Oil & Natural Gas Technology

DOE Award No.: DE-FC26-06NT42951

Quarterly Progress Report
(January 1 – March 31, 2008)

Development and Application of Insulated Drill Pipe for High Temperature, High Pressure Drilling

Submitted by:
Drill Cool Systems
627 Williams St
Bakersfield, CA 93305

Prepared for:
United States Department of Energy
National Energy Technology Laboratory

April, 2008

Office of Fossil Energy

Quarterly Progress Report

DOE Award No.: DE-FC26-06NT42951
Recipient: Drill Cool Systems, Bakersfield CA.

"Development and Application of Insulated Drill Pipe for High Temperature, High Pressure Drilling" Al T. Champness, Project Director

Report Date: 20 April 2008
Report Period: 1 January 2008 – 31 March 2008

Executive Summary: This reporting period was devoted primarily to the latter two of the three principal components (below) of the program, each of which is being pursued to provide maximum possible assurance to NETL and to potential customers that insulated drill pipe (IDP) will be rugged, reliable, and serviceable in the HTHP environment. The two components are described in detail in the "Results and Conclusions" section below.

- Mechanical testing
- Development of an inspection plan
- Industry market survey.

Mechanical testing: Mechanical testing is intended to evaluate the strength of IDP under conditions that represent the HTHP environment, with particular attention to the integrity of the plug that seals the annular space containing the insulation. (Figure 1) Because the liner tube is relatively thin compared to the drill pipe wall, the nominal strength of the pipe is

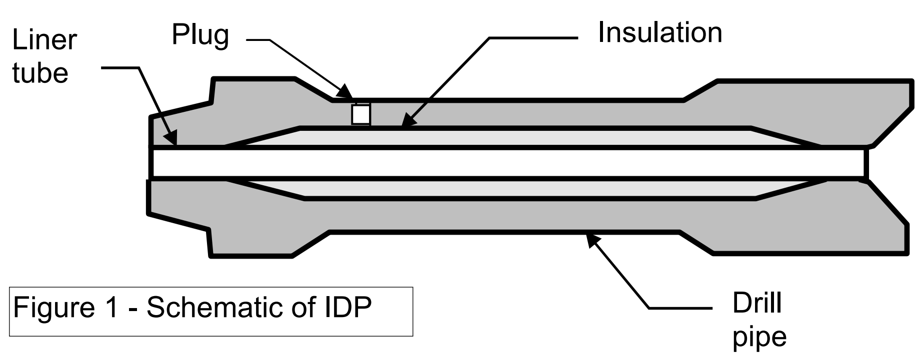


Figure 1 - Schematic of IDP

considered to be the same as that of the parent drill pipe; that is, the liner and insulation neither add to nor detract from the strength of the drill pipe. Mechanical testing was successfully completed at Stress Engineering Services in Houston in late 2007.

Inspection plan: Much of conventional drill pipe inspection relies on visual access to the pipe surface, or on NDT techniques (ultrasonic, etc.) that can look "through" the pipe from the outside to detect flaws on the inside surface. Once the liner and insulation are installed, then visual access is no longer possible, and the inside diameter is no longer a free surface, so it is important to verify that the NDT techniques can still detect flaws inside the drill pipe body (i.e., in the annular space beneath the insulation and liner). To provide quality assurance for the assembled IDP, TH Hill Associates in Houston has developed an inspection plan for the assembly. The process to verify the inspection plan will be to deliberately machine flaws into a virgin pipe body, inspect this pipe with various methods to evaluate their accuracy, install the liner and insulation, and re-inspect the assembled IDP to verify that the chosen method(s) can still identify the flaws. A contract is in place with TH Hill (see Appendix A for scope of work) and all the materials (three sizes of drill pipe) have been acquired. At report date, the drill pipe awaits machining, both to modify it for installation of the liner and insulation, and to machine the flaws that will form the inspection targets.

