A review of key tools for oil pipe blockage operation in gas wells under pressure

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abstract: Blockage in tubing is an important guarantee for gas wells under pressure. The internal blockage is to close the channel inside the tubing through a sealing device, the pipe string can be lifted and lowered under pressure. In order to prevent natural gas from leaking through the tubing channel during well completion and string lifting operations, a plugging tool in the tubing is required to block the tubing channel, and the blockage is removed after the operation is completed to effectively control the pressure in the well. This article starts with the key tools related to internal plugging operations in Snubbing operation, introduces the basic principles of setting the internal plugging barriers when running the tubing string in completion operations, and introduces the key tools for internal plugging when the tubing runs in completion operations. The internal plugging method of the pipe string under pressure is introduced. The key tools (bridge plugs) and setting methods that have been matured or formed at home and abroad when the pipe string is lifted in workover are introduced. Well technology and key tool selection provide reference. Finally, we analyze and think about the domestically developed self-developed internal plugging tools for pressurized operations in my country. It is believed that internal clogging is not an isolated process of oil, gas, and water plugging, but is usually a process of multi-system construction processes working together. The key domestic tools and equipment also need to further improve their autonomous capabilities in terms of overall performance and stability, as well as intelligence.

1. Introduction
Oil and gas well Snubbing operation device is an important guarantee for the whole process of pressure operation, and the internal plugging operation is the basic premise of pressure operation. Internal plugging is the sealing of the tubing by means of a sealing device and internal plugging of the tubing, which allows the string to be pulled down under pressure. In completions and string trips, plugging operations are needed to effectively control the pressure in the well\textsuperscript{[1-3]}. In order to balance the large up-lift force that downhole pressure creates on the string, Pressure machine and downhole plugging tool are combined operations. There are two types of plugging operations in pressure operation. One is plugging operation in the tubing in the completion operation, and the other is...
plugging operation in the string in the workover operation. The internal plugging process for downhole tubing is relatively easy to complete by installing a rupturing disc, blind plugging, or soluble plugging device (one type) at the wellhead. Up the use of tubbing string jam plug and form a complete set of technical equipment, the drill will be blocked for cable or wire before delivery to the design depth, drill down before install the plug on the tubing string, blocking the oil casing pipe connected, and then down to the design depth, through special methods to remove congestion, communication between the oil casing pipe connected, process technology of gas Wells with pressure operation[4-6].

This article starts with the key tools related to internal plugging operations in snubbing operation, introduces the basic principles of setting the internal plugging barriers when running the tubing string in completion operations, and introduces the key tools for internal plugging when the tubing runs in completion operations. The internal plugging method of the pipe string under pressure is introduced. The key tools (bridge plugs) and setting methods that have been matured or formed at home and abroad when the pipe string is lifted in workover are introduced. Well technology and key tool selection provide reference. Finally, analyze and think about the domestically developed self-developed internal plugging tools for pressurized operations in my country. It is believed that internal plugging operations are not an isolated oil, gas, and water plugging process, usually co-extrusion, testing, fracturing, acidification, etc. The process of working together with special construction techniques. It is also necessary to further innovate, introduce, improve, and develop in accordance with the technological development of key tools for plugging in my country at this stage, and systematize and serialize the plugging operation and process technology in pressurized operations.

2.  Development of blockage in the lower tubing and key tools

2.1. Basic principles of setting up the blocking barrier in the lower tubing

The selection of plugging tools in the tubing is mainly based on the pressure in the tubing to control the selection of tools [7-8]. According to the pressure, single rupture disk and double rupture disk are used. Table 1 is the common recommended practices for tubing plug and rupture disk.

There are six main principles for setting blockage barriers in tubing. 1) When the downhole string is equipped with a seatdown joint and in good condition, the plug matching with the seatdown joint should be selected first; 2) When there is no seat setting joint or joint failure of the downhole string, steel wire plug or cable bridge plug is preferred; 3) If two plugs are used for plugging, the setting position of both plugs should be on the same tubing; 4) The tubing blind plugging tool and/or fracture plate are preferred for the newly run completion string, and at least one seat setting joint should be installed; 5) For horizontal Wells or highly deviated Wells, at least one seat setting joint should be placed above the screen at the bottom of the pipe string and above the inclination point; 6) Two single-flow valves should be selected as the pressure control tools in the tubing. The single-flow valve should be able to meet the diameter requirements of the lower tools, such as steel balls and darts.

Tools for plugging in the tubing include tubing plugs, cable bridge plugs, wire bridge plugs, check valves, rupture disks, blind plugs, etc. Generally, domestic completion tubing does not have a working cylinder that can seat plugs, so the tubing is blocked You can only sit on the tubing body without a mechanical blocking position. At the same time, pit corrosion is easy to form on the inner wall of the tubing, which affects the sealing effect of the plugging tool, and the seat seal is not strong or even falls into the well. This will bring great well control risks to the snubbing operation. Internal plugging tools should be standardized from the number of plug settings, design, structure, selection, inspection and verification, monitoring, etc.

3. Overview of the internal blockage method of the pipe string under pressure

Daqing Oilfield proposes three methods for plugging in the pipe string [9-11]: plugging the pipe string above the protection packer, plugging the pipe string above the water distributor, and blocking the entire pipe string above the check valve. By blocking and protecting the string above the packer, the tubing plug is delivered into the upper tubing of the protection packer, and the tubing plug rubber cylinder is self-sealing.
or compressed rubber cylinder to seal the inner wall of the tubing. This method uses slider-type tubing plug and static pressure intelligent tubing plug as shown in the figure.

![Slider type tubing plugger & Static pressure smart tubing plugger](image1.png)

The plugging method used to plug the pipe string above the water distributor is the eccentric water distributor plug. The outer diameter of the water distributor plug is $\phi 44$mm, which can plug the main hole of the water distributor, but the success rate of plugging is low, which is not suitable for bridge type. The eccentric water distributor is blocked by the layered water injection pipe string. At present, the plugging method of the pipe string above the plugged water distributor is rarely used.

![Eccentric water distributor plug](image2.png)

To block the entire string above the check valve, a $\phi 42$mm small diameter tubing plug is used. Before the water injection well is under pressure, use a test winch to remove all the water distributor nozzles of the well, put them in the dead mouth, and then use the test winch. Throw the plug of $\phi 42$mm small diameter tubing to the upper part of the check valve, and press the plug at the wellhead to block the plug inside the tubing and block the entire string.

![Small diameter tubing plug](image3.png)

### 4. Overview of the development of key tools for internal plugging of pipe strings under pressure

#### 4.1. Development status of bridge plug

The function of the bridge plug is to seal the oil and gas wells. It has the characteristics of fewer construction procedures, short period, and accurate sealing position. The development of bridge plugs is mainly divided into permanent bridge plugs and accessible bridge plugs. Permanent bridge plugs began in the 1980s. The emergence of this type of bridge plug replaced the process technology of cement bridge plug sealing. Halliburton designed EZSV packer and bridge plug, EZSVB improved packer and bridge plug. Schlumberger designed BKR type cement retainer is a typical representative of permanent bridge plugs$^{[12]}$. EZSV type permanent bridge plug can be fed in by drill pipe or tubing, operated by rotating and moving the working string up and down, and can also be transported by cable. The Halliburton bridge plug parameters are shown in the table$^{[13]}$. In 2015, Schlumberger developed the fully degradable bridge plug perforation combined system Infinity, which replaced the bridge plug with a fully degradable fracturing ball and ball seat to seal the layer. This system is the first full borehole bridge plug perforation system in the oil and gas industry that does not require intervention. It does not require milling operations, and does not generate bridge plug debris and affect surface equipment$^{[14]}$. 

![Bridge plug parameters](image4.png)
Table 1 Halliburton Bridge permanent plug EZSV type parameters

| Size   | Maximum Applicable Temperature | Can Withstand External Squeezing Force/PSI | Can Withstand Internal Squeezing Force/PSI | Maximum Endurance (with LID) (KG) | Maximum Endurance (no LID) (KG) |
|--------|--------------------------------|------------------------------------------|-------------------------------------------|----------------------------------|-------------------------------|
| 7"     | 177°                           | 10000                                    | 8000                                      | 45359                            | 18144                         |
| 9-5/8" | 177°                           | 7500                                     | 9000                                      | 45359                            | 22680                         |
| 13-3/8"| 121°                           | 5000                                     | 9000                                      | 45359                            | 22680                         |

Domestic Xi’an Kecai Energy Equipment Co., Ltd. has developed a permanent bridge plug for blocking the bottom layer and selective fracturing of 5 1/2" cased wells. As shown in the figure. The bridge plug consists of a central tube, an upper cone, a lower cone, upper slip, lower slip, rubber cylinder, anti-outlet ring, tension rod, lock ring, etc. The maximum outer diameter is 114mm, the length is 485mm, the working temperature is 120°C, and the maximum working pressure is 50MPa. The sealing load is 160~200kN. The permanent bridge plug has a simple structure and fast lowering speed. It can be set by cable or hydraulic pressure. The maximum working outer diameter of the removable mechanical setting bridge plug developed by Donghao Puyang City is 114mm and the total length is 557mm. The setting pressure difference is 35~70MPa, and the working pressure difference is 35MPa. The structure has the characteristics of simple structure, stable performance, and repeatable setting. The removable bridge plug tool developed by Dezhou Zhonglian Petroleum Machinery Co., Ltd. consists of a setting mechanism, Anchoring mechanism, sealing mechanism and other parts. It adopts a unique self-locking structure and has a reliable two-way pressure bearing function. It can achieve reliable sealing without auxiliary sealing. In summary, domestic permanent bridge plugs have also been rapidly developed in recent years. And the development of desirable bridge plugs, especially desirable bridge plugs, has been greatly improved, but there is still a big gap between foreign advanced technology, especially overall performance and stability, and intelligence.

Figure 4. The permanent bridge plug produced &The desirable bridge plug developed

Table 2 Types and basic working parameters of bridge plugs produced

| Manufacturer          | Type                     | Maximum outer diameter (mm) | Total length (mm) | Setting pressure difference (kN) | Working pressure difference (MPa) |
|-----------------------|--------------------------|-----------------------------|-------------------|---------------------------------|----------------------------------|
| Xi’an Kecai           | Permanent bridge plug    | 114                         | 485               | 160~200kN                       | 50                               |
| Puyang Donghao        | Desirable mechanical setting bridge plug | 114                      | 557               | 35~70MPa                        | 35                               |
| Zhonglian             | Desirable bridge plug    | 114                         | 1300              | 18~20MPa                        | 50                               |
| GWDC                  | Fully soluble bridge plug | 88.9~139.7                 | -                 | 35~70MPa                        | 70M                              |

4.2. Development and application of bridge plug setting method

According to the setting method, the bridge plug is divided into mechanical, hydraulic setting and multi-stage non-explosive hydraulic setting[15-16]. Mechanical setting of steel wire bridge plugs, wire seat seals and recovery bridge plugs (wire bridge plugs) are developed to complete the completion of oil and gas porous type wells and oil and gas well completions. The purpose is to reduce operating costs by using mechanically seated bridge plugs. Commonly used combination tools are: running tool, 501-2875-01-11 w/1-1/2” QLS; fishing rod, 503-2875-00-01; fishing tool (Otis), 2-1/2” GS
(40GS21800); X-type variable buckle, 1.75” outer diameter 14UN. The structure of mechanical setting steel wire bridge plug and its combined tools are shown in the figure.

Figure 5. Structure of mechanical setting steel wire bridge plug

The hydraulic setting tool is a setting system controlled by electronics, electricity, and hydraulics. It can be used to seat recyclable bridge plugs or permanent bridge plugs; the main components: seat seal motor, seat seal pump, motor battery, electronic controller, electronic timer, thermal insulation sheath.

The multi-stage non-explosive hydraulic setting tool is composed of key components such as controller, timer, motor battery, motor and hydraulic pump, and thermal insulation sheath. The timer is used to control the start and end time of the seat seal. The controller is responsible for controlling the working process of the motor battery and the motor. The motor battery is responsible for powering the motor, the motor is responsible for converting electricity into mechanical force, and the hydraulic pump is responsible for converting the motor mechanical force into hydraulic pressure. Driving force.

Comparative analysis at home and abroad can find that the development of bridge plugs abroad is more systematically based on the systemic development of blockage, deblocking, efficiency, risk and cost. Bridge plug operation is not an isolated process of oil, gas, and water plugging. It is usually a process that works together with special construction techniques such as squeezing, testing, fracturing, and acidizing. According to the current development of bridge plug technology in my country, bridge plug technology needs to be further innovated, introduced, and improved.

| Table 3 Common parameter combinations of hydraulic setting tools |
|------------------|-------------|-------------|-------------|-------------|
| Tubing size      | 2-3/8”     | 2-7/8”     | 3-1/2”     | 4-1/2”     |
| Maximum outer diameter | 1.75”     | 2.22”     | 2.72”     | 3.75”     |
| Minimum inner diameter | 0.650”    | 1.00”     | 1.312”    | 2.19”     |
| Seating range    | 1.75”~2.05” | 2.22”~2.55”| 2.72”~3.05”| 3.75”~4.02”|
| Seat seal pressure (PSI) | 8000       | 8000       | 8000       | 20000      |
| Maximum working pressure difference (PSI) | 7500     |
| Medium environment | H2S        |
| Maximum downhole temperature (°C) | 200 C     | 200 C     | 200 C     | 200 C     |
| Seating method   | Wire work, cable work Coiled tubing operation | Wire work, cable work Coiled tubing operation |
| Unblock recycling method | GS type recycling tools and general recycling procedures | GS type recycling tools and general recycling procedures |

5. Conclusion
This article starts with the key tools related to internal plugging operations in working under pressure. It introduces the basic principles of setting the internal plugging barrier when running the tubing string in completion operations. The internal plugging method of the pipe string under pressure is introduced. The key tools (bridge plugs) and setting methods that have been matured or formed at home and abroad when the pipe string is set up for workover are introduced, and the following main conclusions are obtained.

(1) The selection of blocking tools in the tubing is mainly based on the selection principle of the
pressure in the tubing to control the tool. According to the pressure, it is decided to adopt a single rupture disk or a double rupture disk. Internal plugging tools should be standardized in terms of the number of plugs, design, structure, selection, inspection and verification, and monitoring.

(2) Introduce the three commonly used methods for inducing blockage in the pipe string, namely, plugging and protecting the pipe string above the packer, plugging the pipe string above the water distributor, and blocking the entire pipe string above the check valve. The characteristics of internal blockage during well-lifting pipe string operation are introduced to provide ideas for on-site process selection.

(3) Introduce the key tools (bridge plugs) and setting methods that have matured or formed a series of strings at home and abroad when starting workover. It is found that there is a large gap between domestic and foreign individual tools, especially the overall performance and stability. There is still a big gap in terms of sex and intelligence.

(4) There is still a lot of room for growth in my country's domestically developed independent research and development of internal plugging tools under pressure. The author believes that the key to improving my country's internal plugging key tools is to change the single thinking mode. It is mainly embodied that the internal plugging operation is not an isolated oil, gas, and water plugging process, but is usually a process that works together with special construction techniques such as squeeze injection, testing, fracturing, and acidification. Then, it is necessary to further innovate, introduce, improve, and develop according to the technological development status of key tools for plugging in my country at this stage, and systemize and serialize the plugging operation and process technology in the pressurized operation. So that the domestic key equipment and tools have truly developed and made breakthroughs.

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