SubSea MudLift Drilling: from JIP to the Classroom

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Abstract

As the worlds proven oil reserves continue to be depleted through consumption by the industrialized nations, oil and gas producing companies must continue to explore for new petroleum deposits. Although there is production in the GOM in water as deep as 5000 feet, some of the most promising deposits may be in water depths in the 6000 to 10,000 foot range. Current drilling technology will not allow exploration in these ultra-deep waters. The SubSea MudLift Drilling Joint Industry Project (SMDJIP) was formed to develop the technology to successfully drill in water depth as great as 10,000 feet.[1]

The outcome of this JIP is a drilling process referred to in the petroleum industry as "SubSea MudLift Drilling" (SMD). SMD is a major step change in offshore oil and gas drilling, and it was realized in the very early stages of the JIP that education and training for everyone involved in SMD would be essential for success of the project. In SMD, a set of fluid pumps are placed on the sea floor to lift the drilling fluid from the wellbore annulus to the surface via a return line, reducing the pressure exerted on the wellbore by the drilling fluid from the sea floor to the surface. The placement of the pumps on the sea floor simulates a dual fluid gradient in the wellbore, where in conventional drilling a single gradient is exerted over the entire interval from the drilling rig (located at the surface) to the bottom of the well. (Fig. 1)

The history of the SMDJIP and how industry and academia teamed up to develop the equipment and procedures necessary to drill in these ultra deep waters, as well as the educational and training program that was developed to transfer this new technology to the petroleum industry is discussed.

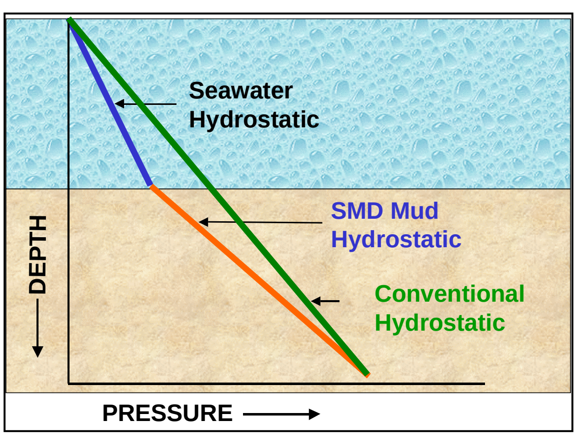


Figure 1. Dual Gradient Principle.

I. Introduction

In conventional floating drilling operations that are conducted in offshore oil fields from drillships and semi-submersible drilling rigs, the Blowout Preventer stack (BOP) is positioned on the ocean floor, and connected to the drilling vessel by a marine riser. The circulation path for the drilling fluid (mud) starts in the mud pits located on the drilling vessel, through the

