Study on Gas Hydrate Blocking Mechanism and Precaution in Wellbore of Deep Water Drilling

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Outline

- Introduction
- Multiphase flow influence on the hydrate blocking
- Hydrate blocking prediction and prevention during the whole drilling process
- Conclusion

1. Introduction

Gas hydrate will be easily formed under the deepwater drilling condition.

- **High pressure and low temperature around the mud line**
- **Complicated pressure and temperature in the wellbore**

1. Introduction

The formation of gas hydrates during deepwater drilling may have several such adverse effects as:

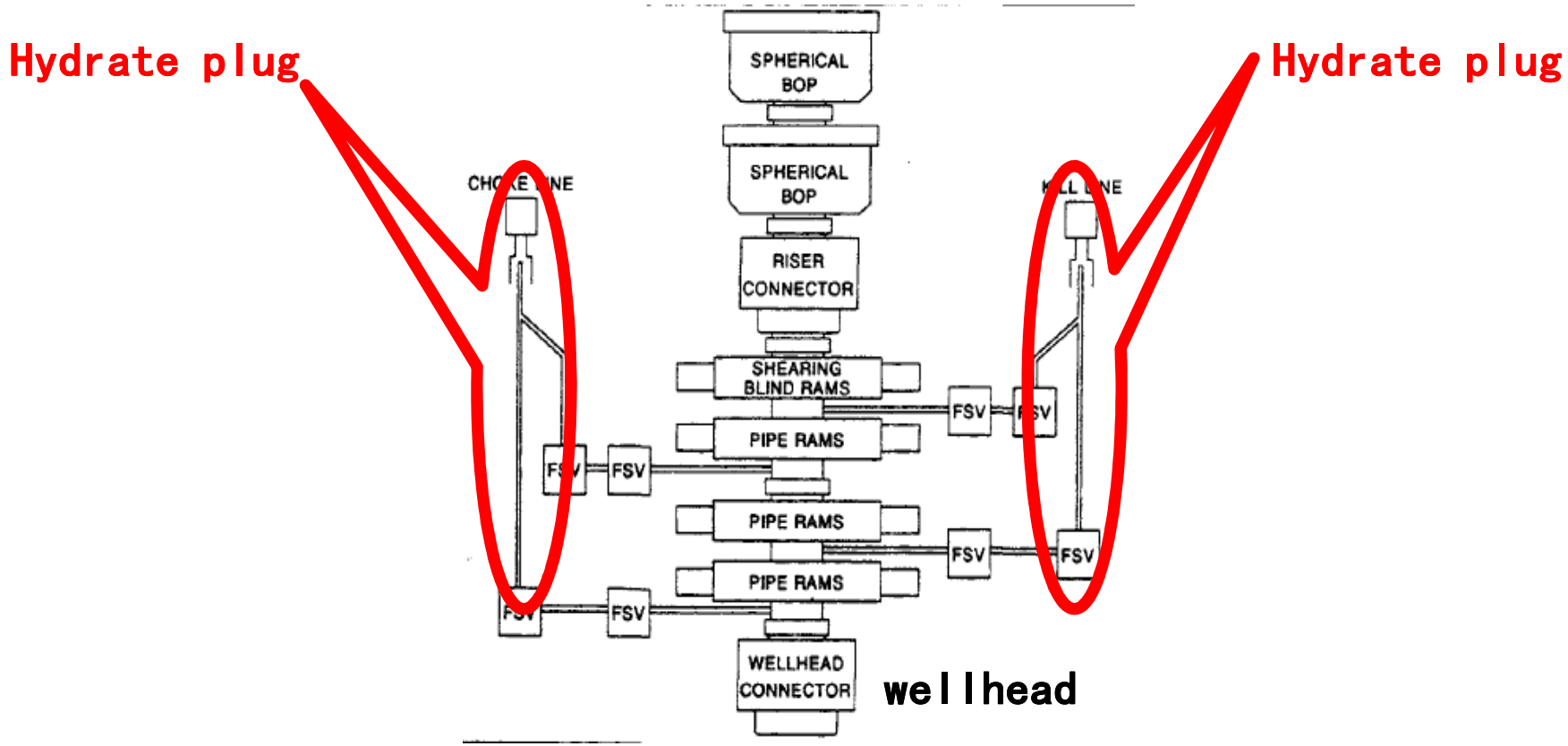
- **Blocking the choke line and well kill line, which prevents their use in well circulation;**
- **Plug formation at or below the BOP's, which prevents well pressure monitoring below the BOP's;**
- **Plug formation around the drillstring in the riser, BOP's, or casing, which prevents drillstring movement;**
- **Plug formation between the drillstring and the BOP's, which prevents full BOP closure;**
- **Plug formation in the ram cavity of a closed BOP, which prevents the BOP from fully opening.**

1. Introduction

(1). seven days after shut-in,plug the chokeline and kill line of the bottom eight riser joints.

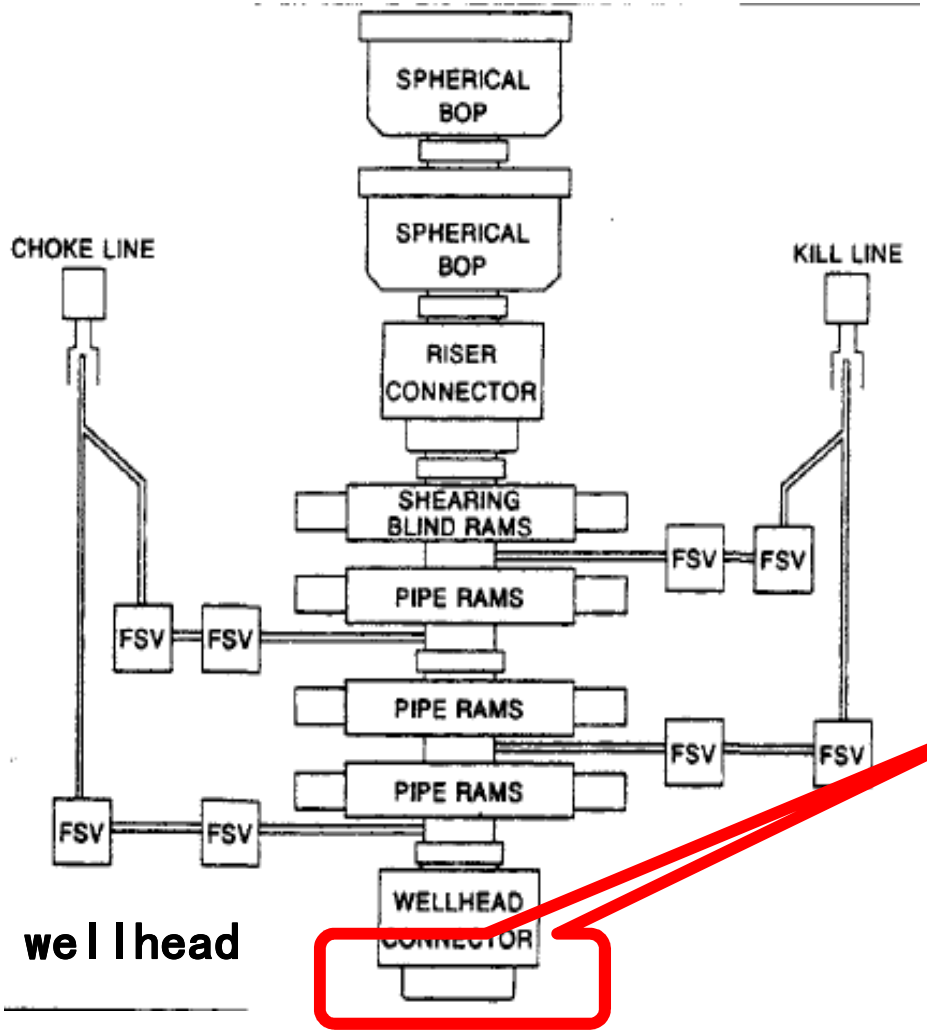
surface pressures： 3,100 psi （21.4 Mpa），

mudline temperature：40° F （4℃）.



1. Introduction

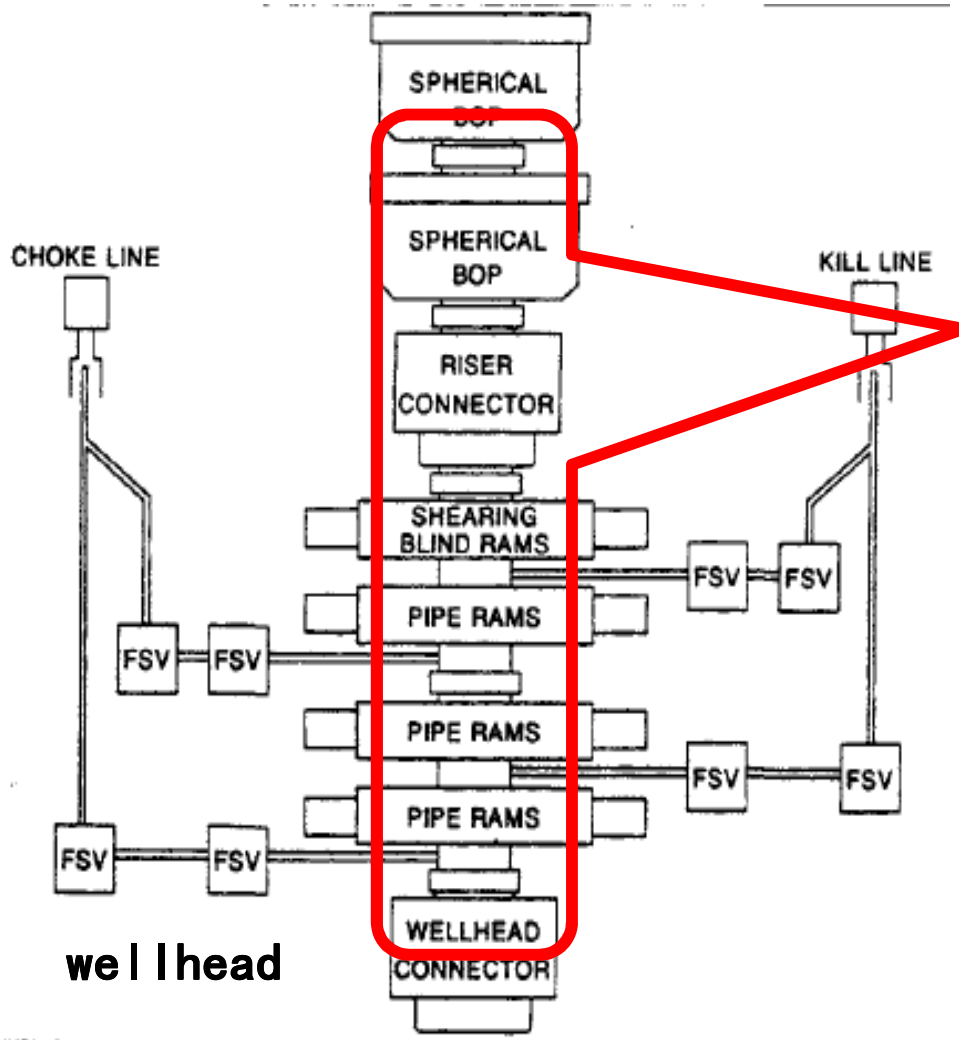
(2). plug formation at or below the BOP's

