

Hydrate Core Drilling Tests

Topical Report

Reporting Period: September 2002

by:

John H. Cohen

Thomas E. Williams

MAURER TECHNOLOGY INC.

Ali G. Kadaster

Bill V. Liddell

ANADARKO PETROLEUM CORP.

November 2002

DE-FC26-01NT41331

Maurer Technology Inc.

2616 West T.C. Jester

Houston, TX 77018

TR02-40

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Abstract

The “Methane Hydrate Production from Alaskan Permafrost” project is a three-year endeavor being conducted by Maurer Technology Inc. (MTI), Noble, and Anadarko Petroleum, in partnership with the U.S. DOE National Energy Technology Laboratory (NETL). The project’s goal is to build on previous and ongoing R&D in the area of onshore hydrate deposition. The project team plans to design and implement a program to safely and economically drill, core and produce gas from arctic hydrates.

The current work scope includes drilling and coring one well on Anadarko leases in FY 2003 during the winter drilling season. A specially built on-site core analysis laboratory will be used to determine some of the physical characteristics of the hydrates and surrounding rock. Prior to going to the field, the project team designed and conducted a controlled series of coring tests for simulating coring of hydrate formations. A variety of equipment and procedures were tested and modified to develop a practical solution for this special application. This Topical Report summarizes these coring tests.

A special facility was designed and installed at MTI’s Drilling Research Center (DRC) in Houston and used to conduct coring tests. Equipment and procedures were tested by cutting cores from frozen mixtures of sand and water supported by casing and designed to simulate hydrate formations. Tests were conducted with chilled drilling fluids. Tests showed that frozen core can be washed out and reduced in size by the action of the drilling fluid. Washing of the core by the drilling fluid caused a reduction in core diameter, making core recovery very difficult (if not impossible). One successful solution was to drill the last 6 inches of core dry (without fluid circulation). These tests demonstrated that it will be difficult to capture core when drilling in permafrost or hydrates without implementing certain safeguards.

Among the coring tests was a simulated hydrate formation comprised of coarse, large-grain sand in ice. Results with this core showed that the viscosity of the drilling fluid must also be carefully controlled. When coarse sand was being cored, the core barrel became stuck because the drilling fluid was not viscous enough to completely remove the large grains of sand. These tests were very valuable to the project by showing the difficulties in coring permafrost or hydrates in a laboratory environment (as

opposed to a field environment where drilling costs are much higher and the potential loss of equipment greater).

Among the conclusions reached from these simulated hydrate coring tests are the following:

- Frozen hydrate core samples can be recovered successfully
- A spring-finger core catcher works best for catching hydrate cores
- Drilling fluid can erode the core and reduces its diameter, making it more difficult to capture the core
- Mud must be designed with proper viscosity to lift larger cuttings
- The bottom 6 inches of core may need to be drilled dry to capture the core successfully

Table of Contents

Disclaimer	ii
Abstract	iii
Table of Contents.....	v
List of Figures.....	vi
1. Introduction	1
1.1 Description of Effort	1
1.2 Background	1
1.3 Objectives	2
2. Core Test Equipment and Procedures.....	3
2.1 Background	3
2.2 Drilling/Freezing Facility.....	3
2.3 Coring Equipment.....	9
2.4 Drilling Fluid.....	11
3. Coring Test Results.....	12
3.1 Cylinders for Coring Tests	12
3.2 Coring Results	12
3.3 Summary.....	15
4. Conclusions.....	17
5. References.....	18
Appendix A: Hydrate Test Coring Apparatus: Report on the Tests Conducted at the Maurer’s Drilling Research Center (by The University of Oklahoma)	
Appendix B: Hydrate Test Log	

List of Figures

Figure 1.	Methane Hydrate	1
Figure 2.	Core Drilling/Freezing Facility Schematic.....	4
Figure 3.	Freezing Chamber.....	4
Figure 4.	Drilling Chamber	5
Figure 5.	Partially Frozen Simulated Hydrate Cylinder	6
Figure 6.	OU Prototype Freezing Apparatus	7
Figure 7.	Liquid Nitrogen Tanks	7
Figure 8.	Vacuum Filling Freezing Chamber	8
Figure 9.	Storing Simulated Hydrate Cylinder in Freezer Truck	8
Figure 10.	Environmental Coring Rig	9
Figure 11.	Core Bits	10
Figure 12.	Core Catchers	11
Figure 13.	Drilling/Coring Operation	13
Figure 14.	Ice Core.....	14
Figure 15.	Core from Sample with Coarse Number 1 Sand	15

1. Introduction

1.1 Description of Effort

This Topical Report provides a summary of facility preparation and core-drilling tests conducted at the Drilling Research Center (DRC) in Houston, Texas in support of the Department of Energy (NETL) Alaskan Hydrate drilling project. Anadarko Petroleum and Maurer Technology are conducting this work under contract to the DOE. Funding is provided by both the DOE and the participants, with the participants cost-sharing the work at a rate of approximately 50%.

The purpose of this project is to plan, design and implement a program that will safely and economically drill/core and produce natural gas from arctic hydrates. A significant amount of research has been conducted on naturally occurring gas hydrates, and the project team (Maurer, Anadarko and Noble) will adapt and apply laboratory R&D and technology to hydrate wells in the field.

1.2 Background

Natural-gas hydrates (**Figure 1**) beneath the permafrost have been encountered by the oil and gas industry for years. Numerous drilling problems, including gas kicks and uncontrolled gas releases, have been well documented in the arctic regions by Russian, USA and Canadian engineers. Substantial reserves of natural gas are present around the world in the form of frozen hydrates. Hydrates are natural gas trapped in a frozen mixture of water and earth. Conditions required for hydrates to form include cold temperatures, such as at the bottom of the sea floor and in arctic areas where permafrost exists. One such area is under the tundra of Alaska.



Figure 1.
Methane Hydrate

Little is currently known about the best methods to drill through and produce hydrates. It is the objective of this project to drill in Alaska in an area where hydrates are believed to exist and to collect information to help in future production of this resource. Core drilling will be employed on this project to maximize the amount of data that can be collected and to study the hydrate material so that safe and effective drilling and production methods can be developed for the future.

1.3 Objectives

The overall objectives of this gas-hydrate project are to:

1. Analyze existing geological and geophysical data and obtain new field data required to predict hydrate occurrences
2. Test the best methods and tools for drilling and recovering hydrates
3. Plan, design, and implement a program to safely and economically drill and produce gas from hydrates.

Prior to drilling/coring wells in Alaska, it was deemed necessary to conduct coring tests in a controlled setting at the Drilling Research Center in Houston. Coring equipment and procedures were tested by cutting cores from several frozen cylinders of water and sand designed to simulate hydrates. Objectives including developing methods for coring and retrieving frozen cores intact, as well as testing various bits, core barrels, core catchers, and drilling fluids.

2. Core Test Equipment and Procedures

2.1 Background

A test facility was successfully designed and constructed at MTI's Drilling Research Center (DRC) in Houston and used to conduct a series of hydrate coring tests. Coring equipment and procedures were tested by cutting cores from frozen cylinders of water and sand designed to simulate hydrates. These test cylinders were fabricated in a facility adjacent to the drilling site. Oklahoma University (OU) has previously developed a method to freeze sand and water using liquid nitrogen as a technique to simulate properties of permafrost and hydrate that will be drilled in Alaska. A report (De Sousa, 2002) prepared by OU describing the development of this artificial permafrost/hydrate is included in **Appendix A**.

The sample preparation method was transferred to the DRC where, with the assistance and oversight of Dr. Joao Tadeu Vidal De Sousa (OU), seven simulated hydrate mixtures were frozen in cylinders and cored during the tests. Composition of the cylinders ranged from pure water, to water and sand. Two different sizes of sand were used: medium and coarse grades. Core barrel design was also varied by changing the liner, bit, and core catcher. This was done to determine the best configuration for collecting frozen cores in the field.

2.2 Drilling/Freezing Facility

A core drilling and freezing facility was installed at the DRC. This facility consisted of two pieces of casing (approximately 15 ft in length) placed in the ground (**Figure 2**). The tube on the left is the freezing chamber, and is used with equipment built by OU to freeze simulated hydrate cylinders. The tube on the right is the drilling chamber. Samples frozen in the freezing chamber are transferred to the drilling chamber where they are cored.