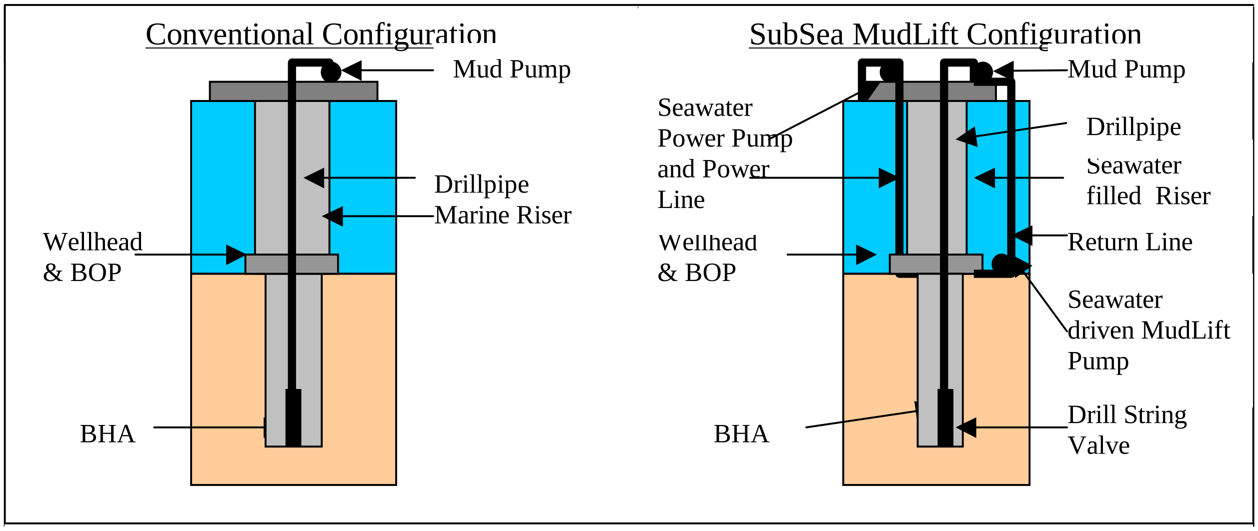


Figure 2. Riser configuration for conventional and SMD systems

surface mud pumps, down the drillstring through the bit, up the annulus to the seafloor, up the marine riser back to the mud cleaning equipment for re-circulation down the wellbore. (Fig. 2a)

The density of the drilling mud is generally increased with depth so that the hydrostatic pressure of the mud is at least equal to the pressure contained within the formations that are being drilled through. This is done to prevent "kicks" and "blowouts." Care also must be taken so that the increasing hydrostatic pressure of the drilling fluid does not exceed the fracture pressure of the shallow lower pressured formations that have already been penetrated. When the hydrostatic pressure of the drilling fluid approaches the fracture pressure of the shallow open zones, drilling is stopped the drillstring pulled from the wellbore, and casing is run to bottom and cemented in place.

Casing is used to isolate shallow weak zones, problem zones and hydrocarbon bearing zones. Every time a new string of casing is run, drilling is resumed with a smaller drill bit. At some point the well runs out of usable hole size - either too small to continue drilling, or economic production rates may not be achievable.

The move to deeper and deeper water results in increased difficulty in drilling.[2] Deeper water requires longer marine risers. This in turn will require more storage space on the drilling vessel during rig moves, and larger deck loads both during rig moves, running of the riser, and during drilling operations. These long risers require larger volumes of drilling fluid just to fill the riser, resulting in an additional increase in deck load. But the major problem associated with ultra-deepwater drilling is the difficulty of reaching the geologic objective with a usable hole size.

In ultra-deep waters, the geologic objectives tend to be deeper below the mudline, which results in additional casing strings that would be required to reach total depth. Not only are the targets deeper, but the window between pore pressure and fracture pressure becomes narrow - resulting in shorter drilling sections between casing strings. Historically, the solution to the increased number of casing strings has been to increase the initial hole size, until we now utilize marine risers with a

19 1/2" inside diameter and a bore on the BOP stack of 18 3/4". Water depths greater than 5000' to 6000' this solution is no longer practical.

II. What is SMD?

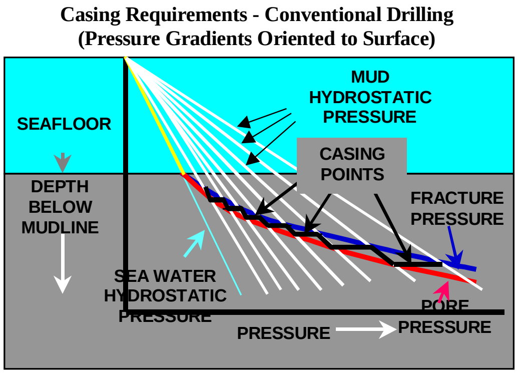
SubSea MudLift Drilling (SMD) is a process that is being developed and has been tested to manage the problems associated with ultra-deepwater drilling. It differs from conventional floating drilling operations in a number of ways. SMD still utilizes a conventional subsea BOP stack and a seawater filled marine riser. A diverter is installed between the top of the BOP stack and the bottom of the riser and seals around the drillstring to divert the circulation path of the drilling fluid from the annulus at the seafloor to a set of MudLift pumps that are installed on the seafloor. MudLift pumps then pump the drilling fluid and cuttings back to the surface through a separate return line. The seafloor diverter also isolates the seawater in the marine riser from the mud in the wellbore. (Fig. 2b)

The MudLift pump can be operated manually, or automatically either to maintain a constant volumetric rate or constant inlet pressure. The standard operating procedure will be to set the MudLift pumps at a constant inlet pressure near that exerted by the column of seawater.

It is the placement of the MudLift pumps on the seafloor that will allow the petroleum industry to successfully drill for oil and natural gas in water depths as great as 10,000'.[3] In conventional drilling operations, there is a single pressure gradient imposed on the entire wellbore from the drilling vessel to the bottom of the hole. In SMD, the actual drilling fluid density will be greater than conventional operations. However, the MudLift pumps location on the seafloor (operating at a constant inlet pressure near seawater hydrostatic pressure) will allow equal pressure at the bottom of the hole as conventional operations, but the pressure exerted at shallower depths will be less, allowing longer drilling intervals between casing strings. (Fig. 1) Longer drilling intervals leads to fewer casing strings required, and a larger wellbore at total depth. The operators can now install large diameter production tubing, which will allow high flow rates making the ultra-deepwater wells economic.

A simple graphical procedure can be used pick casing setting points in the planning stage as explained below.[3] (Fig. 3)

1. Pore pressure and fracture pressure are plotted on the horizontal axis vs. well depth on the vertical axis.
2. For conventional drilling operations a straight line is drawn from the maximum pore pressure at total depth to zero pressure at the surface on the depth axis. This line represents the pressure gradient exerted by the drilling fluid in the wellbore. The intersection of the mud gradient with the fracture gradient is the depth where casing must be set in order to reach total depth.
3. Next a similar line is drawn from the pore pressure at the casing point determined in step 2 to zero pressure at the surface.



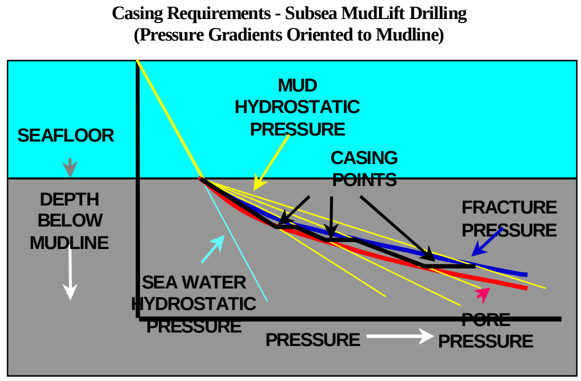


Figure 3. Casing seat selection for conventional and dual gradient drilling.

4. The intersection with the fracture gradient curve is another casing point
5. The process is repeated to the surface.

For SMD operations, a similar process is used. The difference being is that the mud gradient line is drawn from the pore pressure at total depth to the seawater hydrostatic pressure at the seafloor. As can be seen from Fig. 3, SMD will allow the geological objective to be reached with fewer casing strings than conventional drilling.

Although, SMD is being developed to solve many of the problems associated with ultra-deepwater drilling, there are challenges which must be met for the system to be successful:

- There are no commercially available pumps that are designed to operate 10,000' below sea level.
- The standard procedure of operating the MudLift pumps at a constant inlet pressure near seawater hydrostatic will result in an un-balanced u-tube. (Fig. 4) The hydrostatic pressure in the drillstring is greater than the sum of the annular hydrostatic pressure plus the MudLift pump inlet pressure. As long as circulation continues, and the MudLift pump is operating properly, this should not pose too great a threat to fracturing the shallow formations. However, if the MudLift pump is shut down along with the surface rig pump, the entire hydrostatic pressure inside the drillstring will be imposed downhole and will most likely induce formation fracture - one of the major problems with ultra-deepwater drilling that SMD is designed to minimize.

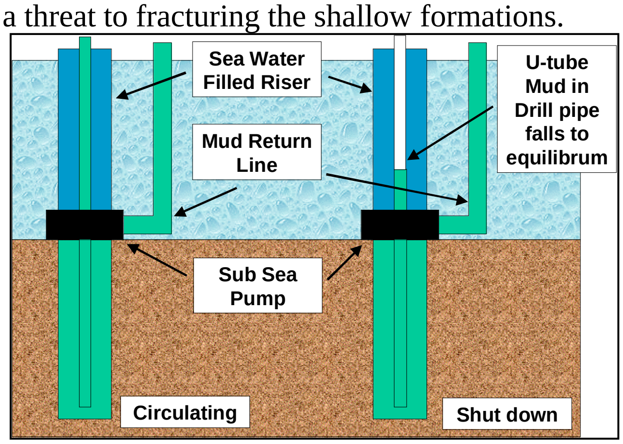


Figure 4. U-tube in SMD.