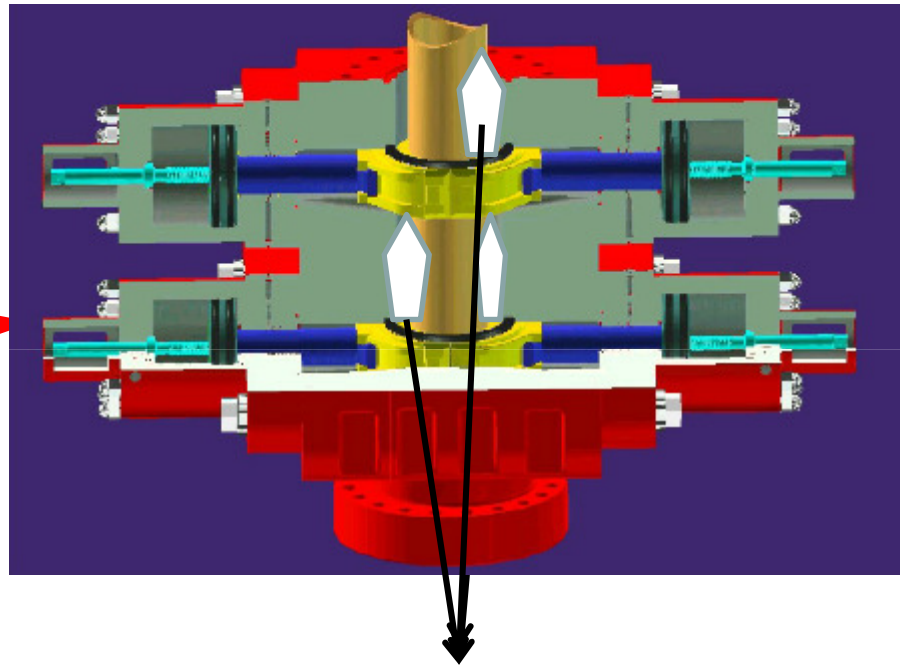




1. Introduction

(3). plug formation around the drill string in the riser, BOP's, or casing



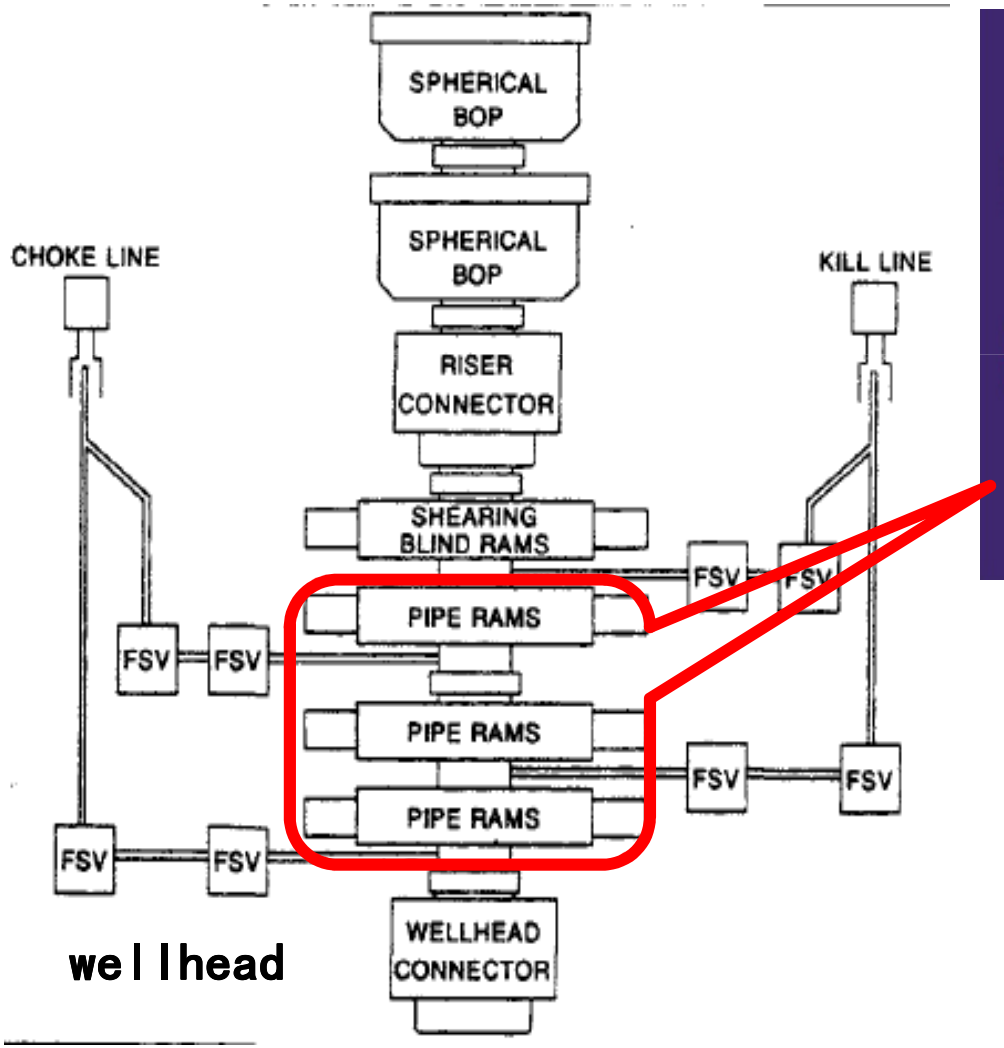


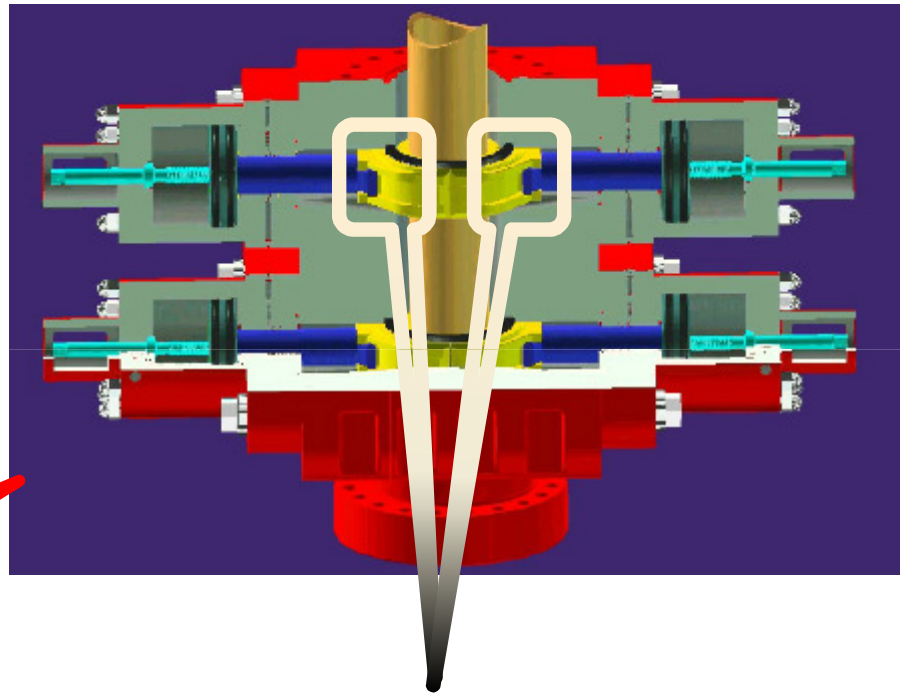
Hydrate plug

Prevents drillstring movement

1. Introduction

(4). plug formation between the drillstring and the BOP's



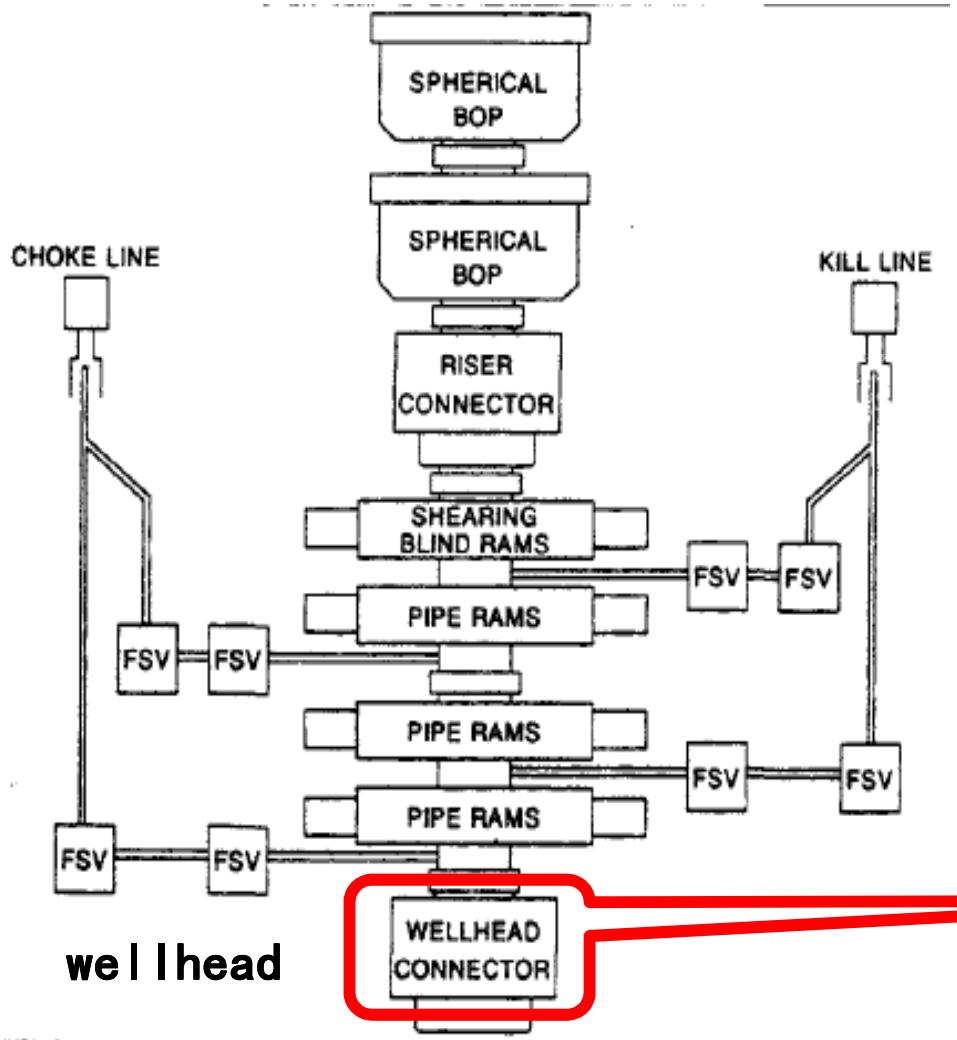


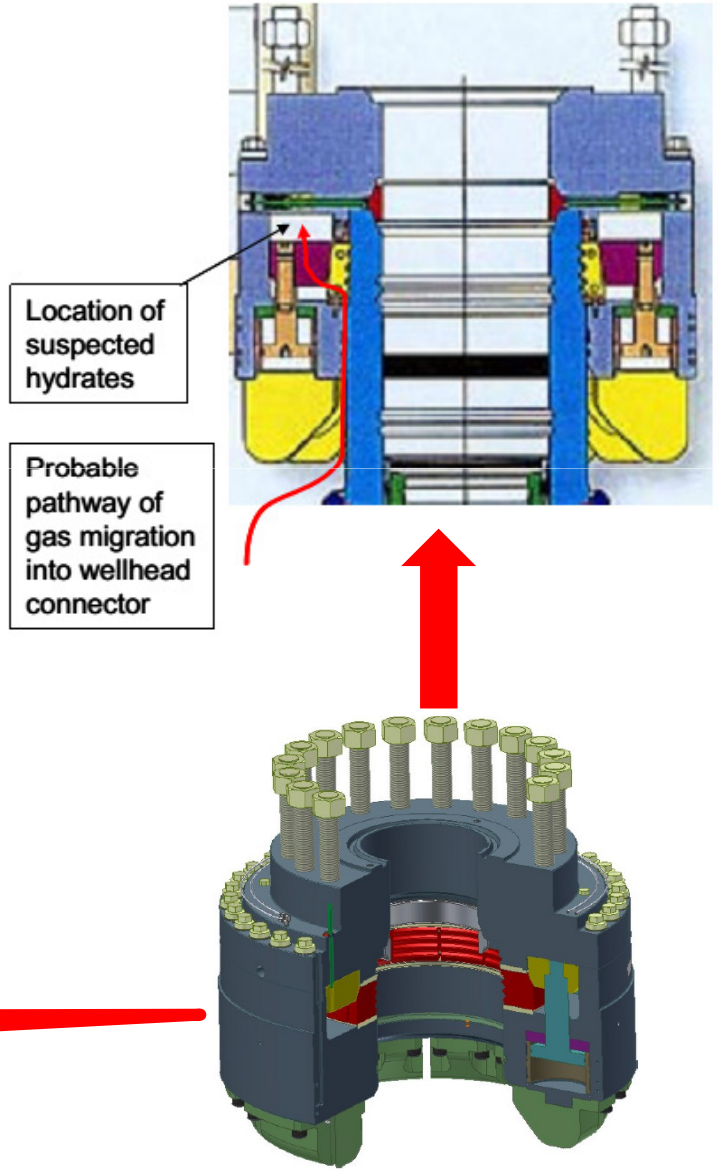
Hydrate plug

Prevents full BOP closure

1. Introduction

(5). plug formation in Wellhead Connector





1. Introduction





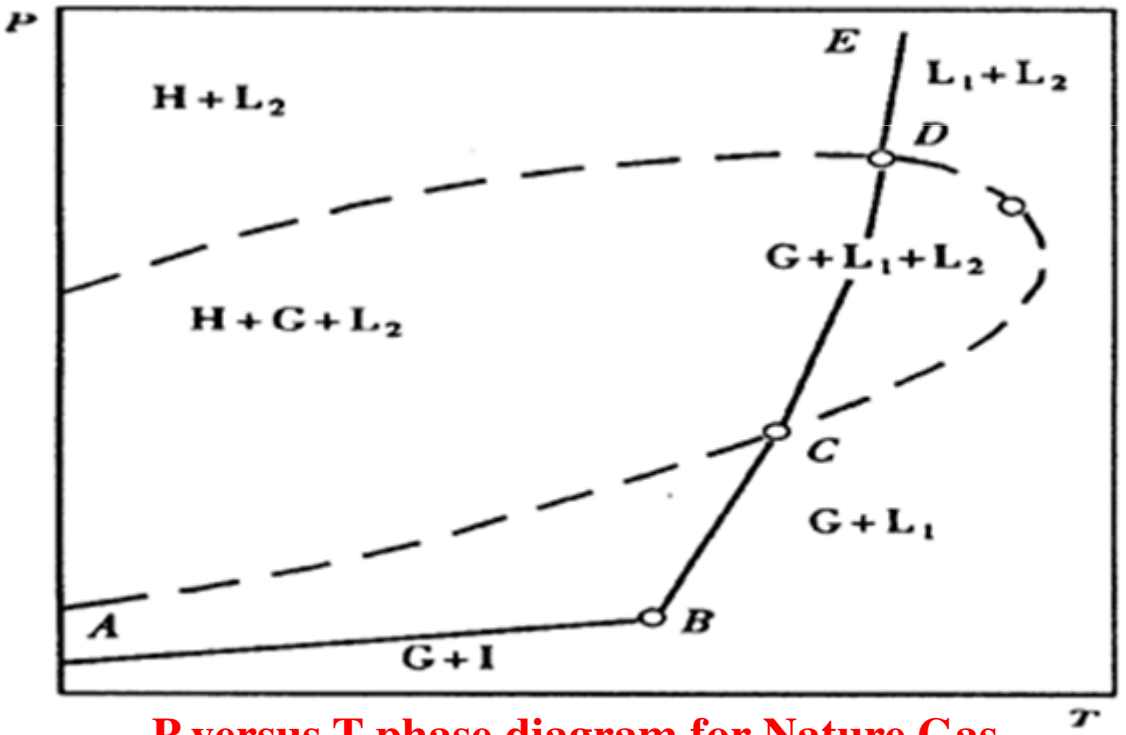




1. Introduction

Two kinds of study about the gas hydrate formation:

- **Thermodynamics of gas hydrate, it is mainly about the hydrate formation conditions, such as the pressure and temperature.**

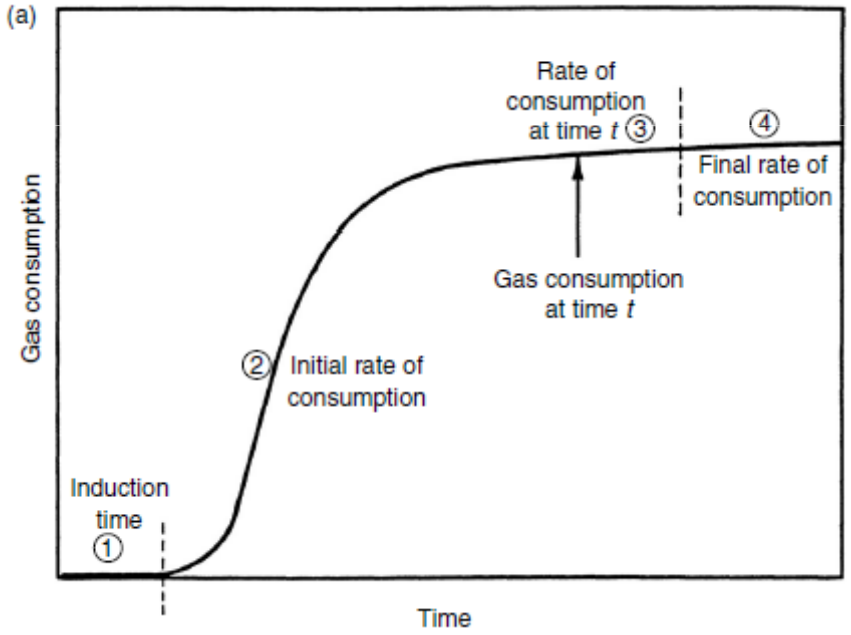


P versus T phase diagram for Nature Gas

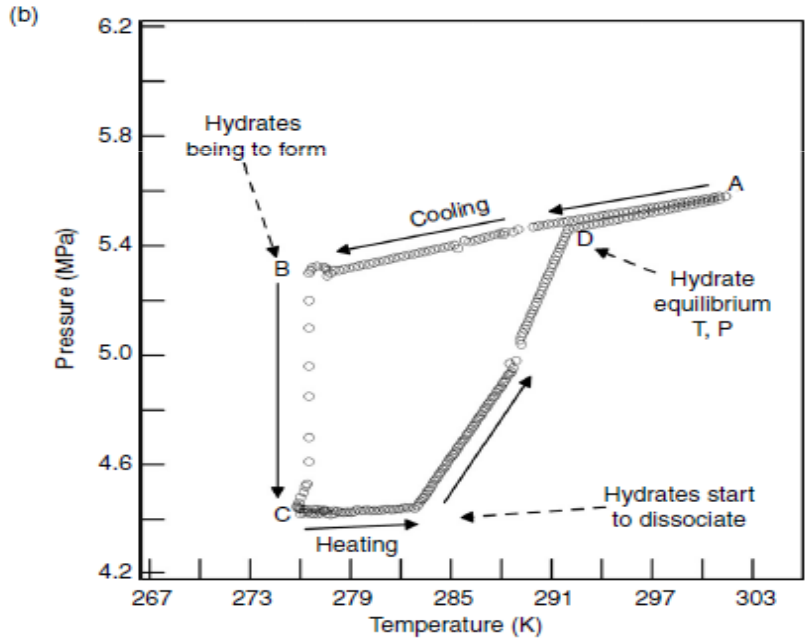
1. Introduction

Two kinds of study about the gas hydrate formation:

- **Kinetics of hydrate formation, it is mainly about the gas hydrate formation and dissociation speed.**



(a) Gas consumption vs. time for hydrate formation



(b) Temperature and pressure trace for formation of simple methane hydrates.

1. Introduction

Most researchers believed that gas hydrate would formed when the condition was in the hydrate formation area of the phase diagram and predicted the hydrate formation area based on the thermodynamics theory .

- **Gao Y H, Wang Z Y, Johnny P predicted the hydrate formation area based on the Van der Waals and Platteeuw theory.**
- **Kotkoskle T K, Peavy M A, Yousif M H, Thierry B studied the hydrate inhibition based on the thermodynamics theory.**
- **Chen S M studied the prevention of gas hydrate formation during the deepwater well suddenly shut in.**

The kinetics should also be considered in the gas hydrate formation prediction.

1. Introduction

Some researchers believed that the hydrate inhibitor helped prevent the hydrate formation in the whole drilling process. It was high input and wasteful. They mistook hydrate formation as blocking. Based on the hydrate kinetic theory, the hydrate formation is different from the hydrate blocking. Based on the blocking mechanism, there is no need to use the hydrate inhibitor in most part of deepwater drilling.

2. Multiphase flow influence on the hydrate formation

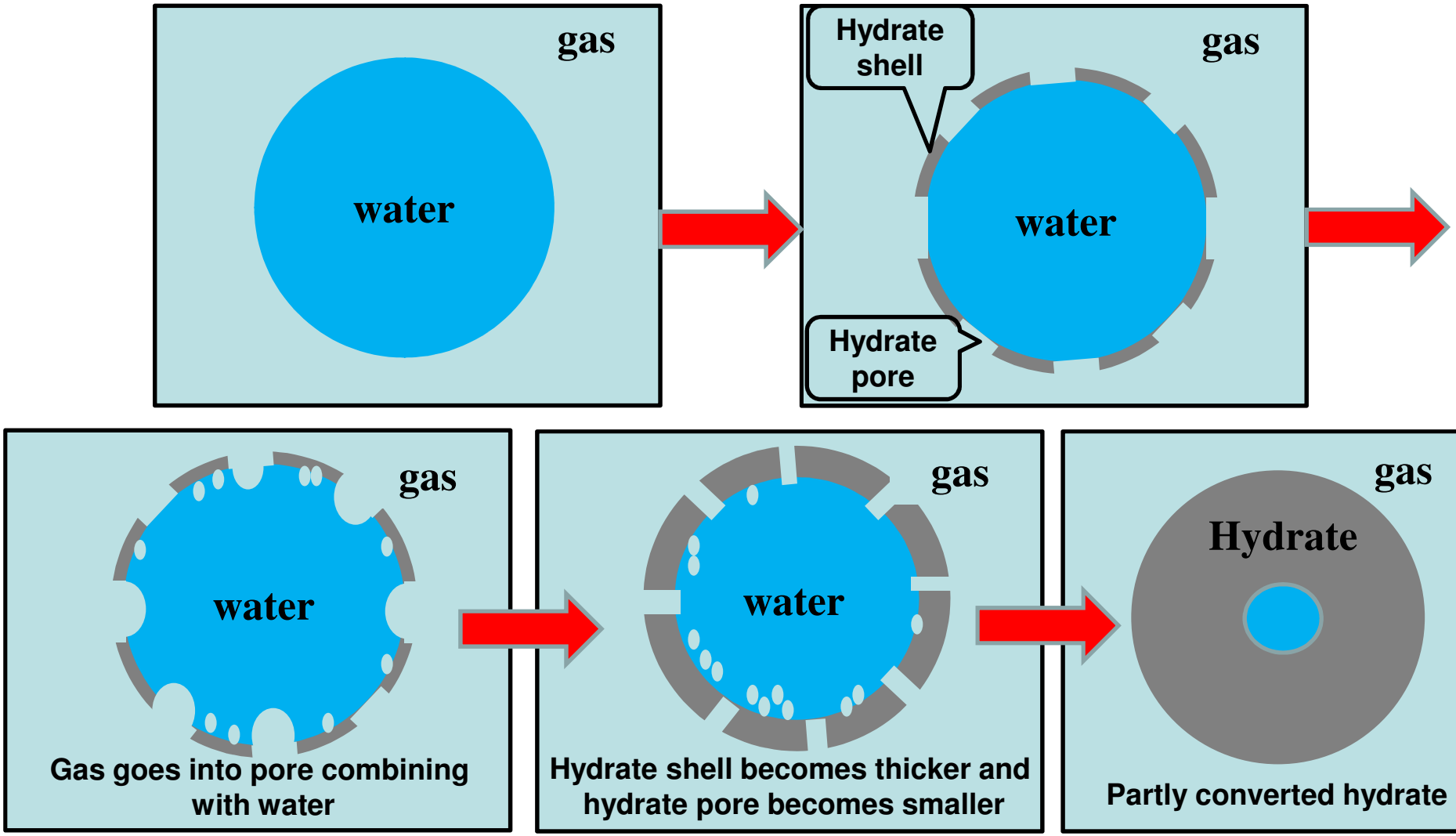
2.1 Gas hydrate film growth

A conceptual picture of the proposed mechanism for hydrate film growth at the hydrocarbon–water interface based on the above experimental results is given:

- ✓ **Step 1: Propagation of a thin porous hydrate shell (film) around the water droplet.**
- ✓ **Step 2: Shell development.**
- ✓ **Step 3: Bulk conversion of the droplet interior to hydrate**

2. Multiphase flow influence on the hydrate formation

2.1 Gas hydrate film growth



2. Multiphase flow influence on the hydrate formation

2.2 The gas hydrate formation will be slowly when there is no surfactant and no stirring.

- ✓ **Sun Z G found that there was no hydrate formation in the static system during 32 hours but when mixed up, hydrate formed after 5-10 mins.**
- ✓ **Ryo Ohmura et al believed that the gas hydrate film in the interface of hydrate slowed down the formation speed in the static condition.**
- ✓ **Jesen et al studied the hydrate formation during different stirring speed and different surfactants, found that high stirring speed could reduced the hydrate formation time.**

2. Multiphase flow influence on the hydrate formation

2.3 The gas hydrate film slow down the hydrate formation

- ✓ **The dissolved gas concentration is low and the mass transfer is the dominant. Only 0.1% gas can be dissolved in the water phase, however, there are 15% mol gas in the gas hydrate particles, which is at least 100 times than the gas solubility. The mass transfer from gas to the hydrate surface is important.**

2. Multiphase flow influence on the hydrate formation

2.3 The gas hydrate film slow down the hydrate formation

- ✓ **The gas hydrate can be formed on the interface of gas bubble and liquid phase. The thickness of gas hydrate on the bubble surface increased quickly in the beginning. After reaching a certain thickness, it would not increase, stopping the dissolved gas molecule transferring from gas phase to liquid phase. And the mass transfer would be influenced.**

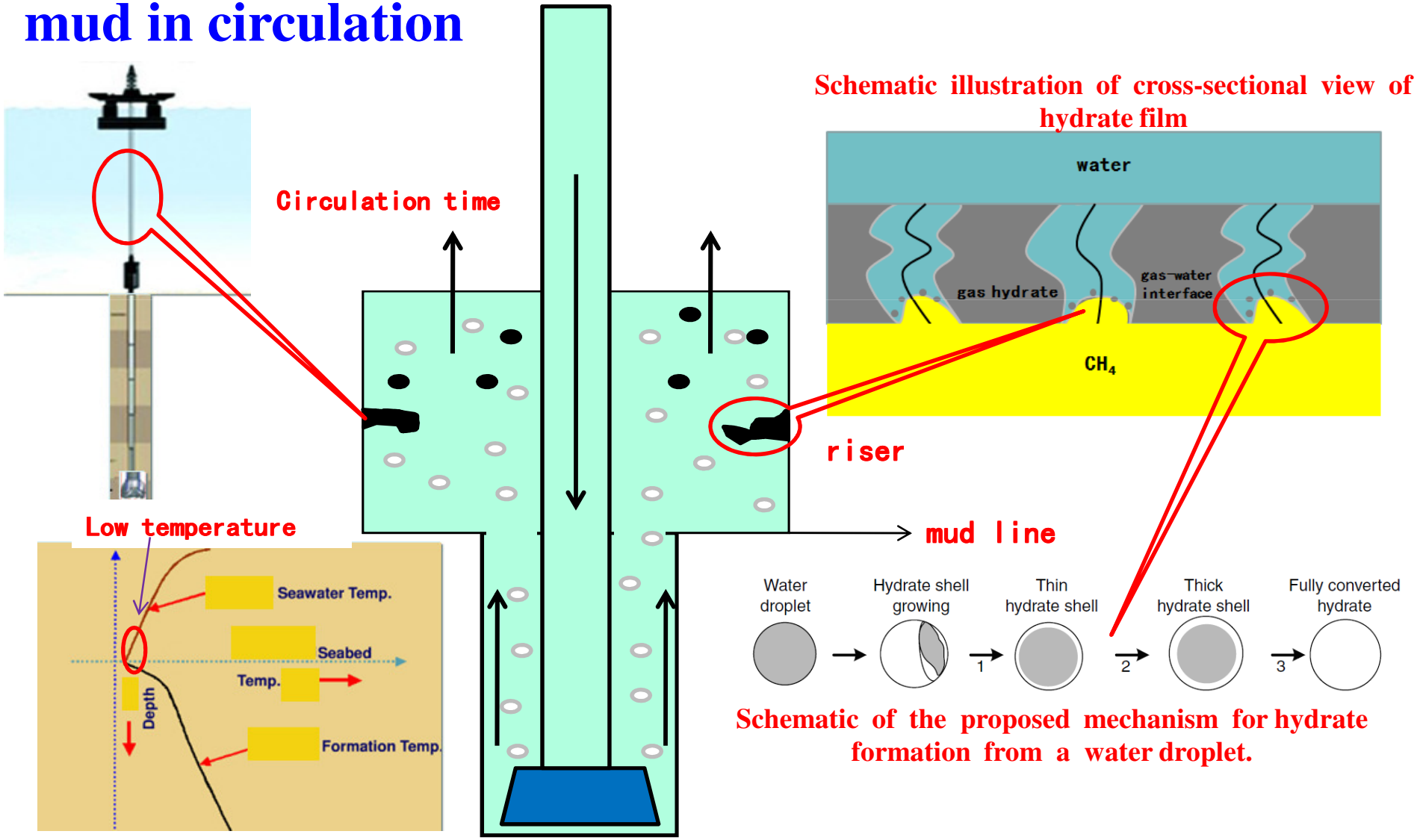
2. Multiphase flow influence on the hydrate formation

2.4 No hydrate blocking in the bubble flow during mud in circulation

- ✓ **In bubble flow, the mass transfer coefficient is small. The induction time of gas hydrate formation is long because of the low gas concentration at the interface. During the induction time, the fluid under the hydrate formation condition flow out of the wellbore.**
- ✓ **The amount of formed hydrate are few, and will be affected by the flowing drilling fluid. They will fall off the wellbore wall and flow with the drilling fluid out of the wellbore.**

2. Multiphase flow influence on the hydrate formation

2.4 No hydrate blocking in the bubble flow during mud in circulation



Schematic illustration of cross-sectional view of hydrate film

Schematic of the proposed mechanism for hydrate formation from a water droplet.

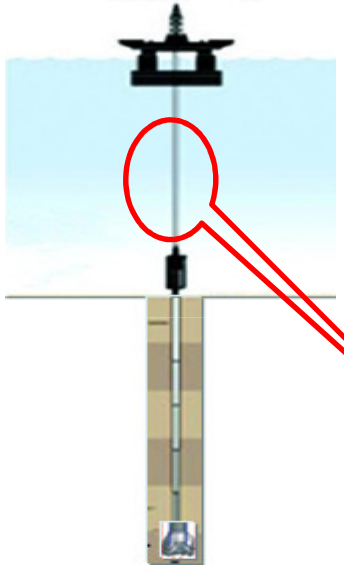
2. Multiphase flow influence on the hydrate formation

2.5 Hydrate blocking may happen in the bubble flow during shut-in time

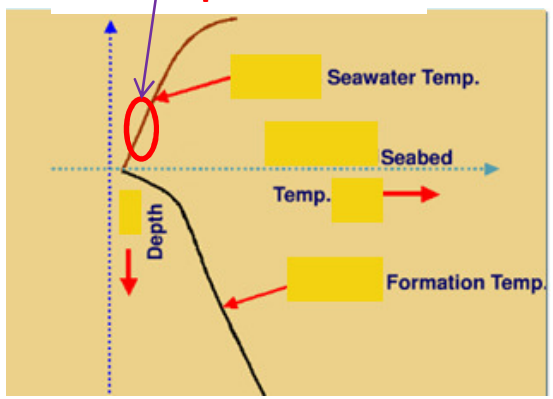
- ✓ **During the shut-in time, because the temperature of drilling mud in the riser decreases, the impact effect of drilling fluid on gas hydrate weakens , Hydrate blocking may happen in riser.**

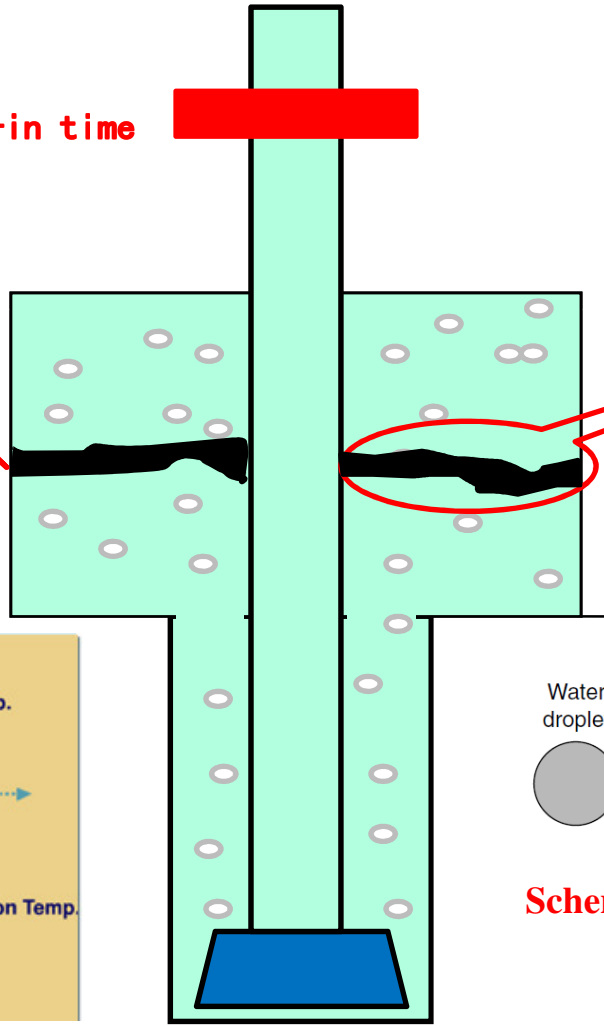
2. Multiphase flow influence on the hydrate formation

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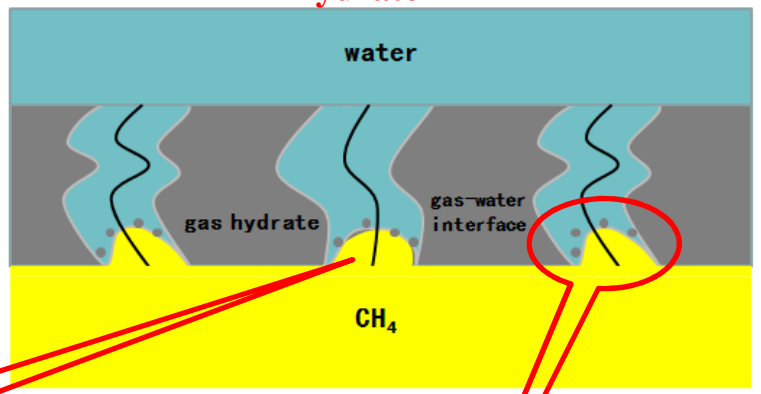


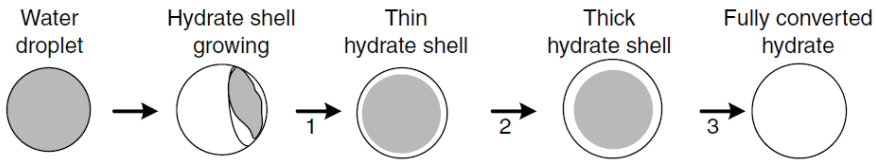
Shut-in time





Schematic illustration of cross-sectional view of hydrate film





Schematic of the proposed mechanism for hydrate formation from a water droplet.

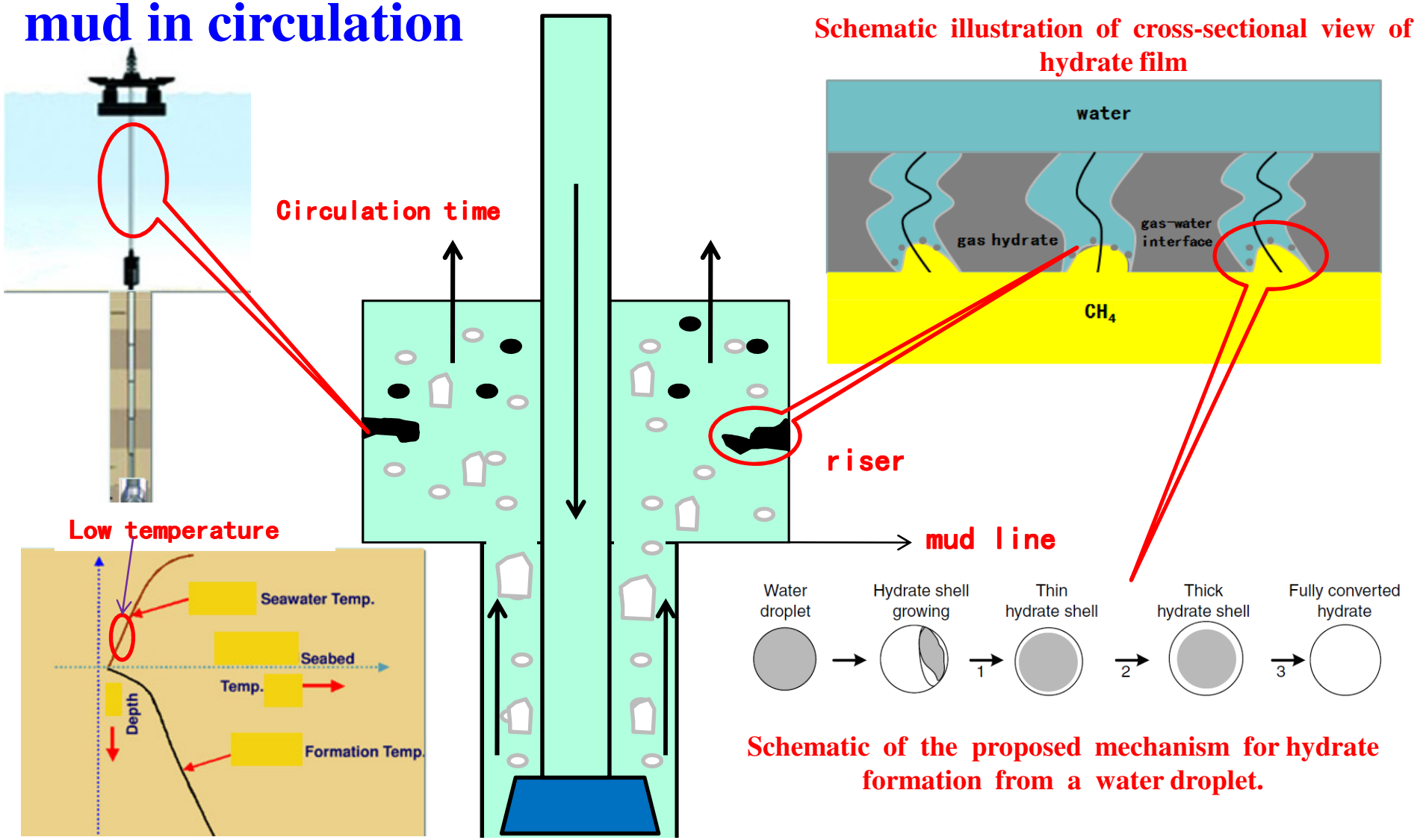
2. Multiphase flow influence on the hydrate formation

2.6 No hydrate blocking in the slug flow during mud in circulation

- ✓ **There are liquid film in the drilling pipe wall and casing wall, Taylor bubble in the center of the wellbore in slug flow. Compared with the same volume of gas bubbles, the total contact area of the gas / liquid interface decrease, and the mass transfer decrease.**
- ✓ **During the induction time of hydrate formation, the fluid under the hydrate formation condition flow out of the wellbore.**
- ✓ **The hydrate film can be formed in the drilling pipe wall and casing wall after the induction time. However, the amount of hydrate are still few because of the low gas concentration in the interface. The formed hydrate fall off the pipe wall and flow out of the wellbore.**

2. Multiphase flow influence on the hydrate formation

2.6 No hydrate blocking in the slug flow during mud in circulation



Schematic illustration of cross-sectional view of hydrate film

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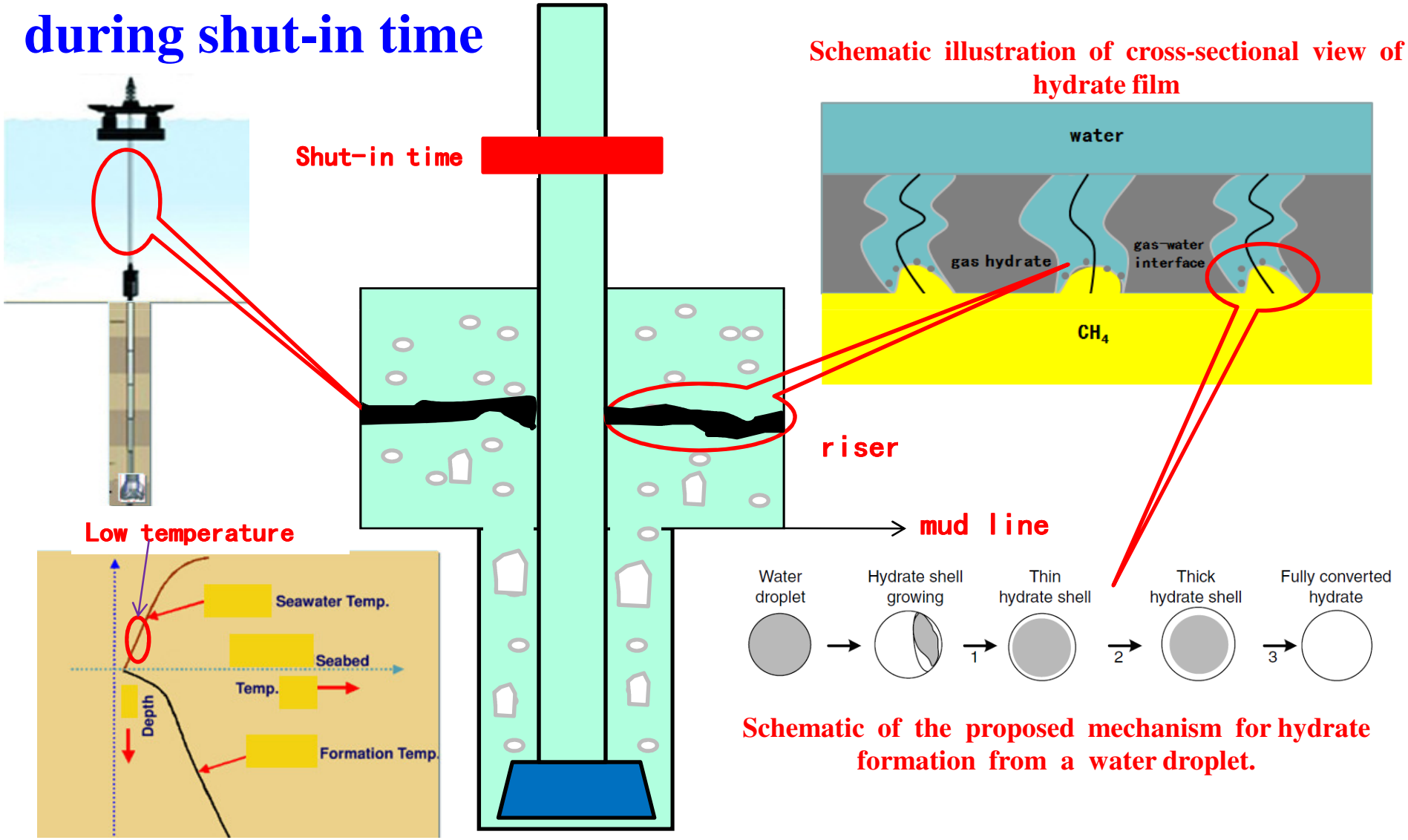
2. Multiphase flow influence on the hydrate formation

2.7 Hydrate blocking may happen in the slug flow during shut-in time

- ✓ **During the shut-in time, because the temperature of drilling mud in the riser decreases, the impact effect of drilling fluid on gas hydrate weakens , Hydrate blocking may happen in riser.**

2. Multiphase flow influence on the hydrate formation

2.7 Hydrate blocking may happen in the slug flow during shut-in time



Schematic illustration of cross-sectional view of hydrate film

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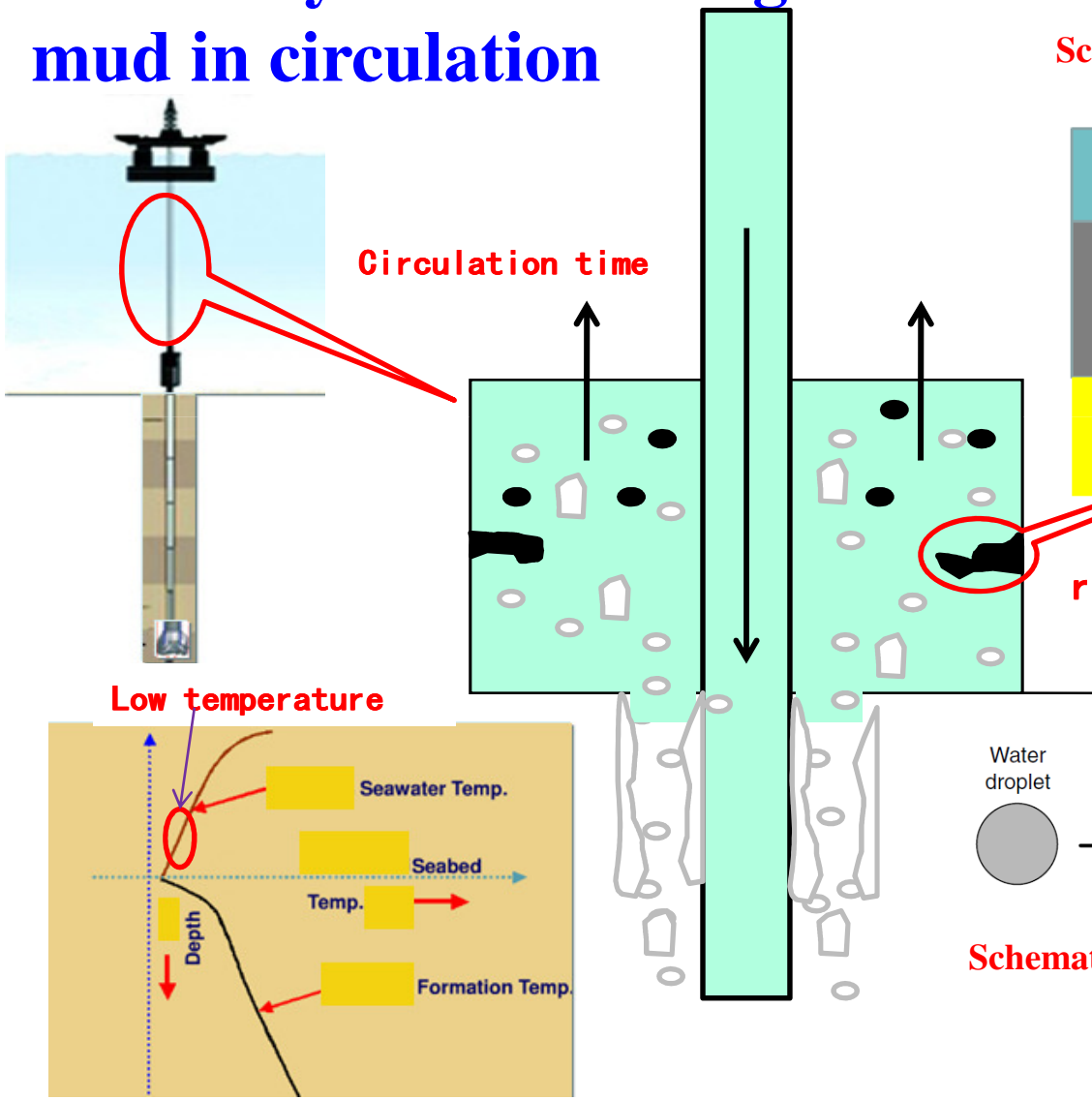
2. Multiphase flow influence on the hydrate formation

2.8 No hydrate blocking in the mist flow during mud in circulation

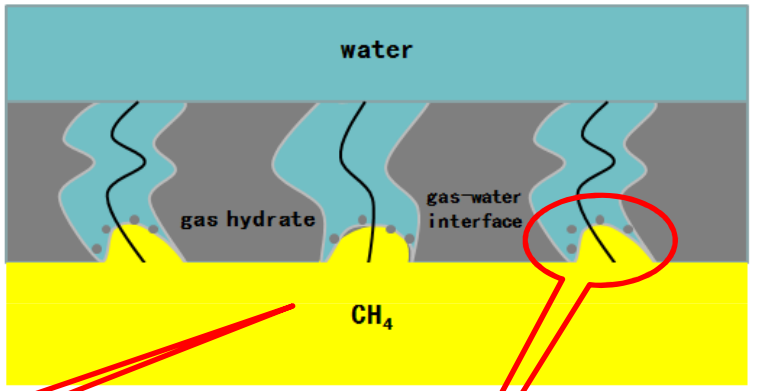
- ✓ **When the mist flow occurs, the discrete droplets are distributed in the continuous gas phase. The drilling fluid velocity is fast and the convective heat transfer coefficient is large, so the heat transfer is large and the loss of heat is few. The fluid temperature is high enough to prevent the hydrate formation.**
- ✓ **If the throttle devices are installed on the wellhead, the fluid temperature will be drastically reduced due to the Joule Thomson effect. The hydrate will be formed around the wellhead.**

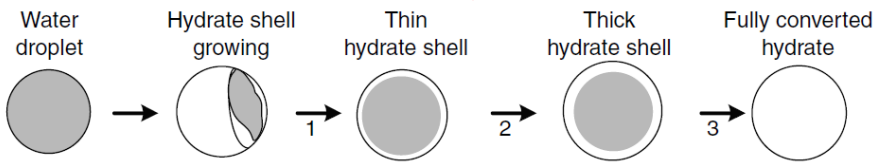
2. Multiphase flow influence on the hydrate formation

2.8 No hydrate blocking in the mist flow during mud in circulation



Schematic illustration of cross-sectional view of hydrate film





Schematic of the proposed mechanism for hydrate formation from a water droplet.

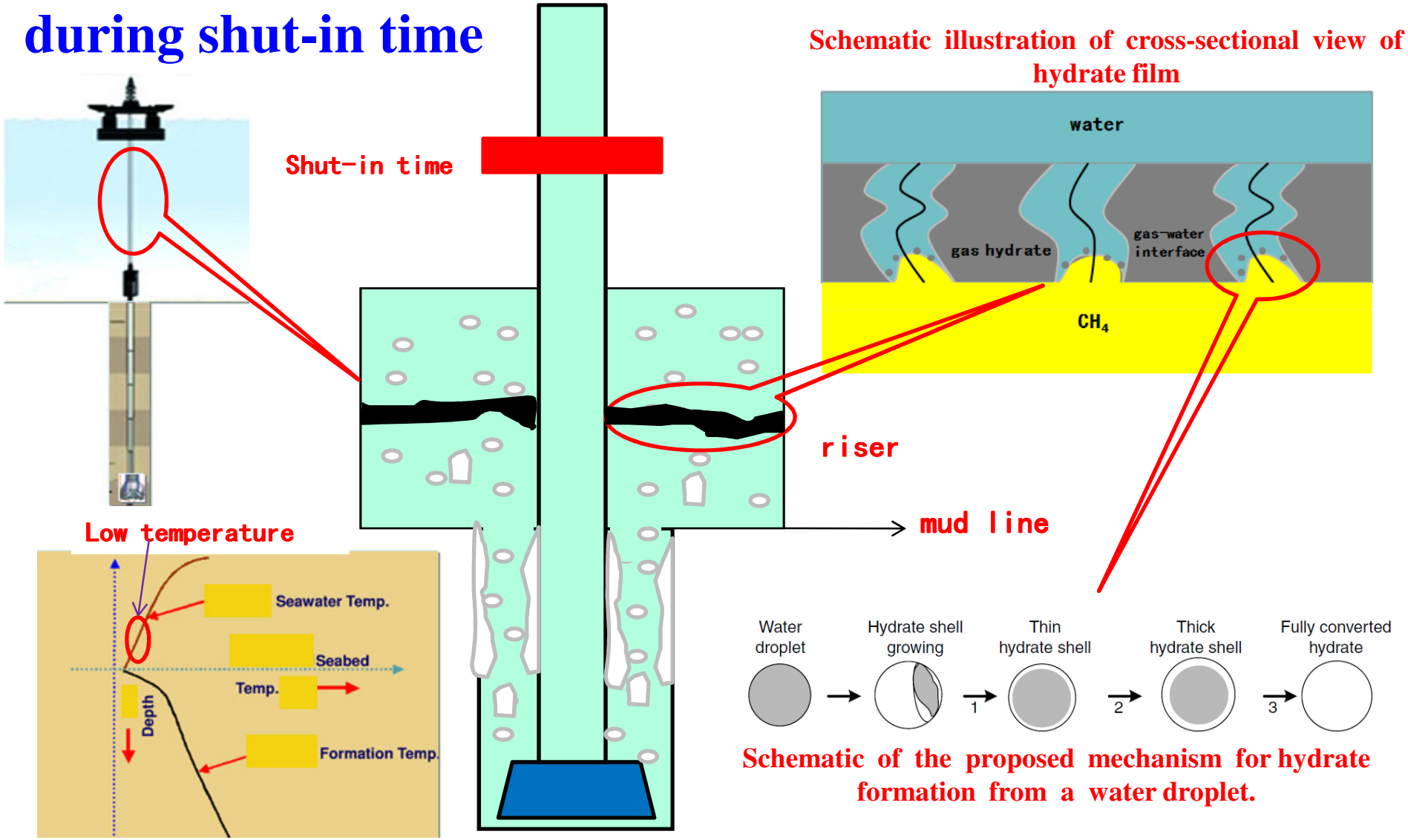
2. Multiphase flow influence on the hydrate formation

2.9 Hydrate blocking may happen in the mist flow during shut-in time

- ✓ **During the shut-in time, because the temperature of drilling mud in the riser decreases, the impact effect of drilling fluid on gas hydrate weakens , Hydrate blocking may happen in riser.**

2. Multiphase flow influence on the hydrate formation

2.9 Hydrate blocking may happen in the mist flow during shut-in time



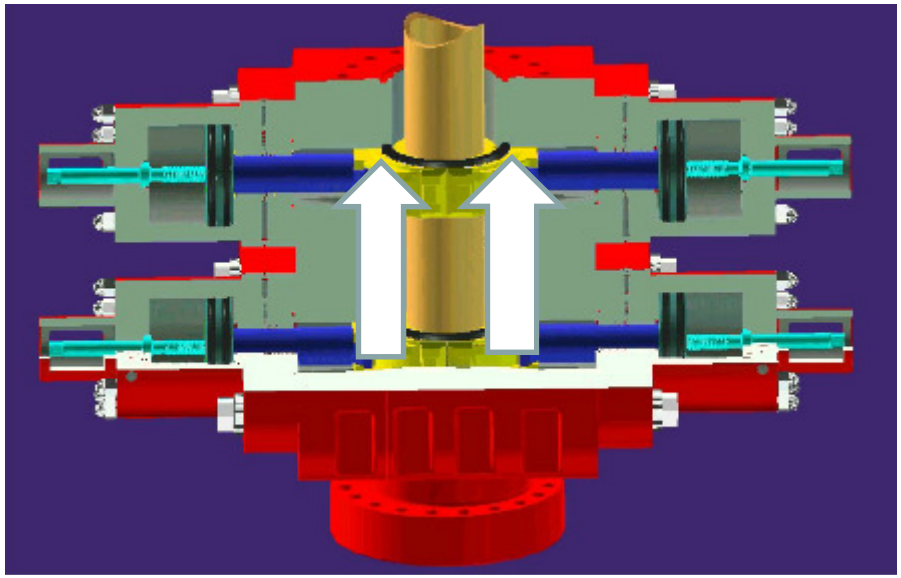
Schematic illustration of cross-sectional view of hydrate film

Schematic of the proposed mechanism for hydrate formation from a water droplet.

3. Hydrate blocking prediction and prevention during the whole drill

(1).When the gas kick occurs, in the BOP position hydrates plug will not form.

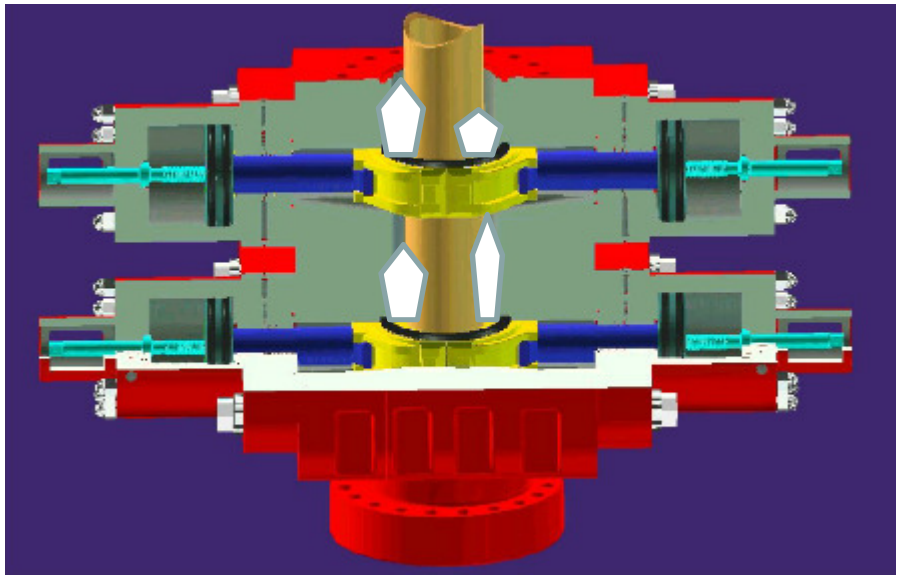
When the overflow occurs, the fluid rate in the wellbore is higher, at this moment, in the wellbore maybe form hydrates. If the buoyancy of bubble is larger than viscosity, bubble goes up in the wellbore passby the BOP position. But as hydrate crystals generated gradually at the gas surface, then it will form a thin hydrate shell. Once bubble surface coverd fully by hydrates, the generation and reaction rate of hydrates will slow down, during this time, hydrates had formed mostly got rid of wellbore by the higher rate, and this time the BOP position is a smooth channel, without bent and other corner, so hydrates will not accumulate in the BOP position and will not plug.



3. Hydrate blocking prediction and prevention during the whole drill

(2).When the gas kick happens, during the shut-in period, hydrates plug will form in the BOP position

During the shut-in period, as BOP inside locked, circulation of drilling fluid stops and higher temperature in the wellbore goes down gradually. When shut-in time is longer, temperature reduces to marine's nearly and BOP inside exists fluid and gas, which is good for formation of hydrates. At this time, since generated hydrates will not flow with drilling fluid, it accumulates a bit by generating a bit, then occurs hydrates plug. Also part of fluid and gas goes into the BOP connector position, then forms plug and induces to the BOP stuck.



3. Hydrate blocking prediction and prevention during the whole drill

(3). During the well kill with the driller's method and engineering method, it won't plug.

During the process of kill in the d riller's method and engineering m ethod, though pressure and tempe rature maybe up to hydrates form ation's and with enough bubble, which means generating hydrates.

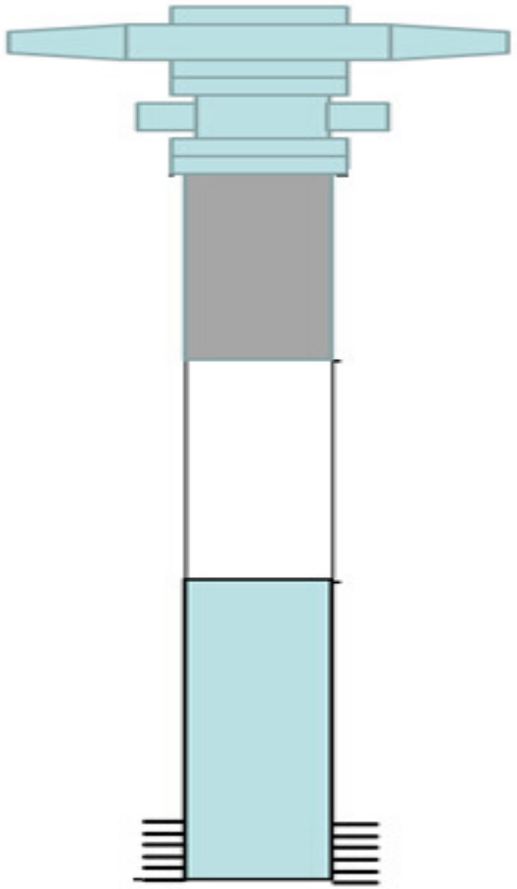
But as the circulation of drilling fluid, generated hydrates fall off a t any time, without enough time to fit hydrates' accumulation at the bend, so it won't plug.



3. Hydrate blocking prediction and prevention during the whole drill

(4). During the process of kill in the static displacement method, it may form plug at the wellhead.

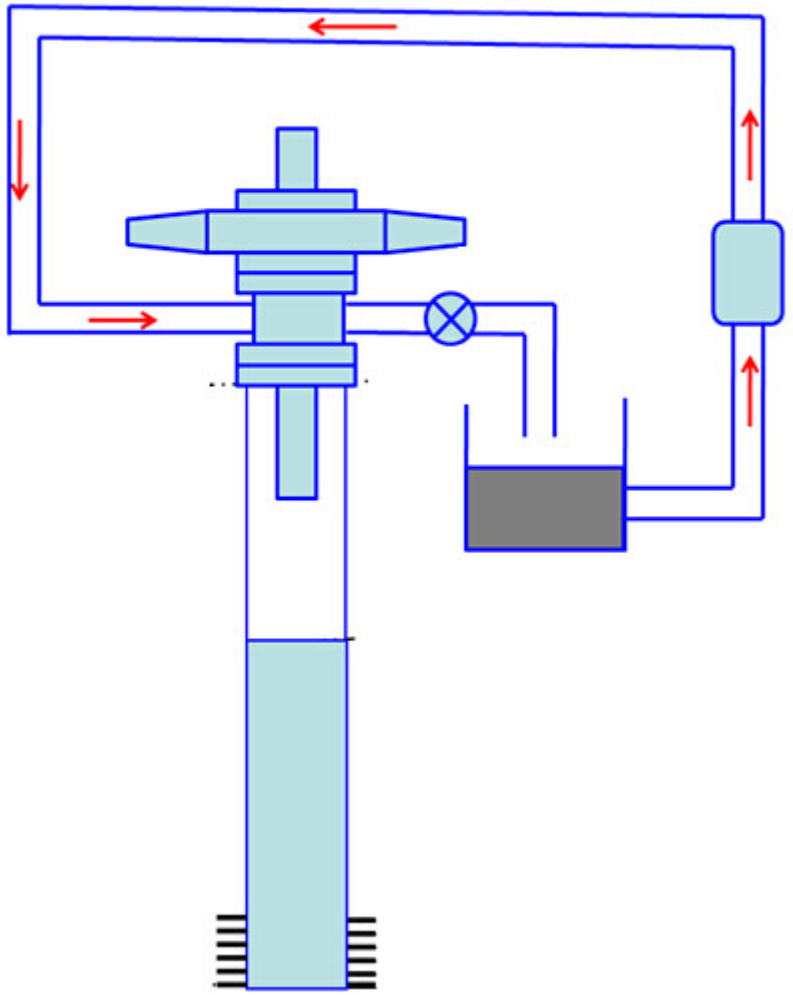
During the process of kill in the static displacement method, with enough temperature and pressure forms hydrates. As for this method, if the waiting time of exchanging between gas and kill fluid is too long, it may forms plug at the wellhead.



3. Hydrate blocking prediction and prevention during the whole drill

(5).During the dynamic replacement method, it won't plug.

During the dynamic replacement method, as injecting kill fluid and discharging gas does at the same time, without the waiting time of kill fluid falling off, so maybe generates hydrates, but also without enough time to fit hydrates' accumulation at the bend, so it won't plug.



4. Conclution

(1). No hydrate blocking happens in the bubble flow during mud in circulation .

① In bubble flow, the mass transfer coefficient is small.

② The fluid under the hydrate formation condition flow out of the wellbore.

③ The formed hydrate are few, and will be affected by the flowing drilling fluid. They will fall off the wellbore wall and flow with the drilling fluid out of the wellbore.

4. Conclution

(2). No hydrate blocking happens in the slug flow during mud in circulation.

① During the induction time of hydrate formation, the fluid under the hydrate formation condition flow out of the wellbore.

② The amount of hydrate are still few because of the low gas concentration in the interface. The formed hydrate fall off the pipe wall and flow out of the wellbore.

4. Conclution

(3). No hydrate blocking happens in the mist flow during mud in circulation.

When the mist flow occurs, the discrete droplets are distributed in the continuous gas phase. The drilling fluid velocity is fast and the convective heat transfer coefficient is large, so the heat transfer is large and the loss of heat is few. The fluid temperature is high enough to prevent the hydrate formation.

4. Conclution

(4). Hydrate blocking may happen during long shut-in when gas kick occurs.

During the shut-in time, because the temperature of drilling mud in the riser decreases, the impact effect of drilling fluid on gas hydrate weakens , Hydrate blocking may happen in riser.

4. Conclution

(5). There is no need to use the hydrate inhibitor during the whole drilling process.

The dissolved gas is few, so the formed hydrate is few. No blocking happens.

(6). There is no need to use the hydrate inhibitor during the mud in circulation when gas kick occurs.

Although the influx gas is different in different multiphase flow pattern and the hydrate will form, no hydrate blocking happens during gas kicks.

4. Conclution

(7). If the shut in time is few when killing well, there is no need to use the hydrate inhibitor .

① The influx gas is few and the formed hydrate is few.

② The formed hydrate will flow out of the wellbore when the well is opened.

(8). The driller's method and dynamic replacement method are recommended when the gas kick happens for preventing the hydrate formation.

As the circulation of drilling fluid, the formed hydrate fell off at any time, without enough time to fit hydrates' accumulation at the bend, no blocking happens.

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Thank you!