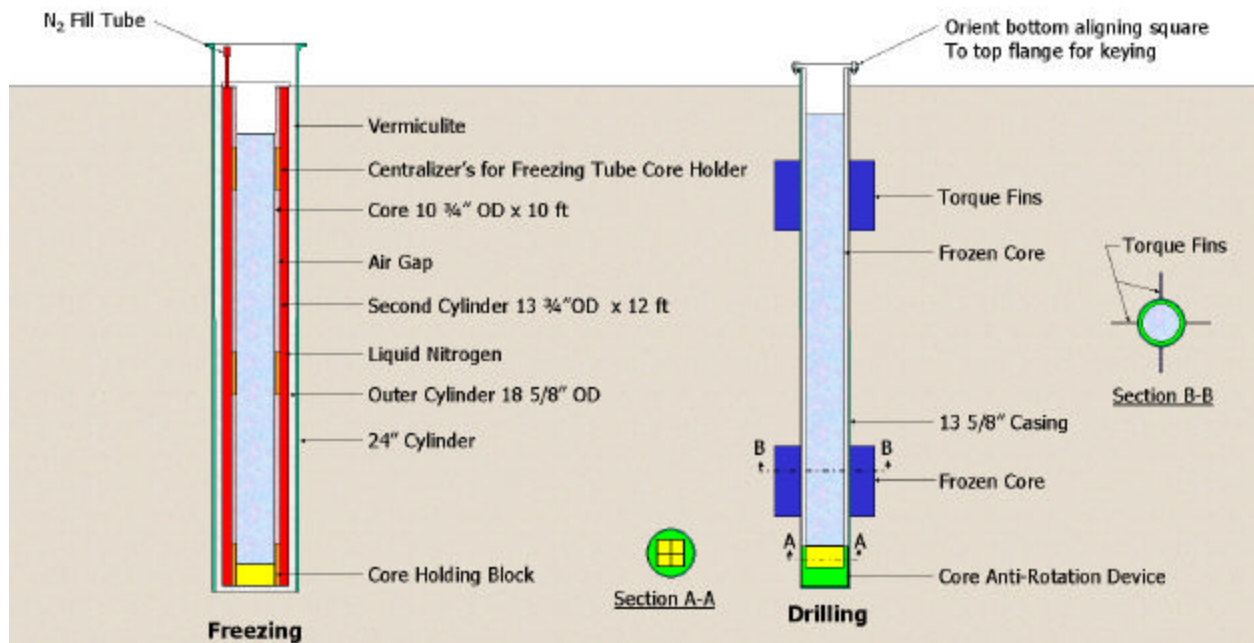


Figure 2. Core Drilling/Freezing Facility Schematic

Figures 3 and 4 show the freezing and drilling/coring chambers, respectively. The fog in front of the freezing chamber is caused by vaporization of liquid nitrogen.



Figure 3. Freezing Chamber



Figure 4. Drilling Chamber

The samples were frozen by placing the OU equipment into the chamber, filling the core tube with sand and water, and then adding liquid nitrogen. Freezing a single cylinder takes almost an entire workday, with most of the time needed for the freezing process. Thermocouples on the core tube monitored the progress of the freezing. These are positioned at the bottom, middle, and top of the tube, and protrude into the tube approximately 0.5 in.

As the freezing chamber cools, it begins to fill with liquid nitrogen (that is, the nitrogen no longer evaporates). Noting when the temperature recorded by each thermocouple drops to levels close to -300°F is an indication of the liquid nitrogen level. The top center of the sample is the last area to freeze due to the insulating effect of the ice that is formed at the outside edge of the tube. **Figure 5** shows a cylinder that has not completely frozen.

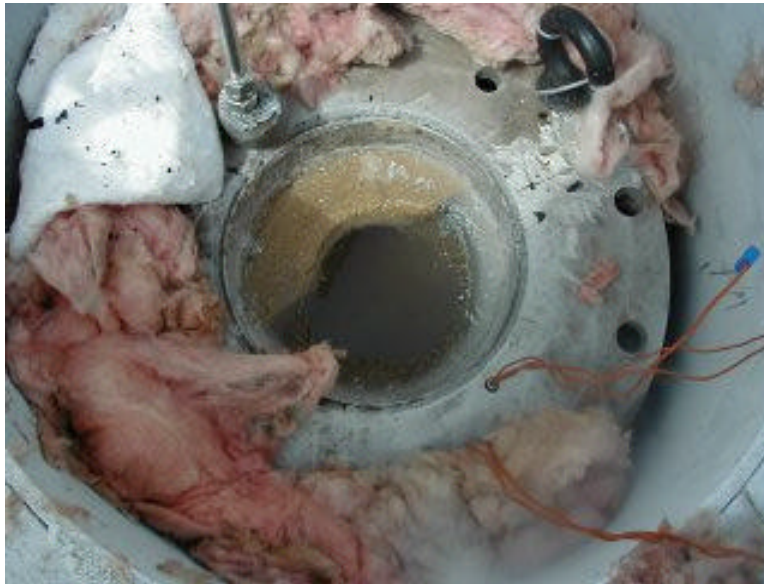


Figure 5. Partially Frozen Simulated Hydrate Cylinder

The prototype apparatus developed by OU **Figure 6**) consists of three nested tubes, with the inner tube forming a chamber for the simulated hydrate sample, and the outer two the freezing and nitrogen chambers. The original design placed the liquid nitrogen in the outer annulus and left an air gap between the nitrogen and core chamber. This was done to slow the freezing process and increase temperature uniformity of the frozen cylinder. This approach was based on the assumption that the cylinder would be moved directly from the freezing chamber to the drilling chamber. However, during the coring tests, the simulated hydrate cylinders were stored in a freezer truck overnight so that they could finish freezing and achieve uniform temperature.



Figure 6. OU Prototype Freezing Apparatus

To speed the freezing process at the DRC tests, liquid nitrogen was introduced into the chamber in direct contact with the simulated hydrate cylinder chamber. This reduced freezing time considerably. **Figure 7** shows two nitrogen tanks feeding the freezing chamber during preparation of one of the frozen simulated hydrate cylinders.



Figure 7. Liquid Nitrogen Tanks

During the first coring tests, it was observed that the frozen core was being washed away (reduced in diameter) during the drilling process. To determine if this was caused by the mud or by the amount of sand in the core, more test cylinders were made

with water only. For solid ice cylinders, the freezing chamber was evacuated before being filled with water so that the ice would be homogeneous with no entrapped air. **Figure 8** shows the vacuum pump on the table and the bucket in front from which water was drawn during the filling process.



Figure 8. Vacuum Filling Freezing Chamber

After freezing, the cylinders were removed from the freezing chamber and stored in a freezer truck (**Figure 9**). This allowed each cylinder to achieve a uniform temperature before it was moved to the drilling chamber.



Figure 9. Storing Simulated Hydrate Cylinder in Freezer Truck

2.3 Coring Equipment

A small environmental monitoring rig provided by Fugro Geosciences Inc. was used for the coring tests (**Figure 10**). A mining core barrel was used to core the simulated hydrate cylinders.



Figure 10. Environmental Coring Rig

Figure 11 shows two core bits: a PDC bit (lower left) and a carbide bit (upper right). Only the PDC bit was used on these tests. Cores were captured in both stainless steel and Lexan core sleeves. Both types of sleeves worked well. The Lexan holders, when removed with the frozen core, allowed the core to be easily cut into pieces. The purpose of cutting the core into sections for these tests was for ease of shipping. In the field, the core would need to be divided to allow a range of tests to be performed.



Figure 11. Core Bits

The PTS and Core Pro team (which will provide on-site core handling and analysis in Alaska) participated in the tests by removing and preserving the cores to gain experience with handling hydrate cores. They sent several of the frozen test cores to Tulsa, Oklahoma for further testing. They also documented the procedures for training for the field work in Alaska. This effort was followed by a workshop at Anadarko conducted on October 18, 2002.

Several core catchers were provided by the service companies to determine which would work best with frozen core. **Figure 12** shows three core catchers that were provided. None of the catchers worked well when the core eroded and became under sized. The simple serrated catcher did not catch the core. The core catcher with spring fingers and some rough hardmetal applied to the inner surface worked well when the last portion of the core was drilled dry, which allowed maintaining full core diameter. (This catcher is shown standing on its side at the end of the core barrel in Figure 12.)



