**CAPILLARY SUCTION TIME TESTS ON SELECTED CLAYS AND SHALES**

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**TYPE OF REPORT**
THESIS/DISSERTATION

**TIME COVERED**
APPROVED FOR PUBLIC RELEASE IAW AFR 190-1

**DATE OF REPORT (Year, Month, Day)**
1989

**PAGE COUNT**
83

**NAME OF RESPONSIBLE INDIVIDUAL**
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**ADDRESS (City, State, and ZIP Code)**
Wright-Patterson AFB OH 45433-6583

**ABSTRACT**
(Continue on reverse if necessary and identify by block number)

**DISTRIBUTION/AVAILABILITY OF ABSTRACT**
UNCLASSIFIED/UNLIMITED

**TELEPHONE (Include Area Code)**
(513) 255-2259

**OFFICE SYMBOL**
AFIT/CI

**REPORT NUMBER(S)**
AFIT/CI/CIA- 89-097

**PERFORMING ORGANIZATION REPORT NUMBER(S)**

**MONITORING ORGANIZATION REPORT NUMBER(S)**

**PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER**

**SOURCE OF FUNDING NUMBERS**

**TITLE (Include Security Classification)**
(UNCLASSIFIED)

**SUBJECT TERMS**

**ABSTRACT SECURITY CLASSIFICATION**
UNCLASSIFIED
CAPILLARY SUCTION TIME TESTS ON SELECTED CLAYS AND SHALES

by

KEVIN MICHAEL HART, B.S.

THESIS

Presented to the Faculty of the Graduate School of
The University of Texas at Austin
in Partial Fulfillment
of the Requirements
for the Degree of

MASTER OF SCIENCE IN ENGINEERING

THE UNIVERSITY OF TEXAS AT AUSTIN

MAY 1989
CAPILLARY SUCTION TIME TESTS ON
SELECTED CLAYS AND SHALES

APPROVED:

Dr. K.E. Gray

Dr. Eric P. Fahrenthold
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APPROVED:

K.E. Gray
Dr. K.E. Gray

Eric P. Fahrenthold
Dr. Eric P. Fahrenthold
Dedicated to my parents.
ACKNOWLEDGMENTS

I would like to thank Dr. K. E. Gray for his guidance and advice during my time at the University of Texas. I would also like to acknowledge Dr. Eric P. Fahrenthold, for serving as reader of this thesis. I would also like to extend my appreciation to my fellow graduate students at the Center for Earth Science and Engineering, Tom Redford, Earl Warhmund, Ali Mese and Azra Nur Tutuncu. The suggestions and encouragement of my fellow graduate students was invaluable to my completion of this thesis. Also, to the technicians at the Center for Earth Science and Engineering, Stephen Williams, Preston Mewhinney and Charles Stephenson. Without their technical skill and dedication, this project would not have been possible.
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<td>20.</td>
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45. CST, Phillips Andrews Co., Varied Shear Time
46. CST, Texaco Miss. Canyon, Varied Shear Time
47. CST, Pierre Texaco, Varied Shear Time
48. CST, Pierre Mudtech, Varied Shear Time
49. CST, Mancos Mudtech, Varied Shear Time
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51. CST, Standard Arizona, Varied Shear Time
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CHAPTER 1

INTRODUCTION

1.1 Literature review

Shale stability has been an ongoing problem in the drilling of oil wells. Shales contain clays that swell, disperse and slough into the wellbore. These actions result in wellbore instability which leads to decreased penetration rate, lost circulation and other difficulties. Problems associated with drilling problem shale zones have resulted in large additional expenses in drilling the wells.

In addition to problems encountered in drilling, problems related to production are experienced. Wellbore instability often results in poor cementation jobs. Also, a deviated hole will lead to poor log response. If methods used to control problem shales are successful, reduced drilling and completion costs and also better production will result.

Almost every well drilled encounters troublesome shale zones at one time or another. Usually only a temporary delay in drilling the well results. However,
in some cases, the well has to be abandoned. Shales that the cause the most difficulty contain a high percentage of clays. The difficulties occur when the shale swells after being exposed to the drilling fluid.

According to Van Olphen, two mechanisms are responsible for the swelling of clays. These are surface hydration and osmotic swelling. Surface hydration shows little visible signs of swelling. However, the hydration energy is high and large amounts of pressure (>60,000 psi) are required to desorp surface hydration water.