Market survey: IDP has possible applications both on-shore and off-shore, so a fundamental choice to be made in the pipe design is diameter. Current cost and availability of drill pipe preclude building more than one size for initial development, so it is crucial to choose the pipe diameter that will provide the greatest overall benefit to the industry. Drill Cool contracted with a market research company to survey operators and service companies involved in high-temperature drilling, with the objective of answering several key questions: what is the market for IDP? What are the barriers to industry acceptance? And, perhaps most critical, what is the optimum IDP size to meet most industry needs? Unfortunately, response from operators was limited, mostly because the very high level of activity in the industry meant that they just didn't have time to respond to interviews.

<u>Approach:</u>

These components of development are consistent with our fundamental approach, which holds that the underlying principles and performance of IDP have been demonstrated in the past through laboratory tests, field tests, and analysis (see, for example, J. T. Finger, R. D. Jacobson, and A. T. Champness, "Development and Testing of Insulated Drill Pipe", *SPE Drilling & Completion*, June 2002, pp. 131-136).

Our approaches to specific parts of the development are summarized below:

- Mechanical testing – The general approach to mechanical testing has been to identify the operating environment that the pipe will see in HTHP use and to analyze the stresses that will result from that situation. The test plan attempts to reproduce those stresses and then to evaluate their effects.
- Inspection plan – The essential nature of this activity is to machine "standard" flaws into premium drill pipe before the insulation is installed, and then develop an inspection protocol using the standardized method that best captures the nature of the flaws with insulation in place.
- Market survey – Industry interviews in the form of a market survey will be extremely valuable for final design criteria of the insulated pipe. We expect that these interviews will clarify such issues as the optimum size pipe to serve the HTHP market, barriers to IDP use in terms of customer perception, and the proof tests/inspections that industry will consider necessary before using the product.

The primary thrust of this project, then, will come in refining the design to perform in any unique operating conditions not previously considered, and in developing a product that meets industry needs for overcoming current limitations. Part of defining industry needs is to understand what barriers there may be to market acceptance for IDP as a realistic option in high-temperature drilling. This may be a difficult part of this work, and will comprise: identifying the potential market; acquiring an in-depth understanding of their needs and concerns; and providing technical solutions to their needs and persuasive answers to their concerns. There may well be an educational component to this industry interaction because preliminary responses, both to the market survey and to questionnaires distributed at an HTHP trade show in April 2007, indicate that a large majority of people in the drilling business are unfamiliar with the concept of insulated drill pipe. Given the inherent conservatism in the drilling industry, the initial, uninformed, opinion is likely to be negative and we must provide accurate information in response to this attitude.

Results and Conclusions:

Development of an inspection plan: TH Hill Associates has developed an inspection plan for IDP that will help to resolve industry concerns about the ruggedness and survivability of IDP in HTHP wells. This plan is a modification of the industry-standard DS-1 inspection, so it should be widely acceptable even to people who are not familiar with the IDP concept. The inspection methods that will be considered in development of the plan are the following:

- Full Length Ultrasonic Testing (FLUT)
- Ultrasonic Wall Thickness Inspection
- Ultrasonic Slip/Upset Inspection
- Electromagnetic Inspection (EMI)

We have chosen three pipe sizes for use in this development: 3-1/2”, 5”, and 6-5/8”, and in each case we want to use the heaviest available wall thickness to evaluate how deeply into the material we can see with the relevant NDT method. The three selected pipe sizes are on hand and await machining in Houston. Their specific weights, tool joint sizes, conditions, and diameters are the following:

- 3-½ “, 13.30 lb/ft, NC38 connection (used)
- 5”, 19.50 lb/ft, NC50 connection (new)
- 6-5/8”, 27.70 lb/ft, 6-5/8FH connection (premium)

The variation in condition (new to used) will also help us evaluate the effect of wear on the inspection procedure.

A secondary objective of this development will be to determine whether the inspection procedure can measure the concentricity of the pipe and liner (how well the liner is centered in the pipe) and evaluate the insulation fill (whether there are voids in the insulation). This function is less important structurally than flaw detection, but would be a useful addition to the IDP quality control.