Figure 12. Core Catchers

2.4 Drilling Fluid

Special drilling fluids are needed for hydrate drilling and coring because they must be maintained at temperatures below freezing to prevent the ice from melting. For this test we used a potassium chloride water-based mud system. The mud contained 10% salt by weight. This mud worked well for the tests, except that it needed to be thickened with polymer to improve hole cleaning. Without polymer, the mud was too thin to transport coarse sand, resulting in the core barrel becoming stuck.

The mud was stored in a 250-gallon tank that was placed in the freezer truck at night. If the mud temperature rose above the limit during coring operations, dry ice was added to the mud. This approach worked very well. The mud was also cooled during drilling/coring operations since the simulated hydrate cylinders were kept very cold (below 28°F and sometimes as low as 0°F).

3. Coring Test Results

3.1 Cylinders for Coring Tests

Seven frozen cylinders were fabricated to simulate hydrate formations using the OU equipment and the freezing chamber at the DRC (described in Chapter 2). The samples included:

- 4 cylinders with water and fine sand
- 2 cylinders with water only
- 1 cylinder with water and coarse sand

Thirteen individual tests were run coring through these simulated hydrate cylinders. Two tests were run with each cylinder with the exception of the coarse sand cylinder, with which only one test was run. A log of the tests is presented in **Appendix B**.

3.2 Coring Results

Cores drilled from the simulated hydrate cylinders made with fine sand were easily eroded (melted). The drilling fluid was the source of the erosion. OU estimated that these samples were about 33% water by volume. As the cores eroded, their diameter decreased, making them difficult to hold in the core barrel. Commercial core catchers are designed to close only a small amount. Many of the simulated hydrate cores were eroded in diameter by 0.25 in. or more. To reliably catch these cores it was necessary to drill with no fluid circulation so that the core diameter did not erode. Fortunately, only the final 6 inches of core needed to be drilled this way since the core catcher is at the bottom of the barrel. If the catcher can grip even a section of full-size core, it can also retrieve the eroded upper section of the core.

The test with the coarse sand cylinder yielded very important information. First, it showed that cores consisting of coarser material would still erode, and that care needs to be taken to ensure that core diameter is maintained in the field. This test also

showed that the drilling fluid must be carefully designed not only to minimize melting the core, but also to remove larger cuttings. If the mud is not viscous enough to suspend coarser sand, cuttings can build up around the core barrel and cause it to become stuck in the well.

The cylinders made with water only were easier to core. Except for cases when the core catcher was damaged, full cores were caught on these tests. The composition of the hydrate in Alaska will dictate how difficult it will be to retrieve core. If the hydrate is primarily sand, more care will be needed to successfully obtain a good core. If the hydrate is primarily water, coring will be easier.

Figure 13 shows the core barrel during the drilling operation. Two 5-ft cores were taken from each of the cylinders. This procedure was adopted (as opposed to a single long core) to increase the experience handling the cores and because a larger rig with enough space to clear a 10 ft barrel below the mast was too costly for the test budget. The increased core-handling experience proved to be very valuable since it allowed us to determine the difficulties keeping the core the correct size during drilling and what drilling techniques would yield the best core. Discovering that core could not be successfully recovered except by drilling without circulation would have been a very costly lesson if learned on site in Alaska.



Figure 13. Drilling/Coring Operation

Figure 14 shows one of the recovered pure ice cores (that is, no sand). The difference in recovery of the pure ice core versus the lack of success with cores containing fine sand showed that sand allowed the drilling fluid to easily erode the core.



Figure 14. Ice Core

It is believed that hydrate formations in Alaska have more coarse materials mixed with the hydrate and permafrost. To test what effect coarse rock this would have on coring, a simulated hydrate cylinder was made with very coarse (number 1) sand. A sample of core from this cylinder is shown in **Figure 15**. The coarse sand jammed the core barrel during the drilling process. This occurred because the drilling fluid did not have sufficient viscosity to carry the larger sand cuttings out of the hole. These tests showed that a proper viscosity mud will be important to the coring operation and that dry coring should be pursued with care and only after cleaning the hole.



Figure 15. Core from Sample with Coarse Number 1 Sand

3.3 Summary

Tests showed that, even when the drilling fluid was cooled to temperatures well below freezing, the core can be washed out and reduced in size by the action of the drilling fluid. This occurs more readily with delicate cores comprised mostly of sand held together with frozen water. Washing of the core by the drilling fluid caused a reduction in core diameter, making core recovery very difficult. Drilling the last 6 inches of core dry (without fluid circulation) solved this problem. Stopping circulating allowed the bottom of the core to be cut to the correct size and allowed the core catcher to grip the core and hold it in place. These tests demonstrated that it will be difficult to capture core when drilling in permafrost or hydrates without certain safeguards. The fluid must be kept below freezing so that on the trip to the surface the core will not melt and fall from the core barrel.

Tests with coarse sand showed that the drilling fluid must also be kept at the proper viscosity. When the simulated hydrate cylinder included coarse sand, the core barrel became stuck because the drilling fluid was not viscous enough to remove the large grains of sand. This showed there will be a delicate balance in providing enough flow to clean cuttings while not washing the core away, and not becoming stuck when drilling the last 6 inches of core dry. These tests were very valuable in showing the

difficulties in coring permafrost or hydrates in a laboratory environment (as opposed to a field environment where drilling costs are much higher and the potential loss of equipment greater).

4. Conclusions

Seven frozen cylinders were fabricated with fine sand and water, water only, and coarse sand and water. These were cored to simulate operations in hydrate formations. Valuable lessons were learned regarding equipment and procedures for field operations in the Alaskan tundra.

The following conclusions were reached as a result of these tests:

1. Hydrate core samples can be recovered successfully
2. Mining core barrels can recover hydrate cores
3. A spring-finger core catcher works best for catching the cores
4. Either stainless steel or Lexan core sleeves will work for this application
5. Lexan core sleeves made it easier to divide the cores
6. PDC core bits worked well for drilling the frozen hydrate cylinders
7. Chilled potassium chloride water-based mud works well for drilling frozen cores
8. Mud must be designed with proper viscosity to lift larger cuttings
9. Drilling fluid can erode the core and reduces its diameter, making it more difficult to capture the core
10. The bottom 6 inches of core may need to be drilled dry to capture the core successfully

5. References

1. De Sousa, J.T.V. (2002): "Report on the Tests Conducted at the Maurer's Drilling Research Center, Houston, TX, September 16-19, 2002," The University of Oklahoma, Well Construction Technology Center, October. **(Included as Appendix A)**

Appendix A

Hydrate Test Coring Apparatus

HYDRATE TEST CORING APPARATUS

**Report on the
Tests Conducted at the
Maurer's Drilling Research Center, Houston, TX
September 16 – 19, 2002**

**Submitted to
Mr. Bill V. Liddell
Anadarko Petroleum Corporation
17001 Northchase Drive
Houston, TX 77060**

**Prepared by
Dr. João Tadeu Vidal de Sousa**

**The Well Construction Technology Center
Mewbourne School of Petroleum & Geological Engineering
The University of Oklahoma
1101 Lexington Avenue
Norman, OK 73069-8425**

October 2002



TABLE OF CONTENTS

1.	INTRODUCTION.....	1
2.	WORK DESCRIPTION	1
3.	CORING OPERATIONS	5
4.	GUIDELINES TO EFFICIENTLY PRODUCE FROZEN CORES USING THE HYDRATE CORING APPARATUS	5
5.	CONCLUSIONS	6
6.	REFERENCES	7
	Appendix A-1: Testing Results	
	Appendix A-2: Pictures – Tests Details	



1. INTRODUCTION

The purpose of this document is to provide Anadarko Petroleum with a detailed report on the five tests performed at the Maurer’s Drilling Research Center in Houston, TX, in the period of September 16 – 19, 2002, to evaluate the performance of the Hydrate Test Coring Apparatus developed at the Well Construction Technology Center. This apparatus has already been described in details in a previous report.¹ It consists of three concentric casings, 18”x 14”x 10”. The 10” is the core holder, where a mixture of sand and water is loaded. The apparatus height is 12 ft.

