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# Integrated Gas Lift Completion String for Ultra-Deep Reservoir

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**Abstract:** Kenjiyak Oilfield, in Kazakhstan, is an ultra-deep oil reservoir of low porosity and ultra-low permeability, causing a myriad of technical problems when produced with conventional gas lift string. To address these problems, an integrated gas lift completion string has been developed. The completion string integrates fracturing, drainage and gas lift processes, and is capable of accomplishing multiple operations of zonal fracturing, quick flowback, reservoir protection, retrieving and gas lift production, etc., in one trip. This paper introduces the structure and working principles of this string, structural and performance characteristics of the key supporting tools. Meanwhile, it analyses the retrievable gas lift mandrel and drillable-retrievable packer. 47 wells' field application showed this completion string's maximum application was 4,287.63m, the maximum working pressure was 68MPa, the maximum single well daily yield was about 130t and the average drainage duration was 3 days, presenting significant operation performances. The integrated gas lift completion string is expected to provide strong technical support for oil production with low cost and high efficiency, thereby accelerating the development of overseas oilfields.

**Keywords:** Kenjiyak Oilfield, Gas Lift, Integrated String, Gas Lift Mandrel, Retrievable Packer, Ultra-Deep Reservoir

## 1. Introduction

In the period of low crude oil price, there are high requirements for PetroChina to reduce oil production costs in overseas oilfields. The development of overseas ultra-deep reservoirs is facing with both technical and high-cost problems. The Kenjiyak Oilfield in Kazakhstan is an ultra-deep reservoir of low porosity and ultra-low permeability. Currently, its formation pressure coefficient is only 0.6 to 0.8. Therefore, after fracturing, gas lift completion becomes a major method for enhancing oil production in this oilfield.

The adoption of the conventional gas lift string faces the following technical problems in exploiting these oilfields [1-3]: (1) Quite deep burial depth (vertical depth is between 3,700m to 4,400m). If the existing surface equipment are not used, the depth of the continuous gas lift will be deepened by 500m - 1,000m for the gas injection points to meet the proration requirements of oil production allocation. (2) Low permeability (0.5-5.0mD). Oil wells are required to be commissioned after fracturing. The fracturing pressure is expected to be as high as 50MPa for these oilfields. While the conventional gas lift tools' working pressure is less than 35MPa, they cannot be used in one trip operation for gas lift and fracture. (3) High GOR (400m$^3$/t), high crude gum mass percentage (23%) and containing sulfur. Frequent string trips are not in line with the requirements of safety and environmental protection. (4) Low formation pressure coefficient (0.6-0.8). Moving string well killing operation and the fracturing fluid residues can cause secondary damage to the reservoir.

To address the above technical difficulties, the R&D Center of Tuha Oilfield Company of PertoChina has designed the integrated gas lift completion string. This string is developed and improved based on the conventional gas lift completion string, and is capable of gas lift production, quick flowback, reservoir protection as well as retrieving operation, etc. The integrated gas lift string has been applied in 47 wells in Kazakhstan during 2012-2017, the deepest gas lift point reached was 4,287.63m, the highest pressure was 68MPa, the average drainage duration was 3days and the highest single well daily oil production rate was 130t. These filed application parameters showed its excellent performance in oil exploiting.

## 2. Method of Process Design

The formation pressure coefficient of Kenjiyak Oilfield is only 0.6-0.8. Based on a surface gas injection pressure, 8.5MPa, the maximum gas injection depth would be 2,900m if the conventional constant pressure drop was employed as the casing pressure method. But this will not meet the requirements of oil production allocation. Variable pressure drop design methods [4-7] have adopted the principle of "ultimate design", where characteristics of gas lift wells are the basis and deepening gas injection is achieved via reducing pressure losses in gas injection and increasing distances between gas lift valves. Each stage of gas lift valve has a specific pressure drop (PD), which can be calculated by the following formulas.

Under the minimum:

$$P_D=P_{pef}(0.69+S_F) \quad (1)$$

Under the maximum:

$$P_D=0.14+1.38P_{pef} \quad (2)$$

Where: $P_{pef}$ is the effect coefficient of production pressure, while $S_F$ is the safety coefficient.

Based on the method of variable pressure drop, two gas lift design methods are compared by taking well X as an example, and the results are presented in Table 1.

***Table 1.*** *The comparison between the constant and variable pressure drop methods.*

| **Design method** | **Conventional design method** | **Variable pressure drop method** |
|---|---|---|
| **Design principle** | **Constant pressure drop between valves** | **Variable pressure drop between valves** |
| Pressure drop between valves/MPa | 0.34 | n $P_t$+$P_D$ |
| Final drop of casing pressure (7 stages of valves)/MPa | 2.1 | 1.6 |
| Utilization rate of gas injection pressure/% | 75 | 81 |
| Vertical depth (average) of gas injection point/m | 2,850 | 3,126 |

Note: The gas lift valve's OD and port are 25.4mm and 3.18mm, $P_{pef}$=0.043841, $P_D$ minimum value is 0.06MPa and the maximum value is 0.2MPa, n is stress coefficient of casing and tubing, and $P_t$ is production stress.

It can be seen from Table 1 that the constant pressure drop of casing pressure gas lift design method adopts the same pressure drop between valves, and the loss of gas injection pressure is quite big; while, in the variable pressure drop of casing pressure design method, pressure drop between valves are adjusted by the actual needs and the loss of gas injection pressure is small. Therefore, when applying the variable pressure drop method, the location of gas injection point is deepened and the efficiency of gas injection is increased.

## 3. Process String and Main Tools

### *3.1. Integrated Gas Lift Completion String and Its Principle*

Integrated gas lift completion string is composed of 8 stages of retrievable gas lift mandrels (with gas lift valves), 2 stages of sand jetting fracturing sliding sleeves, slickline sliding sleeves, packers, ballseat, tubings, etc. (Figure 1).

The working principle [8-15] is as follows. The integrated gas lift string runs into downhole in accordance with the process design, and the depth discrepancy for each tool shall be less than 5m. The packer should be set and prepared before fracturing. During fracturing, the ball shall be dropped and then the lower layer will be fractured. When the lower layer's fracturing is accomplished, another ball shall be dropped for the second time to fracture the upper layer. When fracturing is over, the oil production wellhead shall be used. Preparation for drainage shall be made. During drainage, throttling at wellhead is not allowed. Gas shall be injected into the annulus by the compressor. The high pressure gas will drive the fluid level down in annulus while the annulus fluid and high pressure gas will enter into the tubing through gas lift valves, the fluid and the gas will be mixed together. The density of liquid column is decreased and therefore, the bottom fluid pressure is decreased and the quick flowback of the residual fracturing fluid is realized. The drained fluid will flow to the blow down pit via the flowline. Meanwhile, the gas with $H_2S$ is lit. After drainage, continuous gas lift production will start, fracturing, drainage, induced flow and gas lift is a continuous process, to achieve the target of efficient operation.

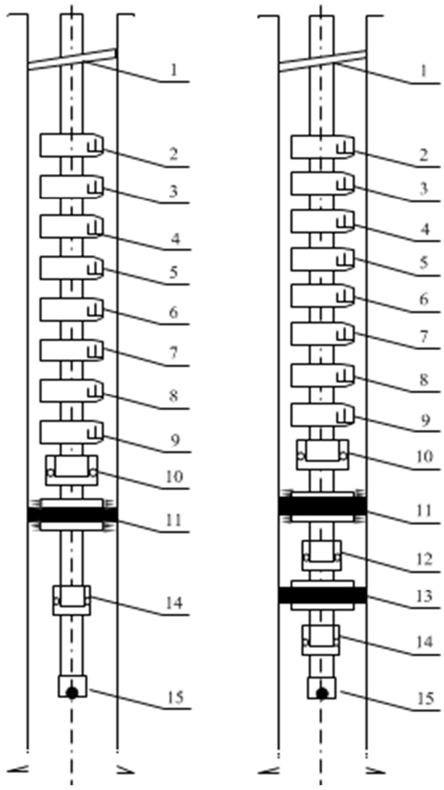


***Figure 1.*** *Commingled and zonal integrated gas lift completion strings.*

1- tubing; 2-gas lift mandrel (with gas lift valves); 3-slickline sliding sleeve; 4-Y455 packer; 5- sand jetting fracturing sliding sleeve; 6-K344 packer; 7-ball seat

### 3.2. Retrievable Gas Lift Mandrel

The gas lift mandrel for fracturing and drainage is up to meet the following requirements: (1) Capacity of enduring high pressure (like 90MPa); (2) Large fluid flow passage, to satisfy the requirements of quick drainage (Keep its ID is the same as Φ88.9mm tubing's ID); (3) Having retrieving function as the conventional gas lift mandrel. For this purpose, KPX-140 one-piece forged retrievable gas lift mandrel is designed as shown in Figure 2.

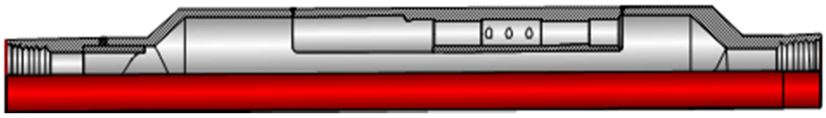

**Figure 2.** *One-piece forged retrievable gas lift mandrel.*

The key points of this tool are one-piece forged structural design and manufacturing process. One-piece forging has replaced piece-wise welding processes. The welding seams are eliminated. The concentration of stress at side-pockets and connecting joints are decreased greatly. The working pressure of the tool has been improved significantly. In the meantime, the design of side pockets on both sides is adopted. The mandrel body has 2 axes, the side pocket axis for fluid passage and the side pocket valve seat axis, which are distributed on both sides of axis of the tool and are on the same plane. This design maximally increases the diameter of fluid passage by using the radial space, thus solving the problems of small outside diameter, large passage and high pressure bearing. Meanwhile, special process treatments make the tool capable of satisfying the requirements of corrosion resistance. As a result, the adaptability of the tool is enhanced greatly. Furthermore, the gas lift valves in side pockets can be retrieved and run by slickline operation so that the replacement of malfunctioned gas lift valves or the adjustment of the gas lift valves can be done without tripping strings.

The working pressure of retrievable gas lift mandrel is 70MPa, maximum OD is 140mm, minimum bore is 73mm and the length is 2,066mm.

Forging replaces piece-wise welding processed and the welding seams are eliminated. The concentration of stress at side-pockets and connecting joints are decreased significantly so that the working pressure of the tool improves greatly. In the meantime, the design of side pockets on both sides is adopted. The mandrel body has 2 axe.

### 3.3. Retrievable - Drillable Packers

There are a few requirements for gas lift completion packers in deep well fracturing: (1) High capacity for pressure differential bearing and ability of satisfying the fracturing requirements; (2) High hermetic performance to satisfy the requirements of gas lift injection; (3) Retrievable nature to decrease the risks and high cost of milling and drilling; (4) Reliability, it can overcome creep of string caused by variations of down hole's high temperature and pressure for a long time. Structure of the retrievable-drillable Y455 packer is shown in Figure 3.

**Figure 3.** *Retrievable - drillable packer.*

This packer is a type of double-slip hydraulic packer and its capacity for bearing bi-direction pressure differential is 90MPa. It integrates retrievability of retrievable packers, drillability of drillable packers and high hermeticity, etc., applying modular design, thus, the components between packers can be easily transplanted and exchanged, making it very convenient for overseas field operation.

String design: Y455 packer is used as the top packer of the string (stage 1). During zonal fracturing, K344 packer is adopted as the second stage packer. The advantages of this packer are double-slip design and high stability. During fracturing, the upper reservoir casing will not bear high pressure; during production, the annulus gas will be prevented from entering the bottom of the tubing; during operation, the killing fluids will be prevented from entering formation, so, the possible oil contamination will be prevented; special tools can be run in for releasing operation; on special occasions, releasing operation can be achieved by drilling or milling, featuring safety and reliability.

For the retrievable-drillable packers, the operating pressure differential is 70MPa, maximum OD is 150mm, minimum bore is 76mm and the total length is 1,650mm. The setting pressure is 18-22MPa and the working temperature is 120°C.

### 3.4. Slickline Sliding Sleeve and Fracturing Sand Jetting Sliding Sleeve

The main functions of slickline sliding sleeve is to provide the circulation passage for string to in killing or flushing operations. By slickline winch, dedicated displacement tool can be run in to achieve repeating on and off operations and the working pressure can be 90MPa.

The fracturing sand jetting sliding sleeve is mainly used as a flow passage for fracturing and production fluids. During fracturing, the dropping ball can open fracturing passage for fracturing operation.

# 4. Technical Indices and Process Characteristics

### *4.1. Technical Indices*

Working pressure: 70MPa
Working temperature: 120°C
Minimum bore of tool: 73mm
Casing ID: ≥157mm
Well depth: 4,000m

### *4.2. Process Characteristics*

(1) Integrated gas lift completion string has 5 functions, including zonal fracturing, fracturing fluid flowback, reservoir protection, gas lift production and trouble-shooting for slickline retrieving. The operation continuity is good, the efficiency is high (without tripping string) and the total cost is low.

(2) After fracturing, drainage operation can be conducted continuously. For low formation pressure coefficient reservoirs, the reservoirs can be protected. Meanwhile, the secondary contamination due to string tripping can also be prevented, and the production time of is extended.

(3) After drainage, gas lift production can be triped out directly. This can induce flow and increase well production.

(4) Gas lift oil production can significantly lower bottom hole flowing pressure, thus improving fracturing performance. At the same time, it takes the advantage of the existing gas sources and the laid gas supply pipelines, requiring few equipments and simple processing.

(5) The string is equipped with flushing passage. Flushing and killing can be achieved by opening and closing the sliding sleeve, increasing the operation's safety and reliability

# 5. Field Application and Performance

From 2012 to 2017, the integrated gas lift completion string has been applied in Kazakhstan for 47 wells. For single well, the design of 7 to 8 stages of gas lift valves reached a gas injection depth as deep as 4,287.63m, and the lifting of ultra-deep reservoirs therefore was realized. The highest fracturing pressure was 68MPa and there was no phenomena of leakage or channeling of string, resulting in a 100% success rate in application. The average drainage duration was 3d after fracturing. The flowback rate was over 90%, which is 6.5d shorter than the conventional flowback operation. The service life of the string, on average, was 5 years, and the longest was 7 years, accomplishing a result of trouble shooting of gas lift valves for over 20 wells without tripping string.

Integrated gas lift completion string makes the wells of stopping flow and the low production wells reproduce. The successful rate in application reached 100%, the commissioning rate was 98%, the highest single well oil rate was 130t, the average oil rate was 23 t/d, and for 5 consecutive years, there was no safety and environment accidents. The integrated gas lift completion string can help to achieve the objective of increasing oil production while meeting the safe operation requirements.

# 6. Conclusions

(1) Integrated gas lift completion string has 5 excellent functions, and its application is featured of simple process, reliable string, long effective duration and low costs so that it is of great value for wide application.

(2) By using the variable pressure drop design method, the gas injection depth is improved, the production pressure differential is effectively increased, the single well production is enhanced and the gas lift operation for ultra-deep reservoir is achieved.

(3) By decreasing string tripping operations, possible oil contamination caused by tripping string in low pressure reservoirs and the construction risks associated with high GOR reservoirs can be effectively avoided, therefore, increasing the overall operation safety.

(4) This string's development enhances the application fields of gas lift recovery technology, providing technical support for low-cost and efficient development of overseas oilfields.

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# Biography

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