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Safety Control Technology of Deepwater Perforated Gas Well Testing

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Abstract

Due to the high difficulties, high investment, and high risks in deepwater oil and gas well testing, major safety problems can occur easily. A key to prevent accidents is to conduct safety assessment and control on deepwater testing and to improve the testing technology. The deepwater of the South China Sea has some special environmental features: long distance from offshore, frequent typhoons in summer and constant monsoons in winter, and the presence of sandy slopes, sandy ridges and internal waves, coupled with the complex properties of oil and gas reserves which bring more challenges to deepwater well testing. In combination with deepwater well testing practice in the South China Sea, this paper analyzes the main potential risks in deepwater well testing and concludes that there are risks of failures of testing string, tools, and ground processes. Other risks are gas hydrate blockage, reservoir stratum sanding, and typhoon impacts. Specific precautions are also proposed in response to these risks in the paper.

Keywords

Safety Control, Well Testing, Deepwater, Risk

1. Introduction

The deepwater zone in the South China Sea which is called "the second Person Gulf" is vast, rich of petroleum and natural gas hydrate reserves [1] [2]. A number of significant discoveries of natural gas reserves have been achieved recently [3] [4]. As an irreplaceable tool in deepwater oil and gas exploration and production, well testing not only provides valuable information for structure and trap evaluation, but also paves the way for effective oil and gas production. However, deepwater well testing technology in China is in its infancy stage currently [5] [6] [7] [8]. In order to meet the strategic needs of deepwater oil and gas exploitation in the South China Sea, safety assessment and control technique of deepwater well testing is investigated.

2. Challenges of Deepwater Well Testing

1) Deepwater well testing should be accomplished with floating drilling platform. Affected by factors like wind, wave, and current, the platform is under constant complex movements such as rising, sinking, and drifting. Besides, the deepwater well testing string should also be constrained by the riser. As a result, the forces on the test string, especially that above the mud line, is extraordinarily complicated, which has brought with significant difficulty for its design and safety control. This challenge is even tougher as water depth increases.

2) The combination of low temperature at the mud line and the rapid drop of pressure once well shut-in is the major lure for natural gas hydrate, which will bring with not only failure to the test, but also dramatic risks to the well control, or even catastrophic accidents.

3) Under water facilities should work against the tough surroundings brought by the great water depth to ensure the entire well testing process is upon reliable foundations. Moreover, other factors including the limited space of the platform, the narrow window of formation pressure, high production rate and high formation pressure, will also add the challenges to well control and surface safety control.

4) As the test is conducted on a floating platform, unpredictable incidents like the breakdown of positioning system, undercurrents, and bad weather, will make the platform drift away from the well head. Under this situation, test string above the mud line should be dismissed from the rest in order to avoid a catastrophe. Consequently, the fast dismission of the string under emergency and the re-connection after that are other challenges in well testing.

3. Potential Risks and Their Preventive Measures of Deepwater Well Testing

3.1. Failure and Its Prevention of Testing String and Facilities

The test string, from which the underground fluid flow to the surface, is composed with three major components: bottom-hole test facilities, testing tubing, and under water facilities. For safety purpose, suitable bottom-hole test facilities should be selected. Besides, the test tubing should be optimized through specific mechanical analysis with the target of safety and high quality. It should not merely satisfy the demand of test process in the toughest environment, but also be convenient in use, suitable in material and economical. According to such principles, the optimization workflow of the tubing design in deepwater testing is shown as following (showing in Figure 1).

3.2. Failure and Its Prevention of Surface Process

A typical surface process of deepwater well testing includes: the flow head, safety

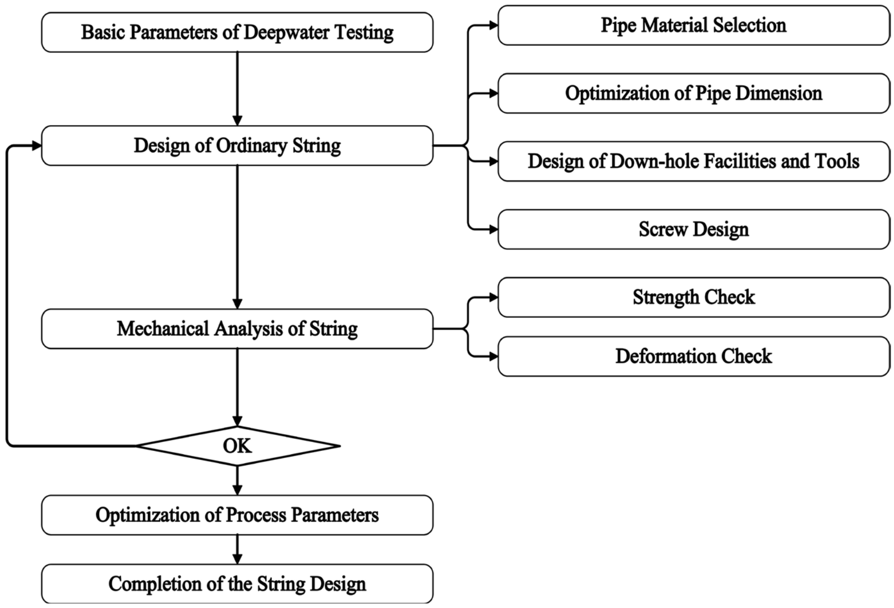

Figure 1. Optimization workflow of the string design in deepwater well testing.

valves, emergency shutdown valves, a desander, choke manifold, a steam boiler and heater, a three-phase separator, a gauge tank, a conveying pump, a temporary supply tank, a burner boom, and connecting manifold, etc. This process is short in flow distance (only dozens of meters from the burner wall to well head), high in pressure, short in flow time (generally about 1 day), and complex in phase change processes. Ice blockage is risky to take place during the test, bringing about great danger to the personnel and the test. So a series of emergency shutdown facilities should be equipped in the manifold to ensure that any place can be artificially shut-in in emergency. A desander is needed to remove sands in potential sand producing formations. A large discharge pump for chemicals is installed at the well head to inject methanol to prevent gas hydrate.

All the pressure vessels in deepwater well testing should be qualified with a third party qualification such as DNV, ABS or Lioyd according to their period of validity. Once the lectotype of facilities is finished, the workflow should be numerically simulated to check whether the temperature and pressure are in proper range, and the capability of the facilities is correct. Then the further optimization of the facilities and pipelines should be conducted.

3.3. Prediction and Control of Natural Gas Hydrate

Natural gas hydrate is a kind of cage-like crystal formed when the gaseous natural gas (like methane and ethane) reacts with water in low temperature (0˚C - 10˚C) and high pressure (over 10 MPa) environment. It is like ice crumbles or compacted snow in appearance, so it is usually called "flammable ice". The density is 880 - 900 kg/m^3. Natural gas with free water are risky to transform into gas hydrate in low temperature and high pressure surroundings. Currently there are a number of approaches to determine the pressure-temperature at which natural gas hydrate comes into being. Roughly, they can be classified as: graph approach, empirical equation approach, balance constant approach, and statistical thermodynamics approach which is the most accurate yet complicated method. On the basis of system theory, the statistical thermodynamics approach connects the macro phase behavior of gas hydrate with the inter-molecular reactions. By employing functions to describe the creation conditions of gas hydrate, this method is beneficial from the solid theoretical foundation and has a wide applicable range. With the help of computer, it can be applied to continuously calculate the temperature and pressure at which gas hydrate forms in a relatively wide range.

According to the classical absorption theory proposed by Vander Waals and Platteeuw, the phase balance conditions of gas hydrate can be applied to determine whether solid hydrate appears at given pressure, temperature and other conditions. As for well testing process, thermal or chemical methods are commonly used to prevent hydrate. The thermal method is applied to heat up the natural gas before choke. If the pressure drop at the choke keeps constant, to increase the temperature of the natural gas before choke means to increase the temperature of the gas after that. Once the temperature of the gas after choke is higher than the critical temperature at which hydrate appears, the target of hydrate prevention is achieved.

Some chemicals are helpful to decrease the balance temperature of gas hydrate. Under certain pressure, the balance pressure decreases as the chemical concentration rises. A lot of investigations have been conducted by researchers all over the world on the chemicals which can impede gas hydrate. Methanol and ethanediol are the most commonly used chemicals for this purpose, and the former is the recognized most effective gas hydrate inhibitor in deepwater well testing. It has the following advantages: 1) low viscosity, easy to injection and allocation; 2) high solubility and volatility, easy to contact with other fluids in the wellbore; 3) easy to be burned with the produced gas. But as methanol is toxic and highly flammable, the safety aspect should be paid more attention to. The procedure of methanol injection should be clearly written in the Operation Procedure, and in the procedures of the testing company and the contractor.

Flow rate is another factor for gas hydrate, which is easier to appear at lower flow rate. Temperature change is violated at the mud line as the temperature at seabed is quite low. As is shown in **Figure 2**, No hydrate appears when the flow rate is 25×10^4 m^3/d.

3.4. Sanding Risks and Control

Reservoirs in deepwater zones are generally shallow in buried depths. Furthermore, the compaction degree is decreased as a large interval of rock formations are substituted by sea water, whose density is less. As a result, sand production is common. In order for sand control, on one aspect, suitable well completion approaches should be adopted according to the specific property of the pay zone; on another aspect, sand control techniques should be applied whenever necessary.

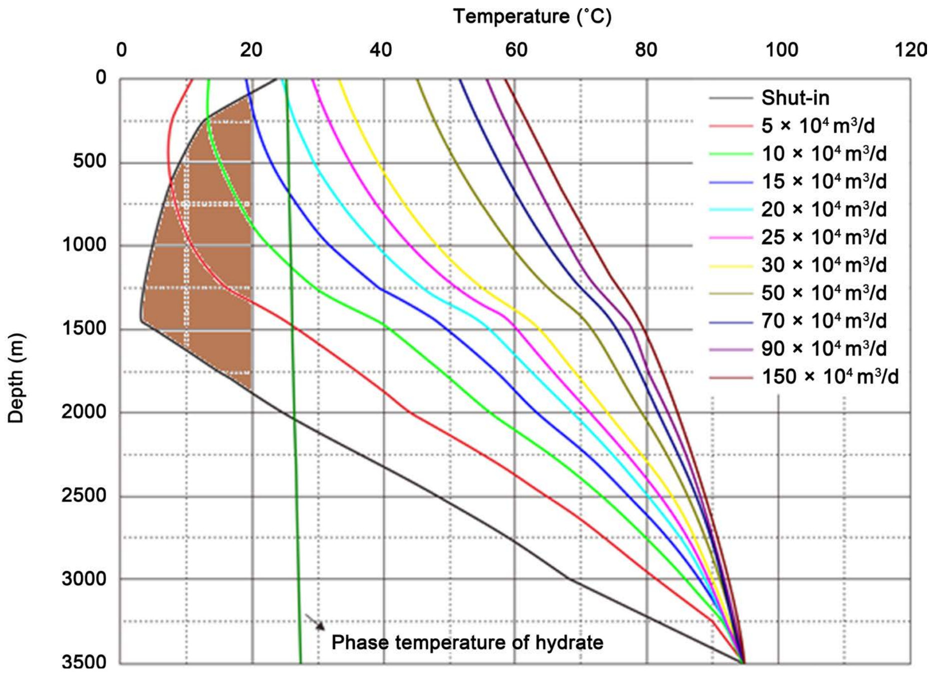

Figure 2. Generated area of hydrate under different flow capacity.

Mechanical sand control techniques are commonly used as the first barrier for sand production in deepwater evaluation wells. Some sand control measurements in Liwan Block, South China Sea are provided here.

1) All the wells are cemented with casing, which is helpful for sand control in the casing. 2) Qty-2 Meshrite screen pipe is attached on DST-TCP string and extended below the packer. Coiled tubing and related lifting frame for sand wash are prepared on the site. 3) Pressure drop in the test is strictly controlled. Proper perforation fluid is selected. The pressure difference in the time-lapse underbalanced perforation is limited to 2.76 MPa. 4) Test valves should be designed to work against the sand. 5) A sand monitor and desander are set at the upstream of the choke manifold. An oil pool is prepared to contain the separated sand. 6) Production pressure difference is closely monitored during the production process, in which the production rate increases gradually from a small beginning. Control the flow pressure at well head within the sand production limitations. 7) Supervise the sand content in the produced fluid by taking a sample every 15 min from the separator.

3.5. Typhoon Prediction

Typhoon is a factor responsible for the excursion of the platform, which further affects the stress state of the pipe string above mud line. Once the excursion exceeds the limitation, the testing tree should be immediately dismissed to avoid the breaking of the string. According to the depth of water and the demands of the testing tree, the safety operation window of the floating platform can be calculated considering factors like the response time of the testing tree, response time of BOP, and drift analysis of the platform. When the platform drifts away to an extent, the bottom-hole valves should be shutdown, testing tree dismissed. The safety operation windows are marked with different colors. Green represents that the dynamic positioning system works well and normal operations can be conducted. Blue-green means that the dismission limit is close, and operation should be pause. The valves in the testing tree should be shutdown. Drifts of the platform should be monitored more closely, and the dismission of the string above mud line is prepared. Yellow zones means immediate dismission should be taken out. If the color is red, that is means the dynamic positioning system is broken down completely. LMRP should be departed from BOP instantly to prevent the well head, BOP and risers from being broken.

4. Conclusion

Due to the limited space, intense facilities and personnel, tough natural environment, and remote distance from land-based supports, any accidents may result in significant loss. In the testing period, as the underground oil and gas is produced to the surface through the testing string, once the linkage of the string is out of control, catastrophe would happen. One of the key points to prevent accidents is to conduct the safety assessment and control in the deepwater testing process. Test data should be gathered within safety limitation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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