There are four basic steps in completion of the inspection plan activity:

1. Three sizes of drill pipe will be bored out and machined to accept liners so they can be converted into IDP.
2. The modified DP will go to an inspection facility where the artificial flaws will be machined into the pipe, and the pipe will then be inspected by four NDT methods to assure that these methods can detect the flaws.
3. The modified pipe, with flaws, will be shipped to Bakersfield where Drill Cool will install liners and insulation, and it will then be returned to Houston.
4. The assembled IDP with flaws will be inspected by the same four methods as before and the methods will be evaluated to choose the most effective one(s).

As noted in the previous Progress Report, Drill Cool was in the queue for a machine shop to modify the drill pipe for installation of the liner and insulation but, as it developed, that shop was unable to perform the work. After an extensive search, another machine shop was located (the current level of drilling activity has put extreme pressure on machine shops in the Houston area) and the pipe has been delivered there. This shop will complete the ID work by the end of April. At report time, we expect to have completed the IDP assembly in Bakersfield by the end of May. A complete description of the inspection plan is given in Appendix B.

Industry interviews/market survey: Drill Cool placed a contract with a market research company for an industry survey, and that company contacted over 100 operators and service companies in an attempt to answer some of the basic questions given previously (What is the market for IDP? What are the barriers to industry acceptance? And, perhaps most critical, what is the optimum IDP size to meet most industry needs?) Unfortunately, the extreme press of business in the oil industry meant that the company had a limited response. Operators were about evenly divided on whether they considered IDP to be worth further investigation, but the responses made clear the fact that many of them didn't really understand the concept. Service companies (directional drilling) were much more enthusiastic, with six out of seven interviewees expressing definite interest in the technology.

On the subject of pipe size, the relatively small sample size did not lend confidence that we

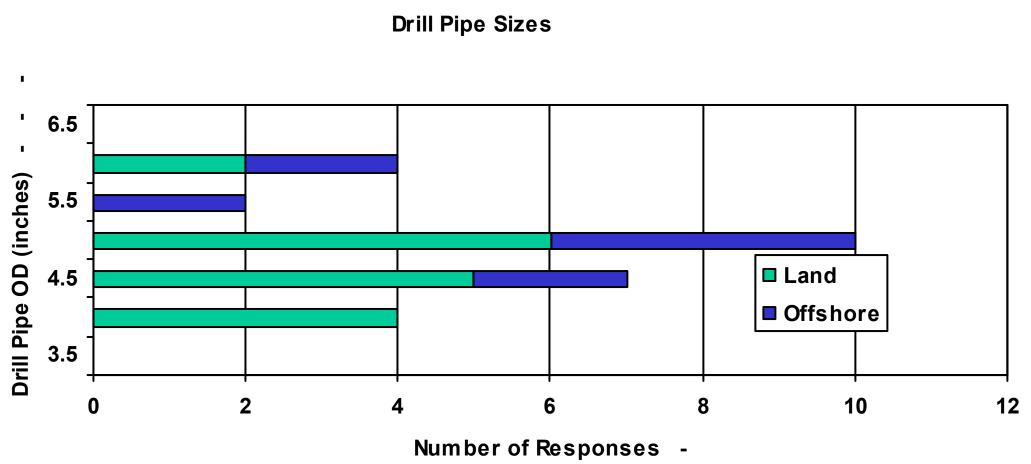


Figure 2 – Desired pipe sizes from market survey

know enough to choose the optimum diameter for a string of IDP to meet industry needs. For example, responses to the market survey are shown in Figure 2.

In comparison, Drill Cool passed out questionnaires at an HTHP trade show in April 2007, and the results of those surveys is shown in Figure 3.

Although some trends are apparent, the small sample size does not give sufficient confidence that we have identified the optimum pipe size. As a generality, almost all interviewees were strongly in favor of the largest possible inside diameter, from both hydraulics and fishing tool requirements. Representatives from both Drill Cool and the market research company will also attend the HTHP Conference in early April, 2008 and will try to gather more information to resolve this question.

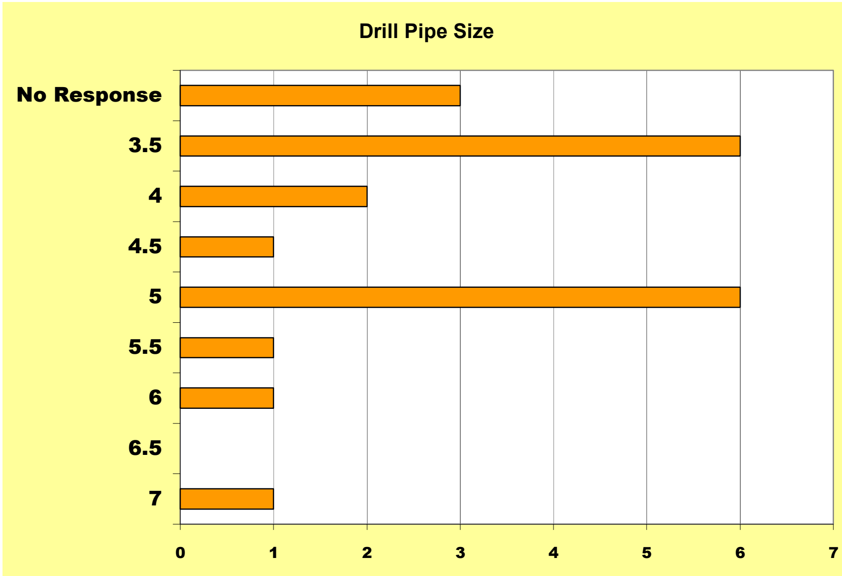


Figure 3 – Desired pipe sizes from trade show survey

Summary: Resolution of the pipe-size question is the principal barrier to moving forward for Phase 2. We intend to address this problem vigorously, so that the choice can be made by late Spring 2008. The inspection plan activity is facing significant delay, so the go/no-go decision point may be pushed back considerably further than we hoped or expected.

Status:

Cost status: The anticipated and actual budget is shown in the Table below:

Task	Task Description	Estimated NETL Expenditure	Actual NETL Expenditure	Estimated Drill Cool Cost	Actual Drill Cool Cost
1.4.3	Industry collaboration/market survey	20860.00	4876.77	13901.00	7685.74
1.4.4	Develop inspection plan	29772.00	3505.54	4350.00	5524.69

Milestone status:

Task Number	Critical Path Milestone Description	Project Duration -- Start: 1 Oct 06 End: 30 Sept 08								Plan Start date	Plan End date	Act. Start date	Act. End date	Comments
		Project year 1				Project Year 2								
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8					
1.4.2	Perform mech. tests									5/28/07	6/29/07	7/17/07	8/29/07	Use exist. pipe
1.4.3	Complete Industry interviews									1/05/07	7/30/07	4/12/07	10/15/07	
1.4.5	Select prototype pipe size									8/15/07	8/30/07			
2.2	Mfg. prototype IDP									2/01/08	6/30/08			
2.4	Prototype field test									7/15/08	8/15/08			
2.6	Test thermal and hydraulic properties									4/30/08	6/30/08			

As discussed in the “Results and Conclusions” section above, the major deviations from planned milestones have been caused by the difficulty in acquiring drill pipe for development of the inspection plan, and in finding a machine shop to modify it.

Appendix A: Scope of Work for Development of an Inspection Procedure

Phase I -- Phase I of the project will involve the following items:

1. Development of a testing protocol to determine the response of the insulated drill pipe to standard inspection methods:

   a. The program will test the effectiveness of the following inspection methods:
      - Full Length Ultrasonic Testing (FLUT)
      - Ultrasonic Wall Thickness Inspection
      - Ultrasonic Slip/Upset Inspection
      - Electromagnetic Inspection (EMI)

   b. Each inspection method's level of effectiveness will be analyzed based on comparison of the test results for the same set of drill pipe test joints with and without the insulation installed.

   c. The number of test joints will be chosen by consultation between TH Hill Associates and Drill Cool Systems.

   d. Standardized flaws (notches, radial holes, etc.) will be specified for each inspection method. Such flaws will be machined into a reference standard joint, which will be used to standardize each inspection process.

   e. The protocol will outline the standardization and inspection processes as well as the methodology for data collection and documentation.

2. Implementation of the experimental inspection program:

   a. The drill pipe test joints will be obtained, and the standardized flaws will be machined into the reference standard joint. The machined flaws will be accurately measured to ensure proper dimensions and orientations.

   b. The experimental inspections will be performed and completely monitored. The inspections will be performed at a testing facility in Houston.

   c. Data generated during standardization and inspection will be collected and recorded.

3. A report will be prepared that outlines the details and results of the experimental inspection program.

Phase II -- Phase II of the project will involve the following items:

1. Analysis of data generated in Phase I:

   a. The data collected in Phase I will be analyzed to study the drill pipe response (with and without insulation) to the standard inspection methods.

   b. Using the inspection results for the test joints without insulation as the standard, the accuracy and effectiveness of each inspection method on the insulated drill pipe will be analyzed and documented.

2. Development of the inspection program and acceptance criteria for insulated drill pipe:

   a. This process will be based on the conclusions of the Phase I analysis.

   b. The program will be designed to address inspection considerations that are specifically related to insulated drill pipe.

   c. The recommended inspection program and acceptance criteria will be presented in a final report with the supporting data and conclusions from Phase I.

Appendix B – Inspection Plan

Summary:

In support of the Inspection Requirements of the Insulated Drill Pipe (IDP) the follow summary describes operations that the each of the six pieces of drill pipe will undergo through this phase of testing.

It has been decided that six (6) pieces of pipe will be used during the Investigation of Inspection Requirements for Insulated Drill Pipe as described below:

Sample #1

6-5/8 S-135 27.7# with 5-1/2FH Connections (approx length: 32.0ft)

Sample #2

6-5/8 S-135 27.7# with 5-1/2FH Connections (approx length: 32.0ft)

Sample #3 (S/N NN97469)

5" G-105 19.5# with NC50 Connections (approx length: 31.5ft)

Sample #4 (S/N NN97454)

5" G-105 19.5# with NC50 Connections (approx length: 31.5ft)

Sample #5 (S/N K8261)

3-1/2 X-95 13.3# with NC38 Connections (approx length: 31.0ft)

Sample #6 (S/N K8252)

3-1/2 X-95 13.3# with NC38 Connections (approx length: 31.0ft)

Description of Basic Work Flow for Inspection Testing:

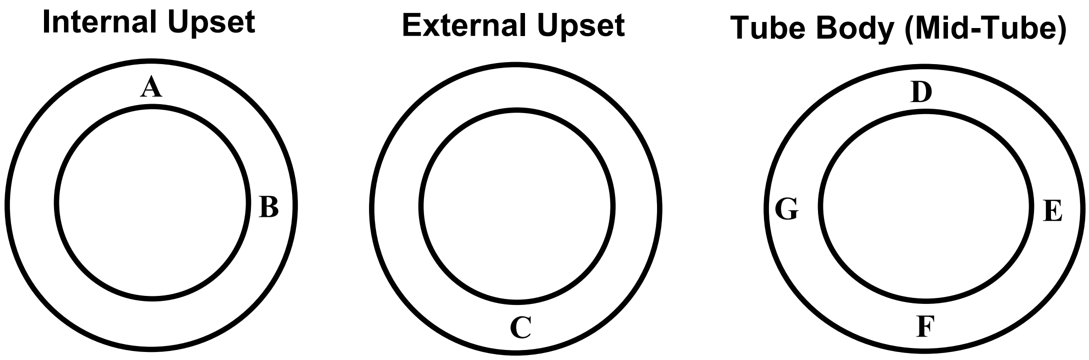
All samples will undergo a total of three inspections. The general flow of this work is as follows:

Step#1: Baseline Inspection

This will be completed to fully characterize each piece of drill pipe in its current state prior to any work being completed. This is done to verify the condition of the pipe and ensure the accuracy of the results.

Each piece of pipe will be oriented radially prior to inspection as to ensure repeatability in inspection and aid in comparing the inspection results. The 0 degree (12 o'clock) position will be positions at the top, vertical point of the pipe. This point corresponds to the point of thread termination (near the shoulder) on the pin of each sample. Prior to inspection a 0 degree line will be scribed into the tool joint (pin end of each sample).

Step #2: Machining of Notch Geometry and IDP Parent Pipe Modifications
Each sample of drill pipe will be machined with a careful selection of notches based on THHA's DS-1 Category 5 inspection methods. To minimize machining costs each sample of IDP will receive a custom selection of notches per the following:



General Description of Notches

Type A – 2 Transverse, 5% of wall Thickness (W.T.) from OD & ID, ½" Length
Type B – 2 Oblique at 6° left hand transverse, 5% of W.T. from OD & ID, ½" Length
Type C – 1 Transverse 5% W.T. form OD (External Upset)
Type D – 2 Transverse, 5% of W.T. form OD & ID, ½" Length
Type E – 2 Longitudinal, 5% of W.T. from OD & ID, ½" Length
Type F – 2 Oblique at 6° left hand transverse, 5% of W.T. from OD & ID, ½" Length
Type G – 1 Wall Reduction 5% of W.T. on ID

DS-1 Required Notch Dimensions

Length: 0.5" max
Width: 0.040" max
Depth: 5% of nominal wall ±0.004"

The following Chart indicates the notches to be included on each sample of IDP involved in this test.

	Type A	Type B	Type C	Type D	Type D	Type E	Type F	Type G
Sample #1 (6-5/8)	X	X	X	X	X	X	X	X
Sample #2 (6-5/8)	X			X				X
Sample #3 (5) (S/N NN97469)	X			X	X	X	X	X
Sample #4 (5) (S/N NN97454)	X			X				X
Sample #5 (3-1/2) (S/N K8261)	X	X	X	X				X
Sample #6 (3-1/2) (S/N K8252)	X			X				X

It should also be noted that any machining required to convert the Drill Pipe Samples into IDP will be completed during this step. Additionally the fill ports required for IDP will oriented at the 0 degree position described previously.

Step #3: Pre-Fabrication Inspection

Each sample will undergo an additional baseline inspection that will now capture and verify the modifications created in Step #2. The Notch Geometries will also be verified and documented by the inspection company.

Step #4: IDP Fabrication

The drill pipe samples will now under the process to fully convert them to insulated drill pipe (IDP). This includes the installation of the liner, termination sleeve, and insulation material. During fabrication certain manufacturing errors will be built into some of the samples as indicated below:

Sample #1: Standard Assembly
Sample #2: Standard Assembly
Sample #3: Standard Assembly with biased liner at Mid Tube
Sample #4: Standard Assembly
Sample #5: Standard Assembly with incomplete insulation fill
Sample #6: Standard Assembly with liner failure and biased liner at Mid Tube

Step #5: IDP Inspection

This final inspection will allow the operator to confirm detection of the machined geometries determined in Steps 2&3 but also investigate the possible detection of manufacturing flaws. I may also be desired to produce a full Visonic 3-D image of Sample #1 to aid in the presentation of the results.

Step #6: Post Inspection Destructive Testing & Inspection

It may be desire to provide a partial section of Samples #3, #5, & #6 to reveal the true characteristics of the manufacturing defects. These sections can then be used to aid in the interpretation of the Inspection Results produced in Step #5.

National Energy Technology Laboratory

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

One West Third Street, Suite 1400
Tulsa, OK 74103-3519

1450 Queen Avenue SW
Albany, OR 97321-2198

2175 University Ave. South
Suite 201
Fairbanks, AK 99709

Visit the NETL website at:
www.netl.doe.gov

Customer Service:
1-800-553-7681