2. WORK DESCRIPTION

Five tests were performed at the Maurer’s Drilling Research Center (Fig. 6). Table 1 shows a list of the tests conducted as well as dates. Differently from the lab tests performed at the Well Construction Technology Center, in Norman, the present tests were conducted with the apparatus placed in a 24” cased well, specially drilled and cased for this purpose. The major reason for placing the 12-ft long apparatus in a cased well was to facilitate the process of pulling the core holder in and out of the apparatus (Figures 7 and 8). However, both the high humidity inside the well and the high temperature of the surrounding formation would be expected to be very detrimental to an optimum freezing of the sand/water mixture. Thus, it would be necessary the use of an efficient insulation of the core apparatus. This will be evident in the first two tests conducted.

Table 1: Tests Performance Schedule

TEST NUMBER	DESCRIPTION	DATE		
		9/16/02	9/17/02	9/18/02
1 - A	Initiating Freezing of Core #1			
1 - B	Concluding Freezing of Core #1			
2 - A	Initiating Freezing of Core #2			
2 - B	Concluding Freezing of Core #2			
3	Freezing of Core #3			

All tests were performed with a 20/40 sand mesh and tap water. Two tests were performed by injecting Nitrogen in the lower part of the annulus space formed by the 18” and 14” casings. The remaining tests were performed by injecting Nitrogen in the annulus space formed by the 14” and 10” casings. Liquid Nitrogen was stored on site in two spherical tanks (Figure 9). These were 320 and 400 gallons tanks.



The hydrate core apparatus was placed in the cased freezing well ($\phi = 24''$) without any load of sand or water (Figure 10). With the core holder in place (10'' casing), it was then filled with sand and finally water was added (Figure 11). Because of the water expansion at low temperatures, the sand and water mixture level was kept one foot below the top of the core holder. The top of the sand/water mixture was covered with a metallic lid to improve heat transfer (Figure 12).

In the first three tests, the apparatus was equipped with five thermocouples. Two of these were used to measure temperatures in the annulus space formed by the 18'' and 14'' casings. They were placed at 10'' and 6'' from the bottom of the apparatus. Because these thermocouples were placed in the annulus originally designed to inject Nitrogen, they were labeled Nitrogen (top) and Nitrogen (middle), respectively. Three other thermocouples were placed in the 10'' casing to measure the peripheral temperature of the core. These thermocouples were placed at 1 ft, 6 ft, and 11 feet from the bottom of the apparatus. They were labeled core (bottom), core (middle), and core (top), respectively. In tests four and five, a sixth thermocouple was placed in the very center of the core, at about 1.5 ft from the top. This thermocouple was labeled core (top/center). In addition, the ambient temperature was also measured in all tests. Thermocouple readers were used to exhibit the temperatures during the tests. These temperature measurements were recorded by hand on a report notebook (Figure 13).

Next, detailed discussions on all tests conducted are provided.

a) **Test #1 – A (Core #1):**

This test was conducted on Monday, September 16, 2002, from 1:37 pm to 5:27 pm. The ambient temperature was in the range of 79.8 °F to 80.6 °F. For this test, the core apparatus was not insulated from the freezing cased well, except for the top that was exposed to the ambient. Improvised pieces of fiberglass insulation material were used (Figure 14). A canopy was used to prevent direct incidence of sunlight on the top of the apparatus (Figure 15).

Before starting the test, the Nitrogen tank was vented to reduce the pressure to 22 psi. Nitrogen was injected in the annulus space formed by the 18'' and 14'' casings. The injection was at a low rate by keeping the injection valve $\frac{1}{4}$ open. Nitrogen injection was stopped at 4:46 pm, but temperature measurements were taken until 5:27 pm. The core was left in the freezing cased well until next morning. All test temperatures are shown in Figure 1.

Comments on the test results: Figure 1 clearly shows that the annulus where Nitrogen was injected was half-filled with liquid Nitrogen from 3:45 pm to 4:46 pm (Nitrogen (middle) = -318 °F). As soon as the Nitrogen injection was ceased at 4:46 pm, the Nitrogen (top) and Nitrogen (middle) temperatures increased dramatically, which can be explained by a rapid transformation of liquid Nitrogen into gas due to the lack of insulation of the apparatus. At 5:30 pm, when the test was concluded, only the lower-mid part of the core was properly frozen. In the upper-mid part, the core center was still unfrozen. The core was left in place until next morning. The next test is a sequence of this test.



b) **Test #1 – B (Core #1):**

This test was run on Tuesday, September 17, 2002, from 8:20 am to 9:54 am. The ambient temperature was in the range of 76.6 °F to 80.6 °F. This test is a continuation of Test #1 – A. With the core holder in place, and as the core temperature increased over night due to the lack of insulation, Nitrogen was injected in the same way previously described to reduce the core temperature. At 9:54 am, when the temperatures of the Nitrogen (top), Nitrogen (middle), core (top), core (middle), and core (bottom) dropped to -28.5 °F, -116.6 °F, 28.6 °F, 8.3 °F, -79.6 °F, respectively, the Nitrogen injection was ceased. At about 11:00 pm, the core holder was removed from the apparatus and placed in the freezing truck (Figures 16 – 19). The freezing truck temperature was set to 25 °F. All test temperatures are shown in Figure 2.

Comments on the test results: Based on the results of this test and test 1-A, it became evident that the core apparatus should be pulled out of the 24” cased well and properly insulated before proceeding with the next test.

On 9/17/02, at 4:35 pm, after 25 hours since the core #1 had been placed in the freezing truck, the core (top), core (middle), and core (bottom) temperatures were 30 °F, 24 °F, -6 °F. The temperatures had increased significantly and the core top (central part) was not completely frozen and should be placed again in the core apparatus for additional cooling before it could be used for coring.

c) **Test #2 – A (Core #2):**

This test was performed on Tuesday, September 17, 2002, from 2:05 pm to 4:13 pm. The ambient temperature was about 90° F. Before starting this test, based on the results of the previous test, a decision was made to pull the apparatus out of the 24” cased hole and insulate it. As no proper insulation material was available on site, three layers of a white wrapping foam material were used around the 20” casing. The bottom of the apparatus was insulated from the ground by placing two layers of hard foam on a wooden plate. With the insulated apparatus in place, testing was commenced. Similarly to the other two previous tests, Nitrogen was injected at a low rate (valve ¼ open). However, Nitrogen was injected in the annulus formed by the 14” casing and the core holder. This was done to ensure that a fully frozen core would be obtained with the poor quality insulation material provided in a reasonable time.

At 4:13 pm, when the Nitrogen (top), Nitrogen (middle), core (top), core (middle), and core (bottom) temperatures were -84.9 °F, -297.5 °F, 23.6 °F, -294.3 °F, -316 °F, respectively, the test was terminated and the core stored in the freezing truck. Although the core top was not completely frozen, the test had to be stopped because no personnel would be available on site for assistance afterward. The test temperatures are shown in Figure 3.

Comments on the test results: Figure 3 shows that although the quality of the insulation material used was not ideal, it was acceptable since very cold core temperatures were



obtained in about two hours. The test results also showed that the decision of injecting Nitrogen in the annulus just outside the core holder (10" casing) was right. Nitrogen was injected in the same way in all subsequent tests.

d) **Test #3 (Core #3):**

This test was performed on Wednesday, September 18, 2002, from 9:37 am to 1:33 pm. Ambient temperature was about 86 °F. Similarly to the previous tests, Nitrogen was injected in the annulus formed by the 14" casing and the core holder. However, Nitrogen was injected in the first 15 minutes at a low rate (valve ¼ open) and, thereafter, the injection valve was opened completely to allow the highest Nitrogen flow rate possible. This was done to ensure liquid Nitrogen level in the annulus well above the mid-height of the apparatus. Thus, reducing the time to freeze the core top, which was the most difficult part to freeze. The initial Nitrogen injection pressure was 38 psi.

At 12:21 pm, the Nitrogen injection was stopped because the first Nitrogen tank was empty. At 12:45, the Nitrogen injection was resumed with Nitrogen from a reserve tank.

In this test, an additional thermocouple was placed in the very center of the core, at about two feet from the top and was labeled core (top/center). Testing should be terminated and the core holder removed from the apparatus only after this temperature was well below 32 °F. A temperature target of about -10 °F was set for this temperature.