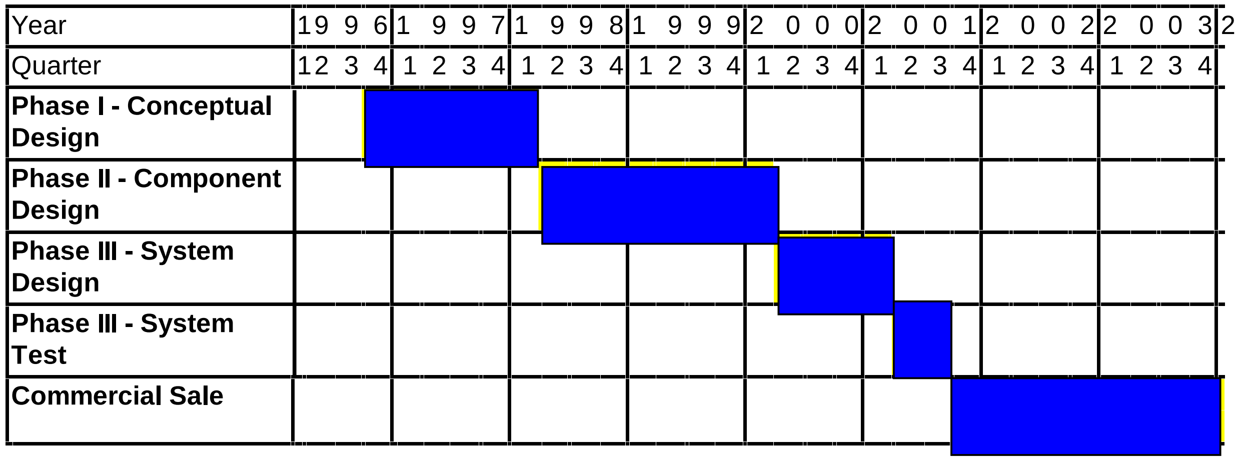


Figure 5. SMDJIP time schedule

- The un-balanced u-tube was probably one of the greatest concerns of the drilling operations and well control operations teams.[4] The equipment designers were asked to design a mechanical valve that would open when the rig pumps were turned on, and close when shut down. The valve was to be designed to support the entire column of mud in the drillstring to prevent an un-wanted u-tube.
- Because even with a mechanical device designed to manage the u-tube, there are times when the device could malfunction or not be in the drillstring, all procedures had to be developed and written so that the rig crew could properly manage the u-tube by other means.
- Crew training is as great a concern to the SMD team as managing the u-tube. In conventional drilling operations, rig crews are trained and drilled to react to certain warning signals so often, that the reactions almost become conditioned responses. One of these responses is to immediately stop circulation and close the BOP's whenever there is any doubt as to what is occurring downhole. In many instances, in SMD, this is exactly the wrong thing to do. Rig crews must be re-trained to operate the SMD equipment and to react properly to the well monitoring equipment.
- Not only the rig crews need to be re-trained, but the engineering and design personnel must be re-educated to thoroughly understand the SMD equipment and the dual-mud density concept.

III. History of the SubSea MudLift Drilling Joint Industry Project, SMD JIP

There have been three phases to the SubSea MudLift Drilling Joint Industry Project. (Fig. 5) Phase I was the conceptual design phase.[5] There were 22 participants in the first phase of the project which at the time was called the "Riserless Drilling JIP". The participants spent a total of $1,050,000 during Phase I on the various engineering studies. The deliverables of this portion of the JIP were:

- Verify the need for the components based upon deepwater fracture gradients, pore pressure, and water depth.
- Agree to a basis of design, including hole size at total depth, final mud densities, circulation

rates vs. hole size, a Gulf of Mexico environment (this was deemed the most difficult deepwater drilling environment), and well control criteria.
- Return line concepts were to be studied and the most sound would be picked.
- Mud lifting concepts were to be screened.
- Develop the routine drilling and well-control operational plans necessary to implement the process, and to determine if the concept was operationally feasible.
- Create a well control and hydraulics model which would simulate the pressure profiles in the wellbore during circulation and kill operations.

At the end of Phase I it was determined that there were no obvious "show stoppers" either operationally or with respect to equipment design.

Phase II was re-named the "SubSea MudLift Drilling JIP", to more accurately depict the equipment configuration decided on at the end of Phase I and the beginning of Phase II.[6] There were nine participants in Phase II who spent a total of $12,650,000. The purpose of this phase was to design, build and shop test all critical components, and to develop all drilling and well control procedures through the HAZOP stage. The goals of this phase were:

- Design and prove each of the critical system components to be reliable enough for commercial service.
- Prove that the components could be integrated into a system that could be installed on a drilling vessel that the participants would likely use.
- Develop all drilling procedures and peer-review them with members of the other project teams (well control, equipment design, training, and testing). The procedures were to be developed to a point where they could be put into training modules.
- Develop all well control procedure to the same level as the drilling procedures.
- Continue to develop the well control and hydraulic simulator, and use it to validate all well control procedures where possible.

These goals were met on time and within budget.

Phase III has 8 participants who have agreed to a budget of $32,069,000.[7] The main objectives of Phase III are to complete the design of the equipment, build the equipment, train all personnel, and drill a test well. The goals of Phase III are:

- Complete the design of all SMD equipment, and build prototypes.
- Conduct a Factory Acceptance Test, FAT, on all SMD equipment.
- Develop all the drilling and well control procedures into a complete training program to be presented to three groups - project management members and representatives of the U.S. Minerals Management Service, rig managers and engineers, and finally the rig crew.
- Decide on which drilling and well control procedures will need to be tested during the test well.
- Determine the location to drill the test well in approximately 1500' of water, and design the well program.

- Develop a drilling program which will allow full testing of all prototype SMD equipment, drilling procedures, and well control procedures.
- Install the prototype on a chosen drilling vessel
- Drill a test well in a chosen location in the Gulf of Mexico. During the drilling of the well all tests will be conducted as spelled out in the drilling program.
- Evaluate the results of the test well, and modify the equipment design, if needed, and modify all procedures as deemed necessary by the results of the test well.

It is the hope of the JIP that after successful completion of the test well, a commercial SMD system will be available to the petroleum industry.

IV. Role of Texas A&M University in the JIP

The Harold Vance Department of Petroleum Engineering has been under contract for the SMD JIP since the very beginning. To date, three faculty members and one Research Engineer have worked on the project in one way or another. In addition, three Ph.D. and seven M.S. students have either earned their degree on this project or their work is in progress.

In Phase I of the project, the University was contacted to see if a conventional well control simulator developed by the Research Engineer (as part of his Ph.D. work) could be modified to simulate what was then referred to as the "Riserless Drilling" concept. The modified simulator was used to study the hydraulics of the system, which was in turn used to determine horsepower and circulation rate requirements of the rig mud pumps and the sea floor pump.[8] The simulator was also used to predict natural gas influx rates on well kicks, as well as the surface gas elusion rates that could be expected from these kicks. From this information, it could be determined if the surface gas handling equipment on the drilling vessel would be sufficient to handle possible gas kicks.

In Phase II, the simulator underwent additional upgrading and was used extensively to model wellbore hydraulics, multiple kick scenarios, the adequacy of conventional casing seat selection, wellbore pressures during normal drilling and circulation operation, and wellbore pressures during kick circulation.[9,10,11,12] It was used to determine expected gas surface rates under various initial influx volumes, formation pressures, well depths, water depths, surface choke pressures, and circulation rates.

The simulator has also been used to study the u-tube phenomenon. U-tube duration and volumes were predicted with varying water depths, well depths, mud rheology, mud density, drillstring sizes, bit nozzle sizes, and initial circulation rates. Finally the simulator has been used to predict the results of many of the drilling and well control procedures that were written for the project.

The effect of the cold water temperatures present in the ultra-deep waters on the rheological properties of the drilling fluid was a concern. One Ph.D. student developed a model to predict the wellbore temperature profile that could be expected when circulating a relatively warm drilling fluid down the drillstring, up the annulus, and back to the surface.[13] One of the M.S. students continued this work.[10] Temperature profiles for the seawater column, and the sub-mudline formations could be varied. The effect of these temperature profiles on the temperature of the drilling fluid could then be predicted. One M.S. student studied the effect of cold temperatures on the rheological properties of Synthetic Based Drilling fluid.[14] Both of these studies were then used to help in calculating expected circulating pressures for the equipment designers.

The author's major contribution to the project was in the development of Well Control (blowout prevention) Procedures.[2] One of the Doctoral degrees was earned for this work. This portion of the project consisted of a detailed study of the deepwater well control procedures currently utilized. From this study, it was determined which procedures would need to be modified, completely re-developed, or left alone. The next step was to make the modifications, based upon the conceptual design from Phase I. A proposed well control training program including course outline was also developed.

Finally, the University has played a key role in the development of the SMD training program. Two of the faculty members (the author included) have played roles in the development of both the SMD Basic Technology and the SMD Well Control courses. They have also been the instructors in the SMD Basic Technology course. The author has also been one of the instructors in the SMD Well Control Course.

V. Procedure Development

At the beginning of the project, a Project Manager/Administrator, and a Project Design Manager were named from one of the member operating companies and the equipment design company. To oversee the work of the project and to approve the Basis of Design, a Project Advisory Group (PAG) was also named from employees of each of the member companies. The engineering work was performed by teams consisting of experienced engineers from each of the various companies involved, as well as contract personnel from consulting firms and Texas A&M University. The teams that were formed were Equipment Design Team, Drilling Riser Design Team, Drilling Operations Team, Well Control Team, Test Team, and Training Team. The extensive cooperation between the different teams, and the joint membership of some of the team members has been a major factor in the project progressing on time and within budget. Representatives of each of the different teams were usually present at the individual team meetings.

Writing the Drilling Operations and Well Control procedures turned out to be a grueling process. The "first draft" of the well control procedures was the author's dissertation.[2] The dissertation was written based upon the Phase I conceptual design. During Phase II many changes had to be made to the procedures as the equipment design and testing proceeded. Not only were the procedures modified to reflect the latest in equipment design, the equipment designs were modified to allow the equipment to be utilized as the drilling operations and well control teams deemed necessary for safe and efficient operations.

HAZOP
RISK ASSESSMENT

MUDLIFT MODE:
ACTIVITY:
REASON(S):
ASSUMPTIONS: PROCEDURES ALREADY HAZOPED NOT REPEATED HERE

Hazard	Consequence	Existing Safeguards	Probability	Initial Risk	Risk Mitigation	Changed Procedure		
						C	P	R

Figure 6. HAZOP form used by the SMDJIP.

The first draft well control procedures were divided up among the members of the Well Control Team (two of the members were faculty members at Texas A&M) to be fleshed out and updated to be consistant with the drilling operations, and equipment design teams work. Many of the relatively short and simple procedures were combined into more thorough and complicated procedures.

After sufficient time elapsed for the well control procedures to be re-written, a meeting schedule was agreed upon by the team members for HAZOP and peer review of each procedure. The team met approximately every two weeks for a formal HAZOP and Peer Review of the scheduled procedure. All Well Control team members were present for these HAZOP meetings as well as members of the PAG, Drilling Operations team, Equipment Design team, Test team, and Training team. The author of the particular procedure to be HAZOP'ed served as moderator and facilitator. A technical writer was present at all meetings and HAZOP's to record most of what was discussed. The technical writer's skill and knowledge of the project has been invaluable to the project.

Prior to each meeting, all expected attendees were supplied with copies of the procedure to be HAZOP'ed so that they would be able to intelligently discuss the procedure. During the HAZOP meetings, the author of the designated procedure presented the procedure via a PowerPoint presentation. Each step was discussed critically, by all in attendance. The Moderator/Facilitator's job, in addition to presenting the procedure, was to keep the meeting on track, so that the engineers did not try to fix any problems that were identified. This is vital to the HAZOP process so that it can be completed in a reasonable time.

(Risk = Consequence X Probability)

RISK MATRIX		*PROBABILITY*		
		LOW	**MEDIUM**	**HIGH**
CONSEQUENCE	**HIGH**	**H X L = M**	**H X M = M**	**H X H = H**
	MEDIU	**M X L = L**	**M X M = M**	**M X H = M**
	LOW	**L X L = L**	**L X M = L**	**L X H = L**

Figure 7. Risk assessment matrix used in the HAZOP process.

After the procedure was presented, the Technical Writer projected a blank HAZOP form from her computer to the projector screen. (Fig. 6) The HAZOP process consists of identifying any potential problems with the procedure in question. The team looked at each step of the procedure critically. After a potential problem was identified, the probability of the problem occurring was agreed upon, and the consequence was estimated. The product of the probability and the consequence is risk. A risk matrix (Fig. 7) was used to determine whether the risk was low, medium or high. If the risk was low, or if the risk was medium, and was deemed no greater than in current conventional drilling operation no mitigation was needed. However if a medium risk was deemed to be higher than conventional drilling operations, and all high risks had to be mitigated to where the risk would be lowered to a low medium or low risk. The mitigation was done outside the meeting. From the results of the HAZOP meeting the author of the procedure again modified his procedure to reflect the needed changes that were identified in the HAZOP meeting. The latest version of the procedure in addition to the completed HAZOP form and the minutes of the meeting were then distributed to all the attendees for further review and comments.

The drilling operations group underwent the same HAZOP and Peer Review process as the Well Control group. At the end of Phase II, all of the drilling and well control procedures were again reviewed for completeness and compatibility with the work of all the other team, and a confidential final report was issued.

VI. Training Program

The basis of the training program that was developed in Phase III was the final versions of all of the drilling and well control procedures, as well as the current equipment design. In Phase III, a test rig and well selected, and equipment and piping schematics were completed. These schematics were also used in development of the training program.

Table 1. Breakdown of participants in training program.

Course	Module	Instructors	Tech Writer	Students	Auditors	Total
1	Basic Tech	2	1	17	5	25
1	Drilling	2	1	16	3	22
1	Well Control	3	1	16	3	23
2	Basic Tech	2	0	14	1	17
2	Drilling	2	0	14	1	17
2	Well Control	3	1	14	2	20

The training program is broken into three modules – SMD Basic Technology, SMD Drilling Operations, and SMD Well Control - to be taken in succession. The three module course was held two times for two different groups of students. A second course was developed for the rig crews (non engineers) and was not taught by Texas A&M University faculty members.

All of the courses were attended by instructors, students, auditing participants, and a Technical Writer. (Table 1) Texas A&M University provided the instructors for the Basic Technology module; the instructors for the Drilling Operations Module consisted of two members of the Drilling Operations Team; and the instructors for the Well Control module were members of the Well Control Team (one of which is a faculty member at Texas A&M). The Technical Writer recorded any errors found in any of the presentations, as well as any questions and comments from the class as to improvements or clarifications that could be made to the course. The auditing participants were instructors from the drilling operations and well control course, as well as other team members. These individuals helped a great deal in answering questions and in the discussions that occurred in the class, and made the instruction much more clear for the students.

The first group of students consisted of members of the PAG, designees of the PAG members, and employees of the U.S. Minerals Management Service (MMS). This session served as a “dress rehearsal” for the next session, as well as an opportunity for interested parties from the member companies to learn the status of the project. The MMS representatives were present since the test well and many, irf not most additional wells that will be drill utilizing this technology, will be located in the U.S. Gulf of Mexico. The MMS has regulatory authority in all oil, gas, and sulfur operations in the U.S. Outer Continental Shelf, and approval of all drilling activity in the U.S. Gulf of Mexico comes through them. They have also been kept abreast of all the work that has been done in the project since the beginning. These representatives attended the course to gain an understanding of the process, and to gain confidence that the project is feasible and as safe or safer than conventional floating drilling operations.

The second group of students to attend the training program were the engineering staff, and managers of the operating company and drilling contractor that were designated to drill the test well. These were the designers and supervisors from the two companies that will be intimately involved with drilling the test well.

Table 2. SMD course outline.

SMD Basic technology	SMD Drilling Operations
Day 1 Lesson 1 - Introduction to SMD Lesson 2 - Key Success Factors in SMD Lesson 3 - Wellbore Pressures Day 2 Lesson 4 - U-Tubing Concepts Lesson 5 - Drillstring Valve Lesson 6 - Gas Kick Behavior Lesson 7 - Pressure Drop Calculations Day 3 Lesson 8 - Simulator Practice Lesson 9 - SMD Toolkit Lesson 10 - Review and Wrap-up	Day 1 Lesson 1 - SMD System Overview Lesson 2 - Depth vs. Pressure Lesson 3 - System Response Day 2 Lesson 4 - Start/Stop Circulation Lesson 5 - Drilling Ahead Day 3 Lesson 6 - Unplanned Shutdown Lesson 7 - Tripping Day 4 Lesson 8 - Tripping Out of Hole Lesson 9 - Running and Cementing Casing Lesson 10 - Balanced Cement Plug

SMD Well Control Day 1 Lesson 1 - Introduction to SMD Well Control Lesson 2 - Equipment and Controls Lesson 3 - Basic Calculations Lesson 4 - Causes of Kicks Day 2 and 3 Lesson 5 - Pre-Kick Information Lesson 6, 7, 8 - Basic Well Control Lesson 9 - Simulator Exercises	Day 4 Lesson 10 - Testing Lesson 11 - Volumetric Well Control Lesson 12 - Lubrication Lesson 13 - Stripping Operations Day 5 Lesson 14 - Trapped Pressure Lesson 15 - Bullheading Lesson 16 - Casing Well Control Lesson 17 - Dynamic Kill Lesson 18 - Emergency Response

Discussion and feedback were requested and encouraged from the first two groups attending the first course and was recorded by the Technical Writer. This information was analyzed by the instructors for improvements to subsequent courses, and in paring down the training program to the level required for the rig crew. After the first two classes were held, meetings were also held with representatives of the operator and drilling contractor as to the topics that should be covered for the rig crew. It was determined that the rig crew did not need to be “educated” in the engineering and theoretical aspects of the system, only trained in the step by step procedures. Most of the engineering type of calculations and theoretical aspects of the program were left out for the rig crew.

For the first two groups, the SMD Basic Technology consisted of ten lessons over a three day period.[15] (Table 2) This module attempted to educate the students on the theory behind the system. The instructors tried to get the students to start to think in the same mindset as the engineers that had been working on the project. The idea was to get the students to gain an understanding of the "dual gradient” that is present, as well as the u-tube that is at least potentially there. The Drilling Operations module was first designed for a five day course held at one of the member company's training facility.[18] During the course of the program, it became obvious to the instructors and students alike, that four days was all that would be required to fully cover ten lessons contained within the module. This module was not intended to be an all inclusive "drilling practices" course. Only the operations that are significantly affected by the SMD concept were covered. It is assumed that all students would be experienced Drilling Engineers and were not in need of basic drilling practices.

The Well Control module consisted of 18 lessons covered in a 5 day period.[19] Again it was assumed that the students are experienced Drilling Engineers and have experience in conventional well control operations. Even though well control is actually a small part of drilling operations, an extraordinary amount of time is spent on well control education and training. The risk and possible costs in money, lost or damaged equipment, wasted hydrocarbons, environmental damage, and possible injury of loss of life, make this time well spent. The other factor that contributed to the length of Well Control module is that virtually every aspect of well control is affected by the SMD system. A very detailed training program for well control was required.

VII. Summary

This paper briefly discusses the history of the three phases of SubSea MudLift Drilling Joint Industry Project, and how industry teamed with academia to determine equipment requirements, and to develop drilling and well control procedures for a totally new process for offshore drilling for oil and natural gas in water depths ranging from 6000' to 10,000' - depths currently not attainable. It discussed how the procedures were written, reviewed, and submitted to HAZOP and Peer Review. The paper discussed how these procedures were turned into a training program for individuals involved in drilling a test well utilizing the SMD system. Finally the paper discusses the actual training modules, including the lessons that were covered in each of the courses.

Acknowledgments

Space would not allow acknowledgement of all of the individuals that have made this paper possible, but the author would be remiss if some individuals were not mentioned specifically. First the author would like to thank the Harold Vance Department of Petroleum Engineering at Texas A&M University, and the SubSea MudLift Drilling JIP for their support in this project. Special acknowledgement should go to Dr. Hans C. Juvkam-Wold, Texas A&M University who has contributed enormously in this project, not only in his work, but also in the supervision of all of the graduate students (including the author) who have worked on this project. Others that should be mentioned are: Mr. Ken Smith, Project manager - Conoco; Mr. Charlie Peterman, Project Designer Manager - Hydril; Mr. Allen Gault, Drilling Operations Team Leader - Conoco; Mr. Fikry Botros, Drilling Riser Team Leader, Conoco, Mr. Curtis Weddle, III, Well Control Team Leader, Cherokee Offshore Engineering; Mr. Dana Witt, Training Team Leader - Conoco, Mr. Jerome Eggemeyer, Test Team Leader - Conoco; and finally Mr. Carmon Alexander, Well Control Team Member - Consultant, Dr. Jonggeun Choe, Simulator Developer - Seoul National University, and Ms. Terri Smith – Technical Writer.

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