrepancy in the data, in that the initial effective permeability to formation brine is higher than the measured routine air permeability value. This is atypical from the usual response, in that routine air permeability measurements are usually conducted on dry (i.e. desiccated) core material which usually results in a higher routine air permeability than the measured liquid perm. Due to the volume of data available for the liquid displacement test, we view the sensitivity data as being reliable, and it is not viable to remeasure the routine air permeability since the matrix may be damaged following the Blairmore brine exposure.

   In general, we are able to conclude from these results that the Blairmore brine has significant potential to damage the Pierson core material. It may be advisable to co-mingle the injection stream with a produced formation brine phase so as to increase the salinity of the mixture thereby reducing the sensitivity of the formation material. It should also be noted that the sensitivity test conducted on core #23 is a worst case scenario since, in the presence of a potentially oil-wetting hydrocarbon phase, the damage to the clays may be isolated from the fresh injection water.

2. Core sample #19 ($k_{air}$ = 3.72 $\phi$ = 8.6%) was used to determine the permeability impairment due to increased velocity. Formation brine, was used as displacing fluid to

ensure no chemical sensitivity was incurred by the sample. An initial permeability to brine of 0.193 mD was established at a base rate of 20 cc/hr. The low effective permeability was due to the restoration of the sample (i.e. oil saturation) and the increased net overburden stress applied to the core. Permeability decreased substantially at 300 cc/hr (critical interstitial velocity) and continued to decrease at each higher velocity. At the maximum displacement rate of 800 cc/hr (1966 m/day) permeability decreased by 36% to 0.123 mD which is considered to be moderate damage.

This test suggests there may be moderate mechanical damage (fines migration) in the field at interstitial velocities of 73 m/day or higher but, due to the relatively low initial permeability, this may not have a significant impact on the overall performance of the reservoir.

**Data Diskette Summary**

A 3½" high density data diskette is included at the end of the report. This diskette contains all pertinent numerical information from the test series summarized in Lotus 1-2-3 style spreadsheet format. This will facilitate the plotting and manipulation of the data as required. A summary of the worksheet files contained on the data diskette is as follows:

| File Name | Contents |
|---|---|
| TABLE4.WK1 | Core #23 - Sensitivity Test<br>Experimental Data |
| TABLE6.WK1 | Core #19 - Fines Migration Test<br>Interstitial Velocity and Permeability Summary |

## CONCLUSIONS

## CONCLUSIONS

At the request of Anderson Exploration Ltd., Hycal Energy Research Laboratories Ltd. conducted a formation damage study for the Pierson area. A comprehensive summary of the study can be found in the "Results and Discussion" section. The major conclusions are as follows:

1. Significant chemical sensitivity of the formation to the Blairmore water due to deflocculation and/or swelling of clays suggests it is not a compatible injection brine for the Spearfish formation.

2. Flow velocity sensitivity was observed but, due to low initial permeabilities, may not have a significant impact on the overall performance of the reservoir.

# TABLES

**TABLE 1**
**ANDERSON - PIERSON**
**FORMATION DAMAGE STUDY**
**ROUTINE CORE ANALYSIS**

| Sample No. | Well Location | Depth (m) | Permeability (mD) | Porosity (fraction) | Grain Density ($kg/m^3$) | Comments |
|---|---|---|---|---|---|---|
| 17 | 4-15-2-29 W1M | 1017.30 | 0.58 | 0.087 | 2750 | -- |
| 19 | 4-15-2-29 W1M | 1016.90 | 3.72 | 0.086 | 2760 | Restored/fines migration |
| 23 | 4-15-2-29 W1M | 1018.30 | 4.19 | 0.067 | 2760 | Sensitivity |
| 31 | 4-15-2-29 W1M | 1019.60 | 1.47 | 0.132 | 2720 | Restored |

**TABLE 2**
**ANDERSON - PIERSON**
**FORMATION DAMAGE STUDY**
**CORE #23 - SENSITIVITY TEST**
**CORE AND TEST PARAMETERS**

| | |
|---|---|
| Core Number | 23 |
| Depth (m) | 1018.30 |
| Field Name | Pierson |
| Well Location | 4-15-2-29 W1M |
| Length (cm) | 5.38 |
| Diameter (cm) | 3.77 |
| Effective Flow Area ($cm^2$) | 11.16 |
| Bulk Volume ($cm^3$) | 60.04 |
| Porosity (fraction) | 0.067 |
| Pore Volume ($cm^3$) | 4.02 |
| Routine Air Permeability (mD) | 4.35 |
| Test Temperature (°C) | 40 |
| Brine Viscosities @ 40°C | |
| Formation Brine (mPa•s) | 0.99 |
| Blairmore Brine (mPa•s) | 0.78 |
| Net Overburden Pressure (kPag) | 15940 |