To improve freezing efficiency, sand was stored in the freezing truck on the previous day. At the time the core apparatus was loaded with sand, the sand temperature was 44 °F.

After the successful conclusion of this test, at 1:33 pm, the core holder was removed from the apparatus and stored in the freezing truck (Figures 20 to 24).

Comments on the test results: Figure 4 shows the temperature results of this test. Very cold temperatures were obtained in the end of the test. Note the core (top/center) temperature at about -11 °F, which means a very successful test with a well-frozen core from bottom to top, except for the very top of the core where a few inches of water was still present due to the lack of insulation on the top of the apparatus. This insulation was not improved because adequate insulation material was unavailable on site.

e) **Test #2 - B (Core #2):**

This test was performed on Wednesday, September 18, 2002, from 2:24 pm to 4:37 pm, and is a sequence of test #2 – A. Core #2 was taken from the freezing truck and pulled in the core apparatus for additional cooling. Nitrogen was injected as described in the previous test.

The core (top), core (middle), and core (bottom) temperatures at 8:05 am, when the core was still in the freezing truck, were 32.8 °F, 18 °F, and 6 °F, respectively.



Comments on the test results: Figure 5 shows the temperature results of this test. Very cold temperatures were obtained in the end of the test. Note the core (top/center) temperature at about -16°F , which means a very successful test. A well-frozen core from bottom to top was obtained, except for the very top of the core where a few inches of water was still present for the same reason previously discussed.

3. CORING OPERATIONS

Successful coring operation was performed with the frozen rock #3 on Thursday, September 19, 2002. The frozen rock was carefully removed from the freezing truck and then insulated. As no adequate insulation material was available on site, the core holder was insulated with two layers of white wrapping foam material. After insulated, the core holder was placed in the coring well. This well was located a few feet away from the well used to make the frozen rock. This well was specially drilled and cased for this purpose.

Figures 25 to 37 show details of the frozen rock preparation and the coring operation. Figure 25 shows the coring tools. Figure 26 depicts the drilling rig. Figures 27 to 29 show the core preparation. Figures 30 and 31 depict the frozen rock placement in the well to be cored. Figure 32 and 33 show the wellhead and the coring tools preparation, respectively. Figure 34 and 35 show the coring operation. Figure 36 and 37 show details of the recovered frozen core.

Improvements in the core procedures will be required since the first recovered core had a diameter significantly smaller than the core barrel (Figure 37). These improvements include mud composition and coring tools. Mud with KCl was used. The presence of KCl in the mud might have accelerated the unfreezing rate of the frozen rock. The reduction in the recovered diameter might also be a result of the friction between the sand and the bit/core barrel.

4. GUIDELINES TO EFFICIENTLY PRODUCE FROZEN CORES USING THE HYDRATE CORE APPARATUS

On Thursday, September 19, 2002, Maurer's Drilling Research Center was provided with guidelines to effectively produce frozen rock cores using the Hydrate Test Coring Apparatus. These guidelines were based on both results from the experimental tests previously discussed and the lab tests performed at the Well Construction Technology Center, Norman- OK. These guidelines are described as follows:



- a) Before pulling the core out of the apparatus, the temperature measurements should be close to the following temperatures, based on the results of the successful tests conducted with cores number 2 and 3:

Nitrogen (Top)	Nitrogen (middle)	Core top	Core middle	Core bottom	Core center (near surface)	Elapsed time
Core number 3						
-185	-310	-39	-319	-319	-11	4 hours
Core number 2 (Refrozen)						
-159	-310	-40	-319	-319	-16	4 hours

- b) Typical liquid Nitrogen temperature at the current test ambient conditions should be -318 °F.
- c) Keep the top of the apparatus well insulated. Current insulation material is poor and should be improved.
- d) As the top insulation of the apparatus is poor, it might be preferable to freeze the core without the metallic cap. The cap was designed to improve heat transfer in the top of the core. Because the poor quality of the insulation, the cap is probably enhancing heat transfer between the core and the ambient, which is preventing the core from being fully frozen in the very top. Tests should be performed with and without the cap for comparisons.
- e) Prevent the top of the apparatus from receiving direct sunlight.
- f) It is recommended to start the injection of liquid Nitrogen at a low rate (injection valve ¼ open). Then, after 15 minutes, slowly increase the rate to the highest possible without overflowing the annulus space where the Nitrogen is injected. The reason for injecting Nitrogen at the highest flow rate possible is to keep liquid Nitrogen level in the annulus well above the apparatus mid-height.
- g) While injecting Nitrogen, watch the injection pressure. Recommended injection pressure is less than 40 psi.
- h) The temperature that is measured in the very top of the core shows a very slow decrease initially. Thereafter, it should decrease at a rate of 1 °F per 2.5 to 3 minutes. This rate may be increased to 1°F per minute if the Nitrogen flow rate is increased.
- i) Sand, water, and any unused core holder should be stored in the freezing truck to optimize the core freezing operation.

5. CONCLUSIONS

The test conditions at the Maurer’s Drilling Research Center (MDRC) were very different from the conditions of the lab tests conducted at the Well Construction Technology Center. During the test at MDRC, both the high humidity inside the freezing cased well and the



reasonable high temperature of the surrounding formation were very detrimental to a fast freezing of the sand/water mixture. This scenario was further complicated by the unavailability of appropriate insulation material on site. Thus, the insulation of the core apparatus was improvised and performed with white wrapping foam material. However, even with such adversities, successful frozen rocks could be produced in about four hours, which shows the excellent efficiency of the hydrate test coring apparatus developed at the Well Construction Technology Center.

6. REFERENCES

1. Goel, Naval, De Sousa, J. T. V., Flenniken, J., and Bishop, M.: "Report on Testing for Laboratory Simulation of Alaska Frozen Rock Encountered During Hydrate Coring", The University of Oklahoma, Well Construction Technology Center, October 2002.