Swelling and softening occurs as a result of osmotic swelling. Osmotic swelling occurs when the concentration of ions at the wellbore wall is higher than that of the drilling fluid. When this is the case, water moves toward the clay surface causing swelling. The amount of swelling depends on concentration of salts in the shale relative to that of the drilling fluid. It follows that osmotic swelling could be controlled if the concentration of the salts in the drilling fluid is higher than that in the shale.

In attempts to overcome the problem of troublesome shales, several classification schemes have been developed utilizing X-Ray diffraction, which
involves classifying the shale according to primary clay content such as montmorillonite, kaolinte etc. However, x-ray diffraction does not reveal surface properties of the clay. In 1969, Mondshine classified shales using methylene blue capacity as the primary method. This classification is shown below.

Later, Chenevert and O'Brien classified shales according to clay content. These clays included montmorillonite, illite and chlorite. O'Brien and Chenevert's classification scheme is shown below:

<table>
<thead>
<tr>
<th>Class</th>
<th>Texture</th>
<th>Texture</th>
<th>Water</th>
<th>Clay</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Soft</td>
<td>20-40</td>
<td>Free and bound</td>
<td>25-70</td>
<td>20-30</td>
</tr>
<tr>
<td>B</td>
<td>Firm</td>
<td>10-20</td>
<td>Bound</td>
<td>15-25</td>
<td>Illite and mixed layer montmorillonite-illite</td>
</tr>
<tr>
<td>C</td>
<td>Hard</td>
<td>3-10</td>
<td>Bound</td>
<td>5-15</td>
<td>Trace of montmorillonite high in illite</td>
</tr>
<tr>
<td>D</td>
<td>Brittle</td>
<td>0-3</td>
<td>Bound</td>
<td>2-5</td>
<td>Illite, kaolin chlorite</td>
</tr>
<tr>
<td>E</td>
<td>Firm-hard</td>
<td>10-20</td>
<td>Bound</td>
<td>2-10</td>
<td>Illite and mixed layer montmorillonite-illite</td>
</tr>
</tbody>
</table>
TABLE 2. CHENEVERT AND O'BRIEN CLASSIFICATION SCHEME

<table>
<thead>
<tr>
<th>Class</th>
<th>Characteristics</th>
<th>Clay Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>soft, high dispersion</td>
<td>high in montmorillonite, some illite</td>
</tr>
<tr>
<td>2</td>
<td>soft, fairly high dispersion</td>
<td>fairly high in montmorillonite, high in illite</td>
</tr>
<tr>
<td>3</td>
<td>medium-hard, moderate dispersion</td>
<td>high in interlayered clays, high in illite, chlorite</td>
</tr>
<tr>
<td></td>
<td>sloughing tendencies</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>hard, little dispersion,</td>
<td>moderate illite, moderate chlorite</td>
</tr>
<tr>
<td></td>
<td>sloughing tendencies</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>very hard, brittle, no significant</td>
<td>high in illite, moderate chlorite dispersion, caving tendencies</td>
</tr>
<tr>
<td></td>
<td>dispersion, caving tendencies</td>
<td></td>
</tr>
</tbody>
</table>

Dispersion is another property of shales that has presented problems for drilling engineers. Dispersion causes shale particles to disintegrate into the drilling fluid. These solids are difficult to remove and cause problems that could lead to hole washout. Clays are dispersed by either hydration or electrostatic forces.

Over the years, there have been many attempts to overcome difficulties encountered in drilling shale zones. Several researchers have designed both water and oil-based drilling fluids to increase wellbore stability. In 1969, Mondshine developed a technique that determined salinity requirements of an oil-based mud in order to provide adequate inhibition. Chenevert introduced the concept of balanced-activity oil-continuous muds. The basic feature of the balanced-
activity muds is that the activity of the water phase of the mud is inert to the shale formation.

Although some success was achieved using oil based muds, cost and environmental factors make it necessary to design a water-based mud to control shale instability. In 1973, O'Brien and Chenevert demonstrated the effectiveness of using Potassium Chloride as a shale inhibitor. In 1982, Steiger advocated the use of potassium/polymer drilling fluids for shale inhibition. These mud systems had the added feature of being less expensive and easier to use than oil-based muds.

Over the years, several tests have been developed in order to overcome problems encountered while drilling problem shale zones. As mentioned earlier, X-Ray diffraction was used to determine clay and mineral content. However, X-Ray diffraction is limited since it does not measure surface properties. In 1969, Darley constructed a model to study borehole stability. Darley's research provided qualitative insight into the mechanisms of swelling and dispersion. The Methylene Blue test has been used by many researchers to measure cation exchange capacity. As mentioned earlier, Mondshine used the Methylene Blue
test extensively in his classification scheme. In 1983, Wilcox and Fisk\textsuperscript{20} used the Capillary Suction Time (CST) test and ensilin data to aid in predicting the behavior of the shale zone being drilled. The CST test is a simple test that can be carried out at the rigsite. Using these two tests, Wilcox and Fisk\textsuperscript{19} developed another shale classification scheme. The CST test was also used by Lauzon\textsuperscript{9} in 1984 in his study of dispersion in shales. Wilcox and Fisk also used the Cst test to measure polymer solid aggregation.

1.2 Formulation of the problem statement

As mentioned in the literature review, various researchers have used X-Ray diffraction, Methylene Blue Capacity, Fluid adsorption (ensilin) and CST data to classify shales and develop drilling fluids that would inhibit shale swelling and dispersion. However, correlative tests on the various procedures with a given shale or clay have not been done.

The purpose of this thesis is to compare the Capillary Suction Time test data with other shale reactivity tests carried out at the Center for Earth Sciences and Engineering. The other tests conducted included:

Ensilin
Methylene Blue Capacity
Specific Surface Area
Gulf Swellmeter
Atterburg Limits
X-Ray Diffraction

By comparing all tests conducted, the behavior of the test shale in the presence of a drilling fluid should be predictable or, at least, consistencies in results noted. This information should assist drilling personnel in evaluating shale swelling and dispersion problems.
CHAPTER 2

EXPERIMENTAL METHODS

2.1 Introduction

The purpose of the experimental work undertaken was to classify problem shales using the Capillary Suction Time test along with other data obtained at the Center for Earth Sciences and Engineering. Along with the CST test, the other experiments performed included: Methylene Blue Capacity, Ensilin, Specific Surface Area, Atterburg Limits and X-Ray Diffraction. Below is a listing of the shales and clays tested and the notations used:

1. Gold Seal Bentonite (GSB)
2. Mancos Mudtech (MMT)
3. Pierre Mudtech (PMT)
4. Standard Texas (STX)
5. Standard Wyoming (SWY)
6. Standard Arizona (SAZ)
7. Texaco Mississippi Canyon (TMC)
8. Pierre Texaco (PTX)
9. Phillips Ekofisk (PEF)
10. Phillips Andrews County (PAC)

The CST tests were run using varying shear rate, shear time and KCL concentrations. The shear rate was varied by using different speeds on the Waring blender. Speeds used were 1, 3, 5 and 7. Shear times were 10, 60, 120 and 300 sec. The KCL concentration range included 0, 0.5% and 15%.

2.2 Description of Equipment

The CST apparatus (shown in fig 1) measures the time required for a fluid to travel a fixed radial distance on thick, porous filter paper. The apparatus measures this property by use of electrodes arranged in a triangular manner. When the fluid reaches the first two electrodes, the timer starts, when the fluid reaches the third electrode, the timer stops and the capillary suction time is recorded. The CST device was first used in sewage treatment\textsuperscript{20}. Wilcox et al. have used the CST apparatus to characterize dispersive properties of shales. Since the test is easy to use and not time consuming, it can be performed at the rigsite. Besides the CST apparatus and the CST filter paper (Venture Innovations), a Mettler balance and a Waring blender are required to carry out the CST tests.
2.3 Procedure

2.31 Sample preparation
   1. Grind sample to pass a 200 mesh sieve.
   2. Dry sample at 120°F overnight.

2.32 Test procedure
   1. Weigh out 7.5 grams of the shale to be tested.
   2. Measure 50 ml of KCL solution being tested.
   3. Pour clay sample into the KCL solution and shear the sample at the specified rate and time.
   4. Pour aliquot into the funnel and measure the CST.
Figure 1: Capillary Suction Time Apparatus

- CST Filter Paper
- Timer Starts
- Timer Stops
- Electrodes
- Cylinder
CHAPTER 3

PRESENTATION OF RESULTS

The CST experiments were conducted using varying shear time, shear rate and KCL concentrations. Table 3 shows the CST data obtained using varying shear time and Table 4 shows the data obtained using varying shear rates. The tests shales are abbreviated as shown below.

GSB - Gold Seal Bentonite
PEF - Phillips Ekofisk
PAC - Phillips Andrews County
TMC - Texaco Mississippi Canyon
PTX - Pierre Texaco
PMT - Pierre Mudtech
MMT - Mancos Mudtech
STX - Standard Texas
SAZ - Standard Arizona
SWY - Standard Wyoming

Figures 1-54 are plots of CST vs time and CST vs Shear rate. These plots are intended to show the effect of shear rate and shear time on the CST. Also, all three KCL concentrations are shown on a single plot in
order to show the effect of increasing KCL concentration.
TABLE 3. CST, VARYING SHEAR TIME
SHEAR RATE = BLENDER SPEED 7

<table>
<thead>
<tr>
<th>KCL</th>
<th>0S</th>
<th>0.5S</th>
<th>1S</th>
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<tr>
<td>OZ</td>
<td>GSB</td>
<td>PEF</td>
<td>PRC</td>
</tr>
<tr>
<td>2.00</td>
<td>2250.00</td>
<td>35.10</td>
<td>53.30</td>
</tr>
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<td>10.00</td>
<td>3215.00</td>
<td>59.00</td>
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<tr>
<td>60.00</td>
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<td>67.45</td>
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</tr>
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<td>120.00</td>
<td>4937.00</td>
<td>66.50</td>
<td>51.70</td>
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<tr>
<td>300.00</td>
<td>3086.00</td>
<td>68.60</td>
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<tr>
<td>0.5S KCL</td>
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<tr>
<td>2.00</td>
<td>243.00</td>
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<td>14.50</td>
<td>22.15</td>
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<td>300.00</td>
<td>22.00</td>
<td>27.70</td>
<td>10.65</td>
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### TABLE 4. CST, VARIED SHEAR RATE

**SHEAR TIME = 120 SECONDS**

<table>
<thead>
<tr>
<th>Ox KCL</th>
<th>GSF</th>
<th>PEF</th>
<th>PAC</th>
<th>TMC</th>
<th>PTX</th>
<th>PMT</th>
<th>MHT</th>
<th>SFX</th>
<th>SAZ</th>
<th>SWV</th>
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<td>OX KCL</td>
<td>GSF</td>
<td>PEF</td>
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<td>TMC</td>
<td>PTX</td>
<td>PMT</td>
<td>MHT</td>
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**0.5% KCL**

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**15% KCL**

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### TABLE 5. X-RAY DIFFRACTION DATA

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The table above provides data on the clay fraction and mixed layer composition for various samples, along with their respective percentages of KAO, ILL, and CHLOR.


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<th>SAMPLE</th>
<th>SPECIFIC SURFACE AREA (m²/gm)</th>
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<th>ATTERBURG LIMITS</th>
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**TABLE 6**

RESULTS OF SPECIFIC SURFACE, METHYLENE BLUE AND ATTERBURG LIMITS TESTS (10, 13, 18)
FIGURE 2. CST, 0% KCL
VARIED SHEAR TIME, BLENDER SPEED 7
FIGURE 5. CST, 0%KCL
VARIED SHEAR RATE, TIME = 120 SEC

CST (SECONDS)

SHEAR RATE (BLENDER SPEED)

STX + PEF PAC TMC PTX MMT
FIGURE 7. CST, 0.5% KCL
VARIED SHEAR RATE, SHEAR TIME = 120 SEC
FIGURE 12. CST, 15% KCL
VARIED SHEAR RATE, TIME = 120 SEC

CST (SECONDS)

SHEAR RATE (BLENDER SPEED)

STX + PEF  PAC  TMC  PTX  MMT
FIGURE 13. CST, GOLD SEAL BENTONITE

SHEAR TIME = 120 SEC

CST (SECONDS) (Thousands)

0 1 2 3 4 5

4.4 4.8 5.2 5.6 6 6.4 6.8

SHEAR RATE (BLENDER SPEED)

□ 0% KCL  +  0.5% KCL  ○ 15% KCL
FIGURE 14. CST, PHILLIPS EKOFISK

SHEAR TIME = 120 SEC

CST (SECONDS)

SHEAR RATE (BLENDER SPEED)

□ 0% KCL  +  0.5% KCL  •  15% KCL
FIGURE 15. CST, PHILLIPS ANDREWS CO.

SHEAR TIME = 120 SEC

CST (SECONDS)

0 50 100 150 200 250 300 350 400

4 4.4 4.8 5.2 5.6 6 6.4 6.8

SHEAR RATE (BLENDER SPEED)

□ 0% KCL + 0.5% KCL ◇ 15% KCL
FIGURE 18. CST, PIERRE MUDTECH

SHEAR TIME = 120 SEC

CST (SECONDS)

SHEAR RATE (BLENDER SPEED)

□ 0% KCL
○ 15% KCL
FIGURE 19. CST, MANCOS MUDTECH

SHEAR TIME = 120 SEC

SHEAR RATE (BLENDER SPEED)

1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0

0.5% KCL

CST (SECONDS)
FIGURE 20. CST, STANDARD TEXAS

SHEAR TIME = 120 SEC

CST (SECONDS)

400
500
600

SHEAR RATE (BLENDER SPEED)

4 4.4 4.8 5.2 5.6 6 6.4 6.8

0% KCL + 0.5% KCL 15% KCL
FIGURE 21. CST, GOLD SEAL BENTONITE

CST TIME (SECONDS) (Thousands)

SHEAR TIME (SECONDS)

□ 0% KCL  +  0.5% KCL  ◇ 15% KCL
FIGURE 22. CST, PHILLIPS EKOFISK

BLENDER SPEED = 7

SHEAR TIME (SECONDS)

CST TIME (SECONDS)
FIGURE 23. CST, PHILLIPS ANDREWS CO.

BLENDER SPEED = 7

CST TIME (SECONDS)

0% KCL

0.5% KCL

15% KCL

SHEAR TIME (SECONDS)
FIGURE 25. CST, PIERRE TEXACO

BLENDER SPEED = 7

CST TIME (SECONDS)

SHEAR TIME (SECONDS)

0.05 KCL

0.06 KCL

0.07 KCL

0.08 KCL

280 240 220 200 180 160 140 120 100 80 60 40 20 0
FIGURE 26. CST, PIERRE MUDTECH
FIGURE 28. CST, STANDARD TEXAS

BLENDER SPEED = 7

CST TIME (SECONDS)

0  100  200  300  400  500  600

SHEAR TIME (SECONDS)

0  40  80  120  160  200  240  280

□ 0% KCL  +  0.5% KCL  ◇  15% KCL
FIGURE 31. CST, 0\% KCL
VARIED SHEAR RATE, TIME = 120 SEC
FIGURE 32, CST, 0% KCL
VARIED SHEAR RATE, TIME = 120 SEC
FIGURE 3.3. CST, 0.5% KCL
VARIED SHEAR TIME, BLENDER SPEED = 7
FIGURE 34. CST, 0.5% KCL
VARIED SHEAR TIME, BLENDER SPEED = 7
FIGURE 35, CST, 0.5% KCL
VARED SHEAR RATE, SHEAR TIME = 120 SEC
FIGURE 37. CST, 15% KCL
VARIED SHEAR TIME, BLENDER SPEED 7

CST (SECONDS)

SHEAR TIME (SECONDS)

GSB    PEF    PAC    TMC    SAZ    SWY
FIGURE 38. CST, 15% KCL
VARIED SHEAR TIME, BLENDER SPEED?
FIGURE 39. CST, 15% KCL
VARIED SHEAR RATE. TIME = 120 SEC.
FIGURE 42. CST, STANDARD WYOMING

SHEAR TIME = 120 SEC

CST (SECONDS) (Thousands)

0 0.5 1 1.5 2 2.5 3 3.5 4

4 4.4 4.8 5.2 5.6 6 6.4 6.8

SHEAR RATE (BLENDER SPEED)

△ 0% KCL + 0.5% KCL ○ 15% KCL
FIGURE 44. CST, PHILLIPS EKOFISK

BLENDER SPEED = 7

CST TIME (SECONDS)

SHEAR TIME (SECONDS)

□ 0% KCL + 0.5% KCL ○ 15% KCL
FIGURE 46. CST, TEXACO MISS. CANYON

BLENDER SPEED = 7

CST TIME (SECONDS)

0 10 20 30 40 50 60 70 80 90 100 110 120

SHEAR TIME (SECONDS)

0% KCL 0.5% KCL 15% KCL
FIGURE 50. CST, STANDARD TIMES

BLENDER SPEED = 7

CST TIME (SECONDS)

0% KCL
+ 0.5% KCL
15% KCL

SHEAR TIME (SECONDS)
CHAPTER 4

DISCUSSION OF RESULTS

4.1 Varied Shear Rate

Gold Seal Bentonite, Standard Texas, Standard Arizona and Standard Wyoming had the largest CST values. Also, the Cst value varied with time in a nonlinear fashion. This is in contrast to Wilcox's assumption of straight line dispersion profiles. Compared to the four standard shales, Phillips Ekofisk, Phillips Andrews County, Texaco Mississippi Canyon, Pierre Texaco, Pierre Mudtech and Mancos Mudtech have relatively low CST values. Also, the dispersion profiles are essentially horizontal, indicating all of the colloidal clay particles breakdown instantaneously, or at least in a very short time.

4.2 Varied Shear Rate

The curves of CST vs. Shear Rate give an indication of bond type. As was the case with varied shear time, Gold Seal Bentonite, Standard Wyoming, Standard Texas and Standard Arizona had high CST values.
relative to Phillips Ekofisk, Pierre Mudtech, Phillips Andrews County, Texaco Mississippi Canyon, Pierre Texaco and Mancos Mudtech. The CST of Pierre Texaco reaches a maximum value and then declines at a higher shear rate. The remaining shales exhibit increasing CST with increasing shear rate. The drop in CST values for the Standard Texas and Pierre Texaco shales can be attributed to aggregation. Aggregation occurs when the maximum dispersion has been reached. Mancos Mudtech and Pierre Mudtech have very low CST values that essentially remain constant under varying shear rate. Since CST values reflect the swelling potential of shales, both Pierre Mudtech and Mancos Mudtech would appear to be low swelling clays. Conversely, since the CST values for Gold Seal Bentonite, Standard Texas, Standard Wyoming and Standard Arizona are very high, the CST test predicts these clays to be high swelling.

4.3 Effect of KCL on CST values.

For all the shales tested, an increase in KCL concentration decreased the magnitude of the CST value. This effect can be attributed to the inhibiting ability of the potassium ion. This inhibiting ability is seen best when looking at the high swelling clays: Gold Seal
Bentonite, Standard Texas, Standard Wyoming and Standard Arizona. The high swelling shales require a larger KCL concentration to significantly reduce the magnitude of the CST value relative to the low swelling shales. The inhibitive ability of the potassium ion has been noted several times in the literature.

4.4 CST vs. X-Ray Diffraction

As mentioned throughout the literature, montmorillonite is the clay most sensitive to swelling. Illite also swells but not to the same extent as montmorillonite. On the other hand, kaolinite and chlorite don't swell to an appreciable extent.

From the X-Ray diffraction data shown in Table 5, Gold Seal Bentonite, Standard Arizona, Standard Texas and Standard Wyoming all have a clay content that is 100% montmorillonite. Also as discussed earlier, these shales were predicted to be high swelling from the CST data. Pierre Texaco also has a clay content that is high in montmorillonite. However its clay fraction is only 57%. As a result, X-Ray diffraction predicts Pierre Texaco shale should swell to a moderate extent. Cst data also predicts moderate swelling for the Pierre Texaco shale.
According to the CST data, Phillips Ekofisk, Phillips Andrews County and Texaco Mississippi Canyon should also be moderately swelling shales. X-Ray diffraction data also predicts moderate swelling since Phillips Andrews County and Texaco Mississippi Canyon contain a large percentage of mixed layer montmorillonite/illite and Phillips Ekofisk contains a fairly large percentage of montmorillonite.

X-Ray diffraction data for Mancos Mudtech and Pierre Mudtech predict low swelling for these shales. This is due to the low clay content of these two shales. Also, Mancos Mudtech contains a large amount of kaolinite and chlorite.

4.5 CST vs Specific Surface Area

The specific surface area of a shale is a measure of reactivity. This is an indication of the likelihood of the shale to swell. The shales with the highest specific surface area were Gold Seal Bentonite, Standard Texas, Standard Arizona and Standard Wyoming. As mentioned earlier, CST data also predicts these shales to be high swelling.

The specific surface area of Phillips Ekofisk, Pierre Mudtech, Phillips Andrews County, Texaco
Mississippi Canyon and Pierre Texaco predict that these shales would exhibit moderate swelling. CST data agrees with this prediction with the exception of Pierre Mudtech. CST predicts Pierre Mudtech to be low swelling the specific surface area predicts moderate swelling for Pierre Mudtech. The results of CST and specific surface area for Mancos Mudtech are in agreement. Both tests predict low swelling for Mancos Mudtech.

4.6 Methylene Blue Capacity vs. CST

The methylene blue test measures the cation exchange capacity of the shales. Methylene blue capacity also gives an indication of the clay content of the shale. The shales that had the highest cation exchange capacity were Gold Seal Bentonite, Standard Arizona, Standard 'exas and Standard Wyoming. This result, which predicts high swelling for these shales, is in agreement with CST data. Methylene blue adsorption data for Phillips Ekofisk, Pierre Mudtech, Phillips Andrews County, Texaco Mississippi Canyon and Pierre Texaco to swell moderately. With the exception of Pierre Mudtech, this prediction is in agreement with CST data. Cation exchange capacity data predicts Pierre Mudtech to swell moderately while CST data
predicts the shale to be low swelling. Both CST and cation exchange capacity data both predict Mancos Mudtech to be low swelling.

4.7 Ensilin vs CST

The ensilin apparatus measures the amount of fluid adsorbed by a shale sample. Wilcox and Fisk have shown that fluid adsorption profiles are generally linear. This is also the case for the tests run on the shales at CESE. Wilcox and Fisk defined the y-intercept of the adsorption profile as the swelling index. The swelling index provides an indication of fluid adsorbed due to surface colloidal clay particles. The swelling index can be used to predict the swelling behavior of shales.

As with all the previous experiments, the swelling index predicts Standard Arizona, Standard Wyoming, Gold Seal Bentonite and Standard Texas to be high swelling. Pierre Texaco, Texaco Mississippi Canyon, Phillips Andrews County, Pierre Mudtech and Phillips Ekofisk are predicted to swell moderately. CST data predicts the same result with the exception of Pierre Mudtech. The CST predicts Pierre Mudtech to be
4.8 Discussion of the CST test

The capillary suction time test is fast and easy to use. It can be performed at the rigsite. However, data from the CST test is not very reproducible. Therefore the data obtained should be used qualitatively. The test is useful and can help drilling engineers predict where the troublesome shale zones are located.

4.9 Classification of Test Shales

Table 7 is a presentation of a shale classification scheme using CST, X-Ray diffraction, Methylene Blue Capacity, Specific Surface Area and Ensilin data. As can be seen from Table 7, the shales Gold Seal Bentonite, Standard Arizona, Standard Texas and Standard Wyoming are classified as high swelling shales. Phillips Ekofisk, Phillips Andrews County, Texaco Mississippi Canyon, Pierre Texaco are predicted to display moderate swelling while Mancos Mudtech is predicted to be a low swelling shale. Pierre Mudtech is difficult to classify due to conflicting results. CST predicts low swelling while the other experiments predict moderate swelling for Pierre Mudtech.
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CHAPTER 5

CONCLUSIONS

1. The Capillary Suction Time test is simple and easy to use, allowing operators to conduct the test at the rigsite. However because of difficulty in reproducing results, the test should only be used qualitatively.

2. The CST along with the Methylene Blue, Specific Surface Area and Ensilin tests performed at the Center for Earth Science and Engineering accurately predicts shale swelling and dispersion. The tests have the added advantage of being able to be conducted relatively quickly. These tests could be carried out at the rigsite while the drilling is taking place.

3. The experiments conducted also demonstrated the usefulness of KCL as an inhibitor of shale swelling and dispersion. From the CST data, it can be seen that KCL concentrations as low as 0.5% are effective in controlling the swelling of Phillips Ekofisk, Phillips Andrews County, Texaco Mississippi Canyon and Pierre Texaco. However a greater concentration of KCL is required to inhibit the swelling of Gold Seal Bentonite,
Standard Arizona, Standard Wyoming and Standard Texas. It is recommended that more concentrations of KCL be tested of the high swelling clays in order to determine the minimum concentration required to inhibit swelling and dispersion.
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VITA

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This thesis was typed by the author.