**TABLE 3**
**ANDERSON - PIERSON**
**FORMATION DAMAGE STUDY**
**CORE #23 - SENSITIVITY TEST**
**PERMEABILITY SUMMARY**

| Displacement Phase | Permeability (mD) | % Change In Permeability |
|---|---|---|
| Formation Water | 10.78 | *0.00 |
| Blairmore Water | 5.56 | -48 |
| * Baseline | | |

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**TABLE 4**
**ANDERSON - PIERSON**
**FORMATION DAMAGE STUDY**
**CORE #23 - SENSITIVITY TEST**
**EXPERIMENTAL DATA**

| Fluid | Injection Volume Incr (cc) | Injection Volume Cuml (cc) | Injection Volume Incr (PV) | Injection Volume Cuml (PV) | Permeability (mD) |
|---|---|---|---|---|---|
| Formation Brine | 8.1 | 8.1 | 2.0 | 2.0 | 10.94 |
| Formation Brine | 17.6 | 17.6 | 4.4 | 4.4 | 10.96 |
| Formation Brine | 20.0 | 20.0 | 5.0 | 5.0 | 10.98 |
| Formation Brine | 20.0 | 20.0 | 5.0 | 5.0 | 10.93 |
| Formation Brine | 25.9 | 25.9 | 6.4 | 6.4 | 10.97 |
| Formation Brine | 29.4 | 29.4 | 7.3 | 7.3 | 10.96 |
| Formation Brine | 31.9 | 31.9 | 7.9 | 7.9 | 11.03 |
| Formation Brine | 37.7 | 37.7 | 9.4 | 9.4 | 11.06 |
| Formation Brine | 41.3 | 41.3 | 10.3 | 10.3 | 11.01 |
| Formation Brine | 44.7 | 44.7 | 11.1 | 11.1 | 11.01 |
| Formation Brine | 47.9 | 47.9 | 11.9 | 11.9 | 11.03 |
| Formation Brine | 51.6 | 51.6 | 12.8 | 12.8 | 10.96 |
| Formation Brine | 55.4 | 55.4 | 13.8 | 13.8 | 10.81 |
| Formation Brine | 61.8 | 61.8 | 15.4 | 15.4 | 10.83 |
| Formation Brine | 64.7 | 64.7 | 16.1 | 16.1 | 10.82 |
| Formation Brine | 67.5 | 67.5 | 16.8 | 16.8 | 10.82 |
| Formation Brine | 72.7 | 72.7 | 18.1 | 18.1 | 10.80 |
| Formation Brine | 95.9 | 95.9 | 23.9 | 23.9 | 10.60 |
| Formation Brine | 109.5 | 109.5 | 27.3 | 27.3 | 10.73 |
| Formation Brine | 115.7 | 115.7 | 28.8 | 28.8 | 10.77 |
| Formation Brine | 121.7 | 121.7 | 30.3 | 30.3 | 10.77 |
| Formation Brine | 122.8 | 122.8 | 30.6 | 30.6 | 10.78 |
| Formation Brine | 124.0 | 124.0 | 30.9 | 30.9 | 10.78 |

**TABLE 4 (cont'd)**
**ANDERSON - PIERSON**
**FORMATION DAMAGE STUDY**
**CORE #23 - SENSITIVITY TEST**
**EXPERIMENTAL DATA**

| Fluid | Injection Volume | | Injection Volume | | Permeability (mD) |
|---|---|---|---|---|---|
| | Incr (cc) | Cuml (cc) | Incr (PV) | Cuml (PV) | |
| Blairmore Brine | 0.0 | 124.0 | 0.0 | 30.9 | 7.96 |
| Blairmore Brine | 3.3 | 127.3 | 0.8 | 31.7 | 7.76 |
| Blairmore Brine | 4.9 | 128.9 | 1.2 | 32.1 | 7.40 |
| Blairmore Brine | 5.3 | 129.3 | 1.3 | 32.2 | 7.35 |
| Blairmore Brine | 5.6 | 129.6 | 1.4 | 32.3 | 7.33 |
| Blairmore Brine | 5.9 | 129.9 | 1.5 | 32.3 | 7.31 |
| Blairmore Brine | 6.2 | 130.3 | 1.6 | 32.4 | 7.29 |
| Blairmore Brine | 6.6 | 130.6 | 1.6 | 32.5 | 7.27 |
| Blairmore Brine | 7.5 | 131.5 | 1.9 | 32.7 | 7.24 |
| Blairmore Brine | 7.9 | 131.9 | 2.0 | 32.8 | 7.24 |
| Blairmore Brine | 8.2 | 132.2 | 2.0 | 32.9 | 7.27 |
| Blairmore Brine | 11.9 | 135.9 | 3.0 | 33.8 | 7.17 |
| Blairmore Brine | 12.2 | 136.2 | 3.0 | 33.9 | 7.18 |
| Blairmore Brine | 12.6 | 136.6 | 3.1 | 34.0 | 7.21 |
| Blairmore Brine | 19.6 | 143.6 | 4.9 | 35.7 | 7.10 |
| Blairmore Brine | 19.9 | 143.9 | 5.0 | 35.8 | 7.10 |
| Blairmore Brine | 20.2 | 144.2 | 5.0 | 35.9 | 7.07 |
| Blairmore Brine | 20.6 | 144.6 | 5.1 | 36.0 | 7.09 |
| Blairmore Brine | 25.9 | 149.9 | 6.4 | 37.3 | 7.05 |
| Blairmore Brine | 37.3 | 161.3 | 9.3 | 40.2 | 6.53 |
| Blairmore Brine | 40.3 | 164.3 | 10.0 | 40.9 | 6.54 |
| Blairmore Brine | 40.6 | 164.6 | 10.1 | 41.0 | 6.55 |
| Blairmore Brine | 40.9 | 164.9 | 10.2 | 41.0 | 6.56 |
| Blairmore Brine | 41.3 | 165.3 | 10.3 | 41.1 | 6.59 |
| Blairmore Brine | 41.6 | 165.6 | 10.3 | 41.2 | 6.57 |
| Blairmore Brine | 48.2 | 172.2 | 12.0 | 42.9 | 6.31 |
| Blairmore Brine | 59.7 | 183.7 | 14.9 | 45.7 | 6.20 |
| Blairmore Brine | 68.2 | 192.2 | 17.0 | 47.8 | 6.23 |
| Blairmore Brine | 79.9 | 203.9 | 19.9 | 50.8 | 5.55 |
| Blairmore Brine | 80.2 | 204.2 | 20.0 | 50.8 | 5.50 |
| Blairmore Brine | 80.6 | 204.6 | 20.1 | 50.9 | 5.54 |
| Blairmore Brine | 80.9 | 204.9 | 20.1 | 51.0 | 5.56 |

**TABLE 5**
**ANDERSON - PIERSON**
**FORMATION DAMAGE STUDY**
**CORE #19 - FINES MIGRATION TEST**
**CORE AND TEST PARAMETERS**

| | |
|---|---|
| Core Number | 19 |
| Depth (m) | 1016.9 |
| Field Name | Pierson |
| Well Location | 4-15-2-29 W1M |
| Length (cm) | 4.94 |
| Diameter (cm) | 3.80 |
| Effective Flow Area ($cm^2$) | 11.35 |
| Bulk Volume ($cm^3$) | 56.07 |
| Porosity (fraction) | 0.086 |
| Pore Volume ($cm^3$) | 4.82 |
| Routine Air Permeability (mD) | 3.72 |
| Test Temperature (°C) | 42 |
| Net Overburden Pressure (kPag) | 15940 |

**TABLE 6**
**ANDERSON - PIERSON**
**FORMATION DAMAGE STUDY**
**CORE #19 - FINES MIGRATION TEST**
**INTERSTITIAL VELOCITY AND PERMEABILITY SUMMARY**

| Injection Rate (cc/hr) | Interstitial Velocity | | | Permeability (mD) | % Change From Baseline |
|---|---|---|---|---|---|
| | (cm/s) | (m/d) | (ft/day) | | |
| *20 | 0.0057 | 4.916 | 16.128 | 0.193 | 0.00 |
| 100 | 0.0284 | 24.578 | 80.641 | 0.192 | -0.50 |
| 200 | 0.0569 | 49.16 | 161.28 | 0.190 | -1.55 |
| 300 | 0.0853 | 73.73 | 241.92 | 0.156 | -19.2 |
| 500 | 0.1422 | 122.89 | 403.2 | 0.146 | -24.4 |
| 1000 | 0.2845 | 245.8 | 806.4 | 0.139 | -28.0 |
| 2000 | 0.5689 | 491.6 | 1612.8 | 0.136 | -29.5 |
| 4000 | 1.1379 | 983.1 | 3226 | 0.130 | -32.6 |
| 8000 | 2.2757 | 1966 | 6451 | 0.123 | -36.3 |

* All permeabilities were evaluated at the base rate of 20 cc/hr to negate any high rate turbulence and permeability velocity effects.

## FIGURES

## FIGURE 1
## ANDERSON - PIERSON
## FORMATION DAMAGE STUDY
## FINES MIGRATION & SENSITIVITY APPARATUS

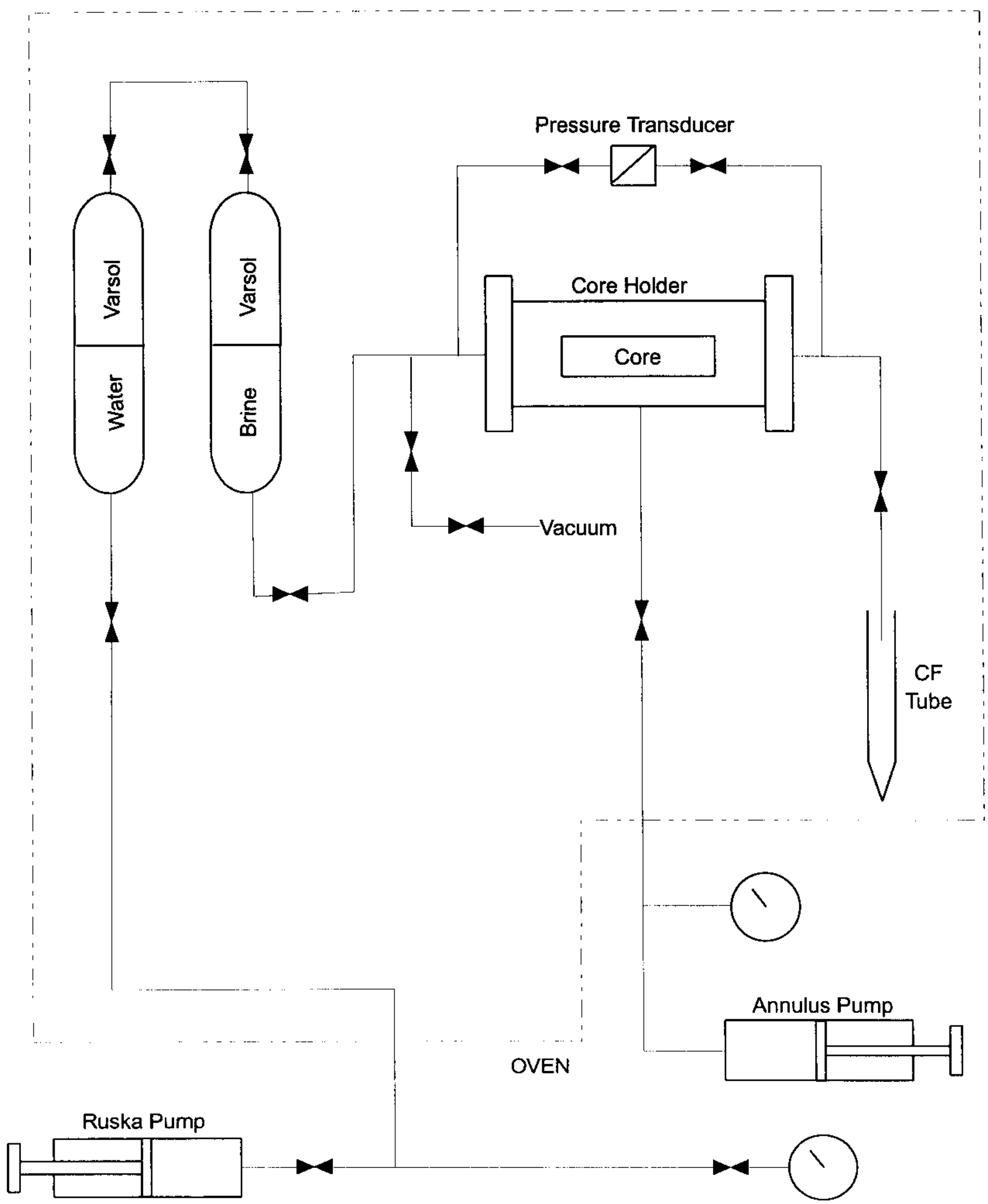


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**FIGURE 2**
**ANDERSON - PIERSON**
**FORMATION DAMAGE STUDY**
**CORE #23 - SENSITIVITY TEST**
**PERMEABILITY SUMMARY**

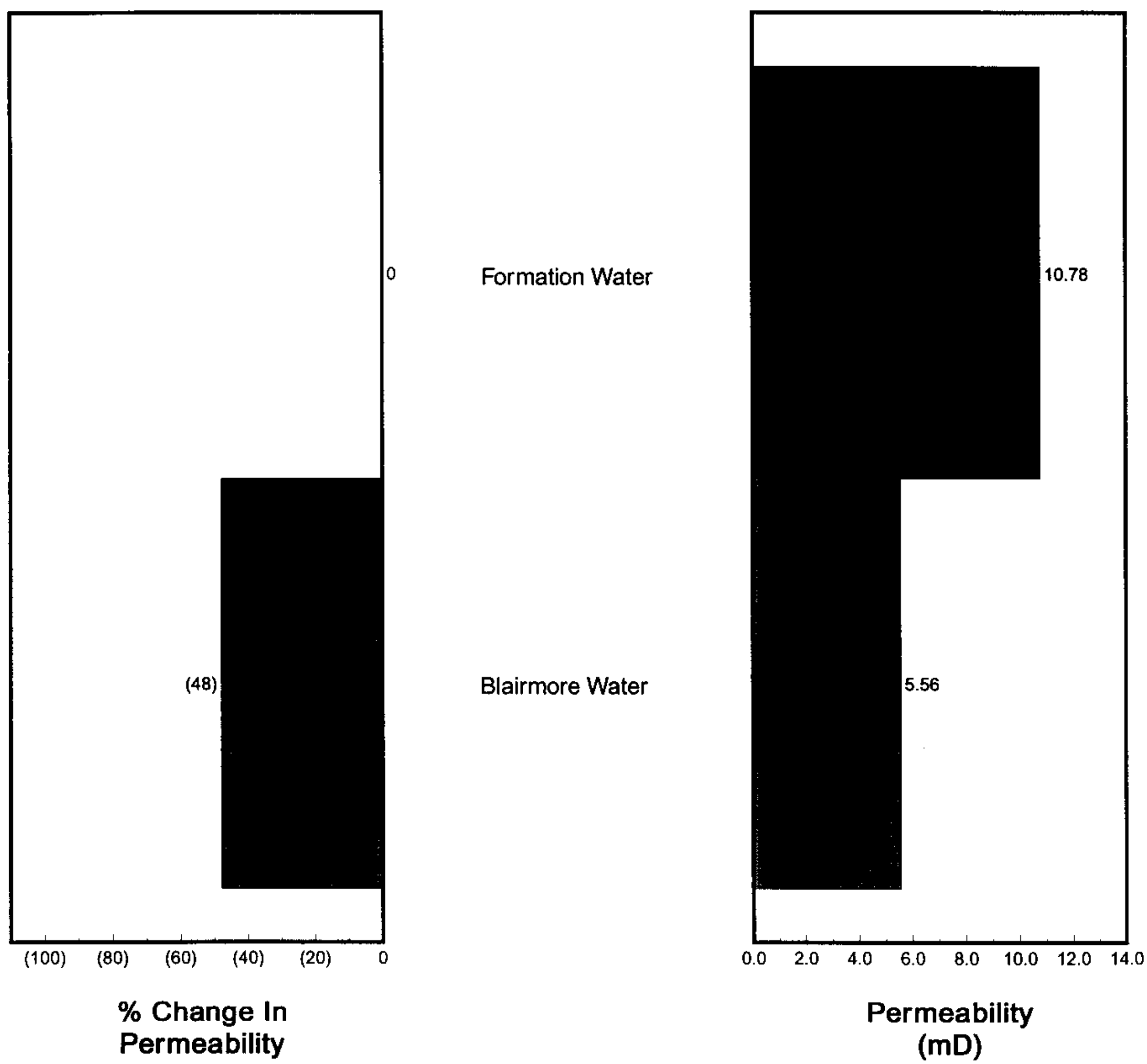


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**FIGURE 3**
**ANDERSON - PIERSON**
**FORMATION DAMAGE STUDY**
**CORE #23 - SENSITIVITY TEST**
**PERMEABILITY vs CUML INJECTION VOLUME**

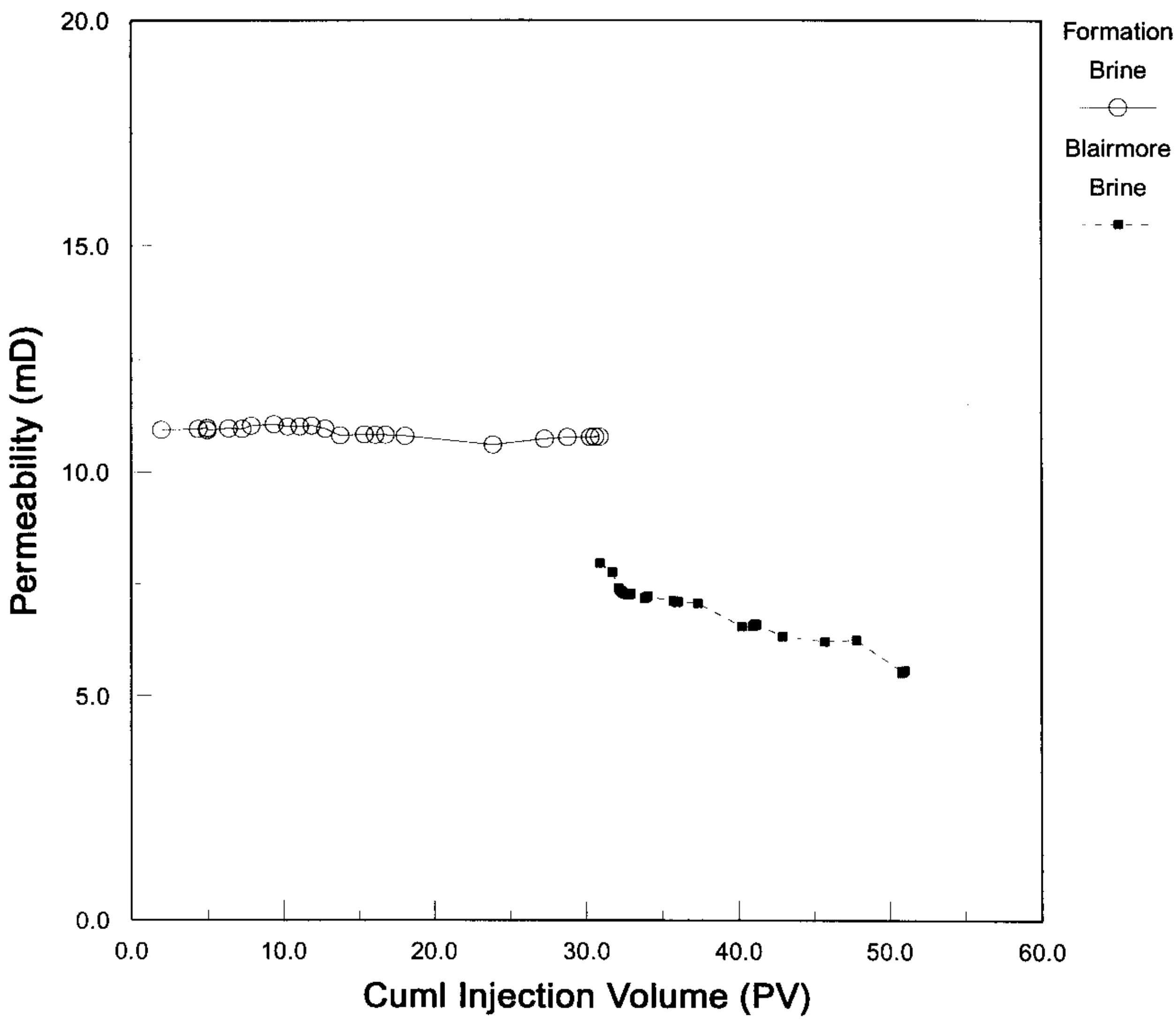


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**FIGURE 4**
**ANDERSON - PIERSON**
**FORMATION DAMAGE STUDY**
**CORE #19 - FINES MIGRATION TEST**
**PERMEABILITY vs INJECTION RATE**

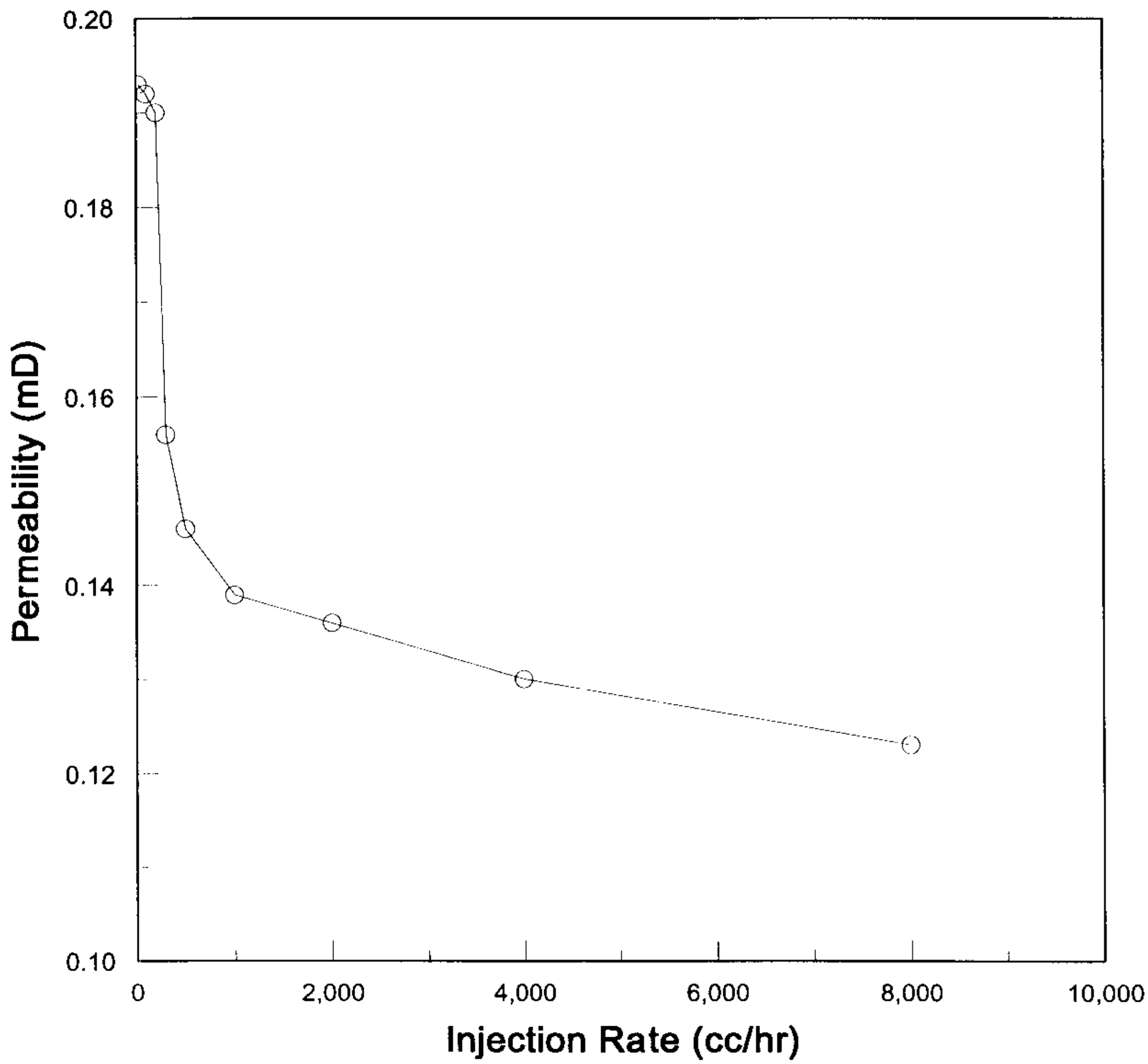
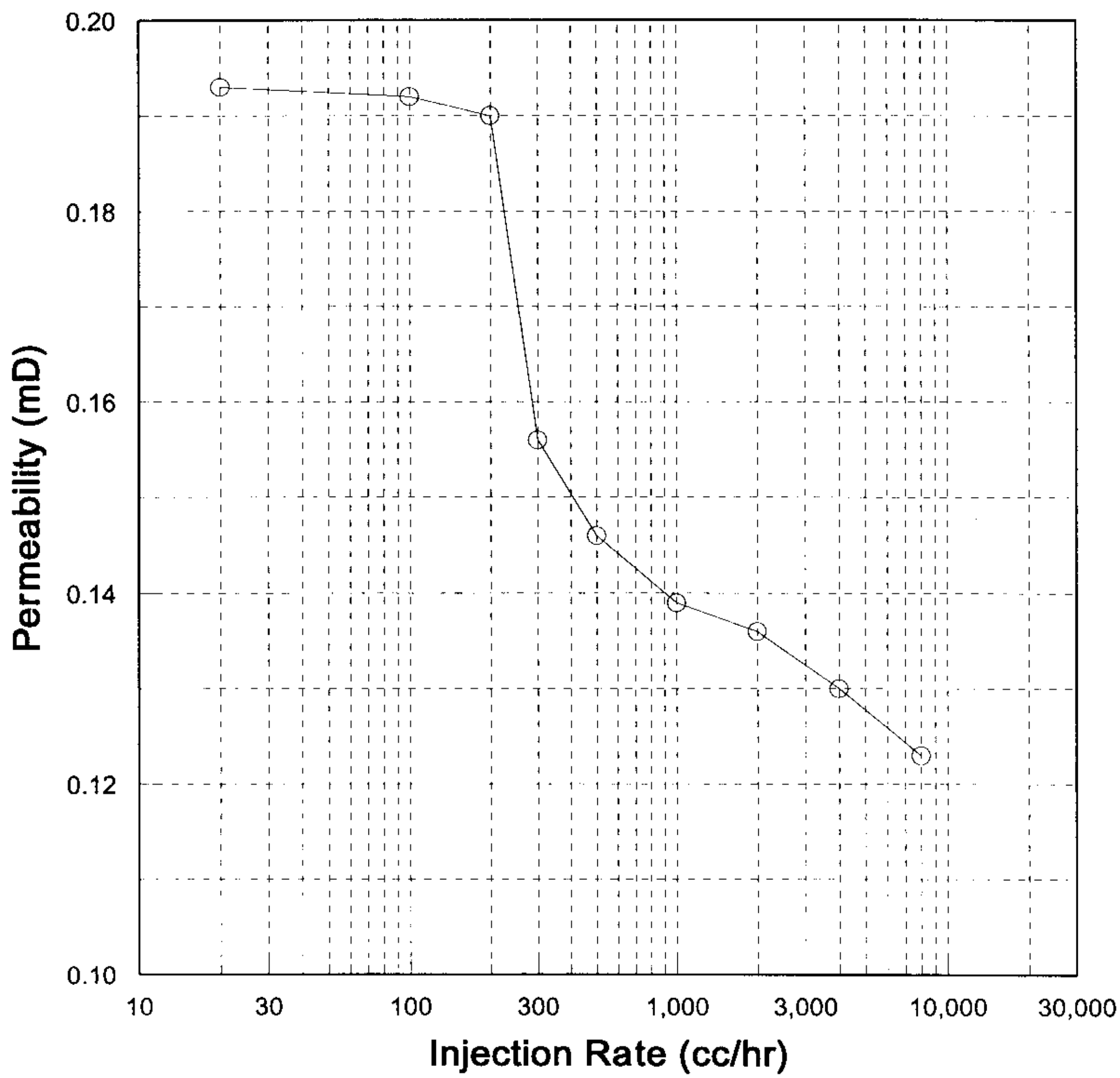


**FIGURE 5**
**ANDERSON - PIERSON**
**FORMATION DAMAGE STUDY**
**CORE #19 - FINES MIGRATION TEST**
**PERMEABILITY vs INJECTION RATE**



DISKETTES

**DATA DISKETTE**