The University of Oklahoma

WELL CONSTRUCTION TECHNOLOGY CENTER

APPENDIX A-1

Testing Results

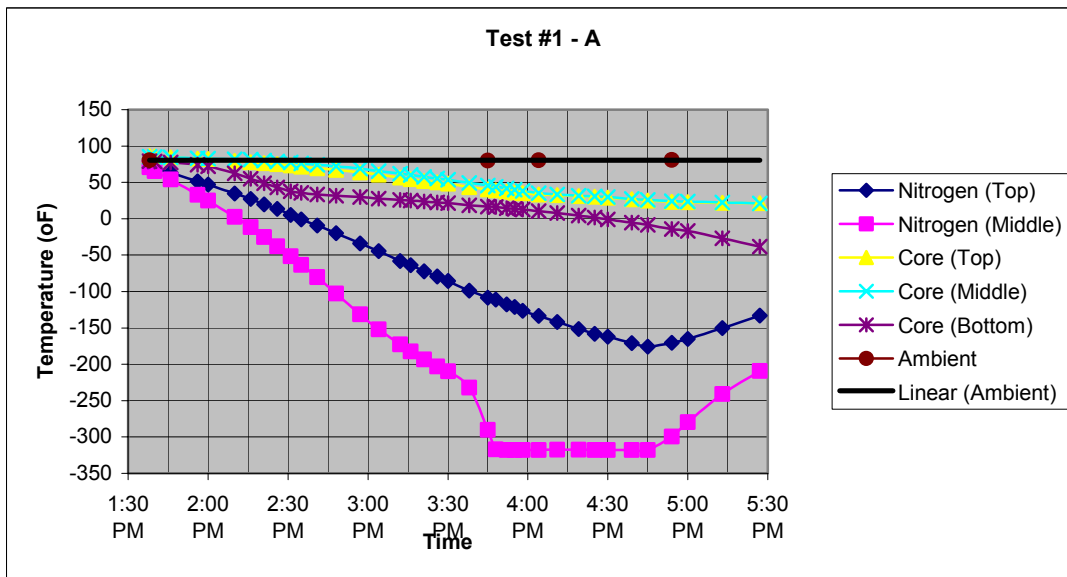


Figure 1: Results of Test #1 – A

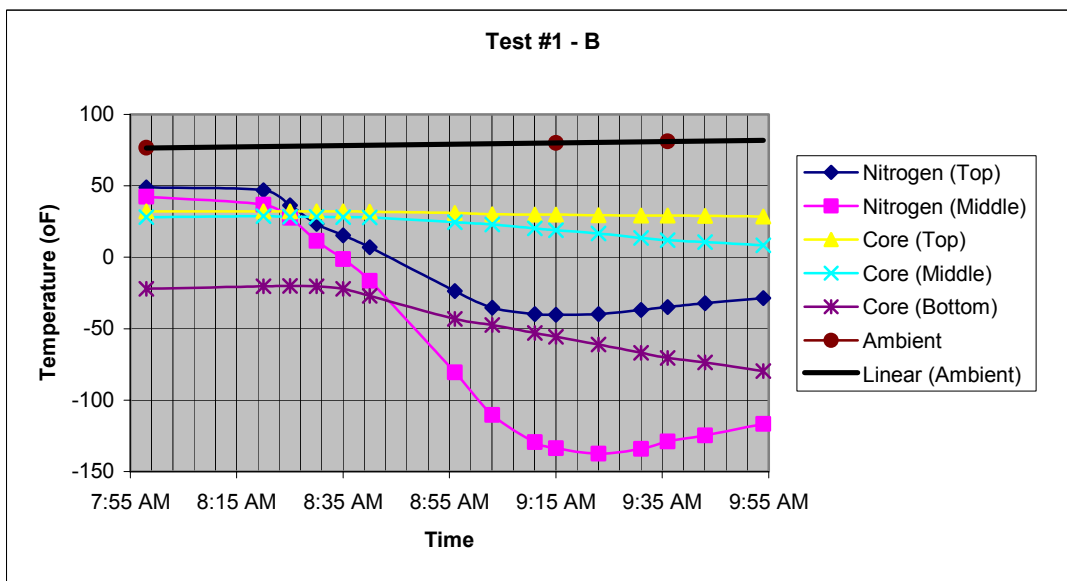


Figure 2: Results of Test #1 – B

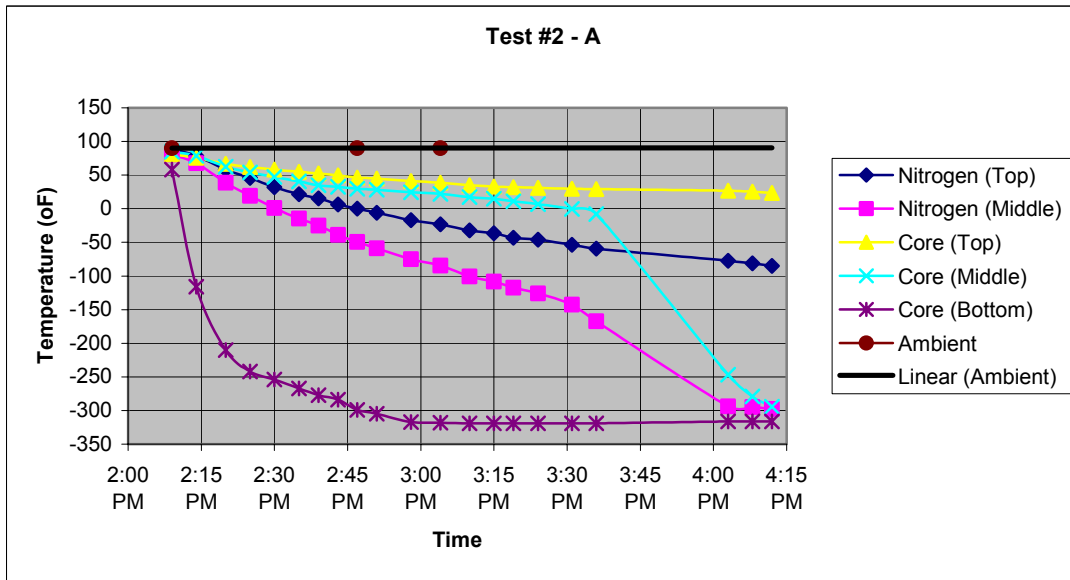


Figure 3: Results of Test #2 – A

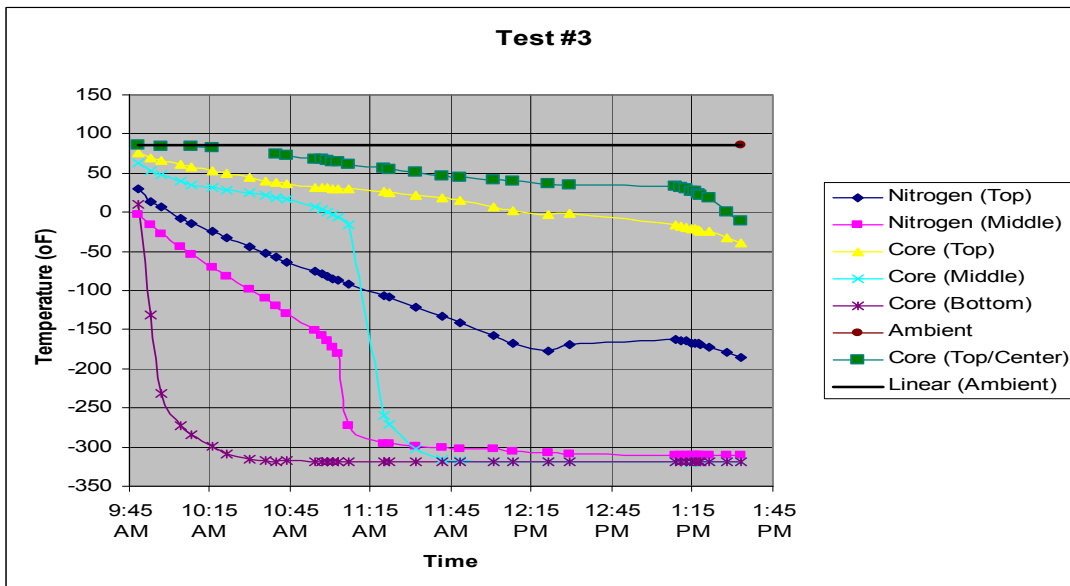


Figure 4: Results of Test #3

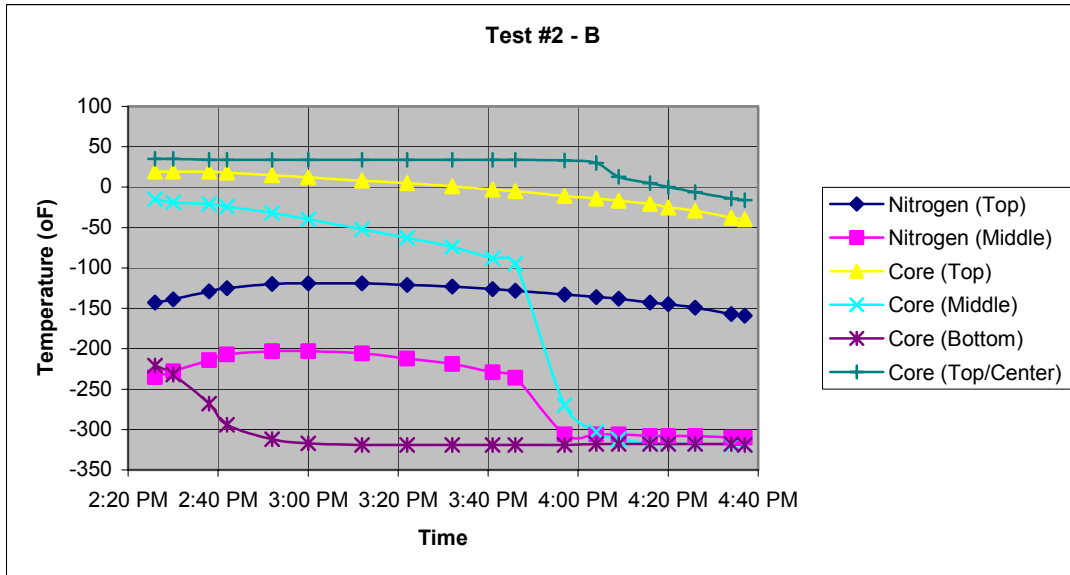


Figure 5: Results of Test #2 - B



APPENDIX A-2

Pictures - Tests Details



Figure 6: Maurer's Drilling Research Center



Figure 7: Core Placement in the Freezing Cased Well



Figure 8: Core Placement in the Freezing Cased Well (Cont'd)



Figure 9: Nitrogen Reservoirs



Figure 10: Core Preparation before Freezing



Figure 11: Core Preparation before Freezing (Cont'd)



Figure 12: Core Preparation before Freezing (Cont'd)



Figure 13: Thermocouple Readers



Figure 14: Details of the Insulation of the Top of the Apparatus



Figure 15: Direct Incidence of Sunlight Protection on the Top of the Apparatus



Figure 16: Bringing Core #1 from the Core Apparatus to the Freezing Truck



Figure 17: Bringing Core #1 from the Core Apparatus to the Freezing Truck



Figure 18: Bringing Core #1 from the Core Apparatus to the Freezing Truck (Cont'd)



Figure 19: Bringing core #1 from the Core Apparatus to the Freezing Truck (Cont'd)

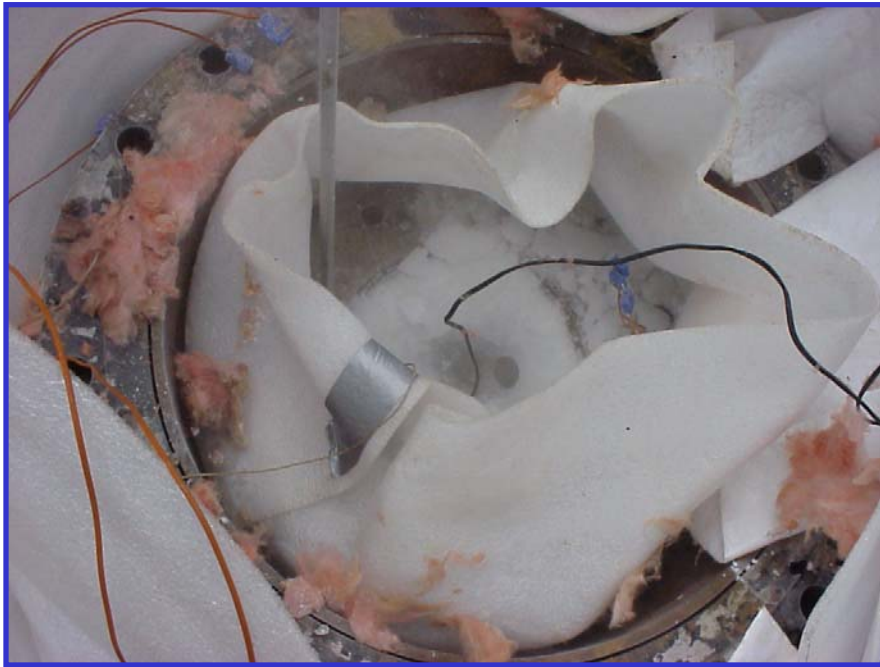


Figure 20: Details of Removing Frozen Core #3 from the Apparatus



Figure 21: Details of Removing Frozen Core #3 from the Apparatus (Cont'd)



Figure 22: Details of Removing Frozen Core #3 from the Apparatus (Cont'd)



Figure 23: Details of Removing Frozen Core #3 from the Apparatus (Cont'd)



Figure 24: Details of Removing Frozen Core #3 from the Apparatus (Cont'd)



Figure 25: Coring Tools



Figure 26: Drilling Rig



Figure 27: Frozen Core Preparation Before Coring Operation



Figure 28: Frozen Core Preparation Before Coring Operation (Cont'd)



Figure 29: Frozen Core Preparation Before Coring Operation (Cont'd)



Figure 30: Frozen Core Placement in the Well to Be Cored



Figure 31: Frozen Core in Place to Be Cored



Figure 32: Wellhead Preparation Before Coring



Figure 33: Coring Tools Preparation



Figure 34: Coring Operation



Figure 35: Coring Operation



Figure 36: Details of the Recovered Frozen Core (Cont'd)



Figure 37: Details of the Recovered Frozen Core (Cont'd)

Appendix B

Hydrate Test Log



Ice Core Test
Maurer Technology Drilling Research Center
2802 Mangum Road, Houston, Texas

PREPARED BY: CRAIG WATSON, NED
SUBMITTED TO: ALI G. KADASTER, APC

September 19, 2002

<u>Start</u>	<u>Stop</u>	<u>Time</u>	
8:00	9:30	1:30	Dress Core Barrel With Standard Core Catcher & Position Fugro Rig Over Bore Well
9:30	10:30	1:00	
			Install Ice Cylinder #1 (Sand & Water) in Bore Well, Fill Mud Tank With KCL Mud at 21 Deg F.
10:30	11:00	0:30	Conduct Pre-Task Safety Meeting
11:00	11:35	0:35	Pick Up Core Assembly & Establish Circulation
11:35	11:40	0:05	Cut Core # 1 - 0' ~ 5', 60 Rpm, 15 Gpm, 30 Psi, 11" Min Feed Rate, Mud 21 Deg F In & 13 Deg F Out.
11:40	12:00	0:20	Retrieve Inner Core Barrel With Zero Core.
12:00	13:00	1:00	Pumped Mud Out Of Bore Well & Recovered 56" of Core Manually, Core Was 3/4" Under Gauge Which Is The Reason The Core Caught Didn't Pull The Core Out When The Inner Core Barrel Was Retrieved. Under Gauge Core Recovered Was Conical From Top To Bottom Which Is An Indication Of Washing.
13:00	13:35	0:35	Dress Core Barrel #2 With Spring Type Core Catcher.
13:35	13:40	0:05	Cut Core # 2 - 5' ~ 10', 30 Rpm, 10 Gpm, 20 Psi, 15" Min Feed Rate, Mud 21 Deg F In & 18 Deg F Out
13:40	14:00	0:20	Retrieve Inner Core Barrel With 53" (88%) Core Recovered. Core was 1/2" to 1/4" Under guage Conical From Top To Bottom.
14:00	15:00	1:00	Moved Rig Off Bore Well & Remove Ice Cylinder. Recovered Bottom 7" Of Core From Inside Cylinder.
15:00	16:00	1:00	Conducted Telecon Conference Call With APC (Ali Kadaster) & MI Drilling Fluids (Randy Ray). Released Fugro Crew @ 16:00 Hours. APC Ordered Lexan Core Barrel Liners from Dynatec.
16:00	18:00	2:00	Placed Drill Fluid In Reefer & Cleaned Work Site.



Ice Core Test
Maurer Technology Drilling Research Center

PREPARED BY: CRAIG WATSON, NED
SUBMITTED TO: ALI G. KADASTER, APC

September 20, 2002

<u>Start</u>	<u>Stop</u>	<u>Time</u>	
8:00	9:00	1:00	Dress Core Barrel With Spring Type Core Catcher. LEXAN Tubes Received 8 AM.
9:00	10:30	1:30	Install Ice Cylinder #2 (Sand & Water) in Bore Well, Fill Mud Tank With KCL Mud at 28 Deg F. Position Rig Over Well Bore.
10:30	10:45	0:15	Conduct Pre-Task Safety Meeting
10:45	11:00	0:15	Pick Up Core Assembly & Establish Circulation
11:00	11:10	0:10	Cut Core # 3 - 0' ~ 5', 60 Rpm, 7.5 Gpm, 15 Psi, 15" Min Feed Rate, Mud 28 Deg F In. Core Barrel Circulating Ports Plugged & 40" Of Core Was Cut With Zero Circulating Returns.
11:10	12:00	0:50	Break Core Rod Connection and Pull Inner Core Barrel. Recovered 50" Full Gauge Core Inside Lexan Tube.
12:00	12:30	0:30	Install Pre-Dressed Inner Core Barrel #4 & 5' Additional Core Rod.
12:30	12:35	0:05	Cut Core # 4 - 5' ~ 10', 50 Rpm, 10 Gpm, 15 Psi, 12" Min Feed Rate, Mud 28 Deg F In. & 24 Deg F Out. Last 6" Of Core Cut With Pump Off.
12:35	12:45	0:10	Retreive Inner Core Barrel With Zero Core.
12:45	13:15	0:30	Lay Down Core Tools & Move Rig Off Well Bore.
13:15	13:45	0:30	Remove Ice Cylinder From Well Bore & Empty Contents. Recovered 60" of Underguage Core Which Was Under Guage 1 1/2" to 3/4" in Conical Shape From Top To Bottom.
13:45	14:00	0:15	Clean Work Site & Release Rig Crew
14:00	18:00	4:00	Freeze Ice Cylinder #3 Containing Water In Nitrogen Freeze Well, Dump High Sand Content Drill Fluid, Batch Mix 100 Gallon & Place In Reefer.



Ice Core Test
Maurer Technology Drilling Research Center

PREPARED BY: CRAIG WATSON, NED
SUBMITTED TO: ALI G. KADASTER, APC

September 23, 2002

<u>Start</u>	<u>Stop</u>	<u>Time</u>	
8:00	11:00	3:00	Standby with Fugro Crew while Mud Tank & Ice Cylinder #3 (Water Only) is removed from refrigerated truck and set into position.
11:00	11:15	0:15	Position rig over well bore.
11:15	11:30	0:15	Conduct Pre-Task Safety Meeting
11:30	11:50	0:20	Pick Up Core Assembly & Establish Circulation
11:50	11:55	0:05	Cut Core # 5 - 0' ~ 5', 25 Rpm, 10 Gpm, 15 Psi, 20" Min Feed Rate, Mud 28 Deg F
11:55	12:10	0:15	Break Core Rod Connection and Pull Inner Core Barrel. Recovered 60" (100%) Full Gauge Core Inside Lexan Tube.
12:10	12:15	0:05	Install Pre-Dressed Inner Core Barrel #6
12:15	12:20	0:05	Cut Core # 6 - 5' ~ 10', 25 Rpm, 10 Gpm, 15 Psi, 20" Min Feed Rate, Mud 17 Deg F (Dry Ice Added)
12:20	12:30	0:10	Break Core Rod Connection and Pull Inner Core Barrel. Recovered 60" (100%) Full Gauge Core Inside Lexan Tube.
12:30	13:00	0:30	Lay Down Core Tools & Move Rig Off Well Bore.
13:00	13:45	0:45	Remove Ice Cylinder From Well Bore
13:45	14:00	0:15	Clean Work Site & Release Rig Crew
14:00	18:00	4:00	Freeze Ice Cylinder #4 Containing Water In Nitrogen Freeze Well, Place Mud Tank in Reefer.



Ice Core Test
Maurer Technology Drilling Research Center

PREPARED BY: CRAIG WATSON, NED
SUBMITTED TO: ALI G. KADASTER, APC

September 24, 2002

<u>Start</u>	<u>Stop</u>	<u>Time</u>	
8:00	10:30	2:30	Standby with Fugro Crew while Mud Tank & Ice Cylinder #4 (Water Only) is removed from refrigerated truck and set into position.
10:30	10:45	0:15	Conduct Pre-Task Safety Meeting
10:45	11:00	0:15	Position rig over well bore, Pick Up Core Assembly & Establish Circulation.
11:00	11:05	0:05	Cut Core # 7 - 0' ~ 5', 70 Rpm, 25 Gpm, 40 Psi, 20" Min Feed Rate, Mud 25 Deg F
11:05	11:15	0:10	Break Core Rod Connection and Pull Inner Core Barrel. Recovered 60" (100%) Full Gauge Core Inside Lexan Tube.
11:15	11:25	0:10	Install Pre-Dressed Inner Core Barrel #8
11:25	11:30	0:05	Cut Core # 8 - 5' ~ 10', 120 Rpm, 60 Gpm, 75 Psi, 20" Min Feed Rate, Mud 24 Deg F
11:30	11:45	0:15	Break Core Rod Connection and Pull Inner Core Barrel. Recovered 60" (100%) Full Gauge Core Inside Lexan Tube.
11:45	12:00	0:15	Lay Down Core Tools & Move Rig Off Well Bore.
12:00	12:30	0:30	Clean Work Site & Release Rig Crew
12:30	14:00	1:30	Remove Ice Cylinder From Well Bore
14:00	18:00	4:00	Freeze Ice Cylinder #5 Containing Water & 20/40 Sand Under Vacuum In Nitrogen Freeze Well, Place Mud Tank in Reefer.



Ice Core Test
Maurer Technology Drilling Research Center

PREPARED BY: CRAIG WATSON, NED
SUBMITTED TO: ALI G. KADASTER, APC

September 25, 2002

<u>Start</u>	<u>Stop</u>	<u>Time</u>	
8:00	13:00	5:00	Freeze Ice Cylinder #7 Containing Water & 8/12 Sand Under Vacuum In Nitrogen Freeze Well
13:00	13:30	0:30	Standby with Fugro Crew while Mud Tank & Ice Cylinder # (6) (Water & 20/40 Sand Vac Freeze) is removed from refrigerated truck and set into position.
13:30	13:45	0:15	Conduct Pre-Task Safety Meeting
13:45	14:00	0:15	Position rig over well bore, Pick Up Core Assembly & Establish Circulation.
14:00	14:05	0:05	Cut Core # 9 - 0' ~ 5', 75 Rpm, 10 Gpm, 15 Psi, 20" Min Feed Rate, Mud 35 Deg F
14:05	14:15	0:10	Break Core Rod Connection and Pull Inner Core Barrel. Recovered 60" (100%) Full Gauge Core Inside Lexan Tube.
14:15	14:20	0:05	Install Pre-Dressed Inner Core Barrel #10
14:20	14:25	0:05	Cut Core # 10 - 5' ~ 10', 100 Rpm, 20 Gpm, 30 Psi, 20" Min Feed Rate, Mud 37 Deg F
14:25	14:35	0:10	Break Core Rod Connection and Pull Inner Core Barrel. Recovered 60" (100%) Core Inside Lexan Tube, Full Gauge @ Bottom Reduced to 2" Cone On Top. (Conical Shaped)
14:35	15:05	0:30	Change out Ice Core Cylinder to #6 (Water & 20/40 Sand Normal Freeze)
15:05	15:15	0:10	Position Rig & P/U Core Barrell #11
15:15	15:20	0:05	Cut Core # 11 - 0' ~ 5', 75 Rpm, 10 Gpm, 15 Psi, 20" Min Feed Rate, Mud 37 Deg F
15:20	15:40	0:20	Break Core Rod Connection and Pull Inner Core Barrel. No Core Recovered. Inspected and found springs inside core catcher damaged, replaced core catcher. Pulled Outer Core Barrel & Bit, Recovered 90% Core Full Gauge At Bottom Reduced To 2.5" At Top (Conical Shaped)
15:40	15:50	0:10	Pickup Core Barrel # 12
15:50	15:55	0:05	Cut Core # 12 - 5' ~ 10', 75 Rpm, 15 Gpm, 20 Psi, 20" Min Feed Rate, Mud 25 Deg F
15:55	16:05	0:10	Break Core Rod Connection and Pull Inner Core Barrel. Recovered 60" (100%) Core Inside Lexan Tube. Full Gauge @ Bottom Reduced to 2.75" At Top (Conical Shaped)
16:05	16:30	0:25	Change out Ice Core Cylinder to #7 (Water & 8/12 Sand Vac Freeze)
16:30	16:40	0:10	Position Rig & P/U Core Barrell #13
16:40	17:00	0:20	Cut Core # 13 - 0' ~ 2.5', 75 Rpm, 20 Gpm, 25 Psi, 10" Min Feed Rate, Mud 30 Deg F, Core Barrel Plugged
17:00	17:15	0:15	Break Core Rod Connection and Pull Inner Core Barrel. Recovered 27" (90%) Core Inside Lexan Tube. Full Gauge
17:15	18:15	1:00	Core Barrel Stuck in Drill Cylinder, Work Same Free Washing Down Backside Until Circulation Is Established.
18:15	18:30	0:15	Add Remaining Polmer to Increase Drill Fluid Viscosity.
18:30	18:35	0:05	Core 2' - 2.5' ~ 4.5', 100 RPM, 50 GPM, 70 PSI, 10" Min Feed Rate, Mud 32 Deg F. Due To High Circulation Rate Mud Splashed Over Bell Nipple Causing Pump Suction To Run Dry.
18:35	18:45	0:10	Break Core Rod Connection and Pull Inner Core Barrel. Recovered 24" (100%) Core Inside Lexan Tube. Full Gauge
18:45	19:00	0:15	Lay Down Core Tools & Move Rig Off Well Bore. Release Rig Crew