The research and application of coiled tubing technology of horizontal well in drainage gas recovery

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Abstract. The Su 75 block is a typical low-permeability, low-pressure and low-abundance gas field, 89.6 percent of the gas wells are water-bearing, so it makes the drainage gas recovery become vital means for sustainable development. Recently, the main drainage gas recoveries are the foam drainage gas recovery, plunger drainage gas recovery, compressor/nitrogen gas lift and so on. These measures do not work in all water-bