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Introduction

The presence of hydrates has primarily been a nuisance or a well control issue when drilling for conventional oil and gas offshore and in onshore permafrost regions. However, methane hydrates could very well become the new source of clean and affordable gas supplies in the United States by 2030. For example, if several large “sweet spots” of hydrates could be defined and developed in U.S. waters, the ultimate recoverable hydrate resource could range from 1,500 to 2,000 Tcf of gas. This is close to the current U.S. domestic natural gas recoverable resource, yet it may be less than 1% of the total in-place methane hydrate resources of the U.S.

To achieve the long term goals of the Federal Government in regard to energy supplies for the U.S.A., the Department of Energy is committed to developing the knowledge and technology base to allow commercial production of methane from domestic hydrate deposits by the year 2015.

Hydrates or clathrates are a crystalline lattice material consisting of molecules of water that have formed an open, cage-like solid lattice that encloses

molecules of methane. Hydrates of a given composition exist under particular pressure-temperature conditions caused by geological conditions. The variability of the pressure-temperature phase diagrams for hydrates is caused by changes in geological conditions during hydrate evolution and by the chemical composition of the hydrate, which may have been enriched with ethane. Under changing geological conditions hydrates can dissociate and be released gradually or explosively, depending on how rapidly the pressure drops or the temperature increases. In addition to hydrates being only quasi-stable, the crystal structure of a hydrate packs methane so efficiently, depending on the purity of the hydrate, it can contain between 70 to 164 times the volume of free gas at standard temperature and pressure vs. the volume of the hydrate prior to dissociation.

Methane hydrates contain enormous volumes of natural gas and are now known to accumulate worldwide on the slopes of continental shelves and below the arctic permafrost where pressures and temperatures are suitable and methane and water are available. The existence and thickness of hydrates zones are determined by the influx of gas and water through shallow sediment, the rapid accumulation of organic rich sediments, the geothermal gradient, the water depth and sea-bottom temperature, and the gas mixture of the hydrate. Analysis indicates hydrates can occupy as much as 500 m of sediments.

Because hydrates will dissociate or release free gas upon a decrease of pressure, increase of temperature, or combinations thereof; premature dissociation around the wellbore must be avoided during the drilling process to minimize wellbore instability and well control issues resulting from

changes in the mechanical and physical properties of the sediments when hydrates dissociate. In addition, the hydrates dissociation into gas and fresh water will create a gas cut mud with a lower mud density causing associated changes in mud rheology that reduce hole cleaning capacity, which may cause wellbore instability and potential hole collapse or a pack off and stuck pipe.

There is an enormous amount of information available in the public domain as to the characterization, composition, and the location of known deposits of methane hydrates. However, the know-how to drill, complete, and produce hydrates in commercial quantities is just beginning to be developed and has received little attention from the oil and gas industry.

Although the focus of this paper is upon drilling for methane hydrates in marine environments, specifically in deep water, the issues are applicable to drilling hydrates on land as well.

Methane hydrates drilling-related challenges include:

1. Narrow margins between pore pressure and fracture gradient in ocean surface sediments and within the hydrate reservoir.
2. Surface hole instability.
3. Subsidence caused by hydrate production.
4. Manage temperatures and pressures within the wellbore during drilling to limit hydrate dissociation in the reservoir beyond the wellbore.
5. Avoid pressure fluctuations (e.g., swabbing, surging, and ballooning) on the hydrate reservoir common to conventional drilling methods.
6. At-balance installation of liners, screens, and completions.

These drilling-related challenges indicate a requirement for technologies that provide more precise wellbore pressure management along with well construction and fluids programs that reduce stress to the fragile hydrate reservoir and at-balance completion.

Several relatively new but now proven technologies developed for oil and gas drilling may have unique application to drilling methane hydrates. The authors' primary purpose with this

paper is to initiate a timely debate on the subject—the question is not *if*, but *when* will it become imperative for the industry to succeed in drilling for this vast gas resource safely and with economic viability.

In cases where methane hydrate drilling with conventional tools, well construction, and fluids programs pose formidable barriers, tools and technology developed for Underbalanced Drilling, Managed Pressure Drilling, Drilling with Casing, expandable tubulars, Drill-in-Liners, and perhaps dual-flow drill pipe, as well as slim and insulated marine risers and other emerging technologies may significantly contribute to overcoming many of the hydrate dissociation challenges that occur in the reservoir prior to completing the production wellbore.

Sooner or later, the industry will have to learn how to drill for commercial quantities of methane hydrates. A number of technical papers and research reports have “Framed the debate.” This paper suggests “Let the debate begin.”

Methane Hydrates – Size of the Prize?

Over the past three decades, expeditions into Polar Regions and deep-water continental shelves all over the globe have consistently reported the presence of methane hydrates. The magnitude of this previously unknown global storehouse of methane is truly staggering and has raised serious inquiries into the possibility of using methane hydrates as a source of energy.

In the U.S., for example, about 900 trillion cubic feet of natural gas has been produced to date. An estimated “remaining recoverable with conventional technology” is 1,400 Tcf. The estimated amount of “in place” methane hydrates is 2,000 Tcf.

Methane Hydrates Drilling Initiatives

A consortium consisting of Japan Exploration Company/JNOC/Teikoku Oil has initiated a multi-year program to drill 16 exploratory wells in deep water offshore southeast Japan.

The Mallik joint-industry project of Canada/JNOC/USGS/DOE/ChevronBP/Burlington extrapolated 53,000cf/d from an exploratory well, NW Territories, Mackenzie Delta.

Hot Ice #1, an effort involving the DOE, Anadarko, Maurer Engineering, and Noble Drilling resulted in a methane hydrates “dry hole,” but

proved out other technologies such as low-environmental impact tundra drilling.

In Siberia, methane hydrates are freed from the water-ice lattice by normal pressure depletion and comprise a portion of conventional gas production.

Methane Hydrates Drilling Challenges

Onshore, the challenges include wellbore instability that may be aggravated by conventional drilling practices, fluctuating bottom-hole pressure, risk of hydrate dissociation beyond the wellbore, and narrow margins in shallow, soft, reservoir media.

For offshore, the challenges are the same as on land, but are further aggravated by water depth, temperature, potentially strong currents, and seabed subsidence.

Managed Pressure Drilling

When one considers the drilling-related challenges of methane hydrates drilling and has a grasp of the definition of Managed Pressure Drilling (MPD), it becomes more or less obvious that MPD may have a unique application. The *IADC Underbalanced Operations Committee* defined MPD as the following:

Managed Pressure Drilling is an adaptive drilling process used to precisely control the annular pressure profile throughout the wellbore. The objectives are to ascertain the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly.

Technical Notes:

- ***MPD employs a collection of tools and techniques that may mitigate the risks and costs associated with drilling wells that have narrow downhole environmental limits, by proactively managing the annular hydraulic pressure profile.***
- ***MPD may include control of backpressure, fluid density, fluid rheology, annular fluid level, circulating friction, and hole geometry, or combinations thereof.***
- ***MPD may allow faster corrective action to deal with observed pressure variations. The ability to dynamically control annular pressures facilitates drilling of what might otherwise be economically unattainable prospects.***

- ***MPD techniques may be used to avoid formation influx. Any flow incidental to the operation will be safely contained using an appropriate process.***

Other Technologies to Consider

1. Drilling the Top Hole in Deep Water

In deep water environments, hydrates have been observed between the mudline to around 4500 ft below. A “riserless top hole drilling package,” a method of dual gradient riserless drilling, may be applicable to batch drill and establish subsea locations with wellhead and casing. Such a system incorporates a subsea rotating control device and subsea choke that enables mud returns to be pressurized with pipe rotation. A subsea pump returns annulus fluids to the floating rig via a mud returns riser or flowline. Such a system is a “riserless” closed loop circulation system and offers precise wellbore pressure management in the top hole by:

- Adjusting the surface mud pump rate.
- Applying backpressure to the annulus at the seafloor.
- Adjusting subsea mud return pumping rate.

2. Underbalanced Drilling

Well-proven tools and technology for Underbalanced Drilling (UBD) appear to be key in improving drilling technology for methane hydrates, particularly in the practice of Managed Pressure Drilling (MPD). UBD is applicable to fixed rigs with surface BOP and floating rigs with subsea or surface BOPs. The essence of MPD is drilling with a closed and pressurized mud returns system. Such a system enables the maintenance of a defined bottom-hole pressure at the reservoir. This could be a key element in limiting hydrate dissociation due to pressure reduction. Such a system also permits drilling ahead while circulating out kicks and greatly enhances the ability to drill and make jointed pipe connections with a more constant bottom-hole pressure, while controlling any influx that may be incidental to the operation. Real-time pressure and temperature monitoring and hydraulic flow modeling developed for UBD and MPD could be particularly useful to a hydrates drilling program.

3. Drilling with Casing (DwC)

Synergistic to MPD and UBD is one-trip casing drilling technology that may address the requirement to avoid pulsating the fragile and frozen wellbore unnecessarily. Robust casing could be one-trip set and cemented to a sufficiently deep depth to minimize the risk of seafloor collapse from the thermal, pressure, or chemical quasi-mining process of producing the methane hydrates over time. DwC may also enable drilling with a less expensive floating rig because of reduced weight of casing.

4. Dual-Flow Drill Pipe

Heat transfer from drilling fluid to annulus returns indicates this type of drill string is worth considering. Returns are directed into one-half of the dual-flow drill pipe near the BHA and a specialized swivel maintains separation of drilling fluid and returns at the rig floor.

5. Low Exothermic Cement

Such casing cement may be required to reduce the risk of the exothermic reaction of curing dissociating the near-shoe methane hydrates. However, this may not be an issue if the hydrates can cool and restabilize before production.

6. Slim and Insulated Marine Riser

Deep-sea currents and the need to insulate the riser (especially in temperate waters) indicate slim riser deep-water drilling with a surface BOP may be applicable technology. The increased velocity of returns (compared to a conventional marine riser) will allow the returns chilled by drilling into hydrates less time for heat transfer to warm the returns, thus reducing dissociation within the riser itself. Further, it is believed a 13-3/8 in. marine riser may be less adversely affected by underwater currents. Drilling with a chilled mud system to maintain bottom-hole temperature (BHT) below 11°C should be sufficient to avoid any dissociation of the hydrate and, thus, associated gas in the return riser. Deep-water drilling with a surface BOP will likely require a subsea isolation valve in case of a drive-off incident.

Other tools developed for the practice of UBD and MPD that may be applicable to methane hydrates drilling are:

- Downhole Deployment Valve (within-casing isolation valve for bit trips, avoidance of pipe light).
- Wireline retrievable drill string check valve (movable to be nearer the next jointed pipe connection).
- Nitrogen Production Unit (enables one of several variations of dual-gradient, e.g., gas lift of cuttings).
- Continuous circulation system (maintains circulation during pipe connections)

Conclusion

The authors feel the relatively new and emerging technologies briefly described within this paper may have unique application to hydrate drilling and reservoir evaluation. Whereas, there are a number of unknowns about the technologies suggested to drill hydrates, now is the time for the drilling industry to begin discussions on how to adapt current technology to drill commercial quantities of methane hydrates. If nothing else, the discussion would assist in a more accurate technology gap analysis.

When first exposed to new and perhaps somewhat revolutionary ideas, human nature often causes us to first look for “reasons why it won’t work.” Given the size of the prize, it may be wise to approach methane hydrates drilling by giving equal or more time to “how to make available technology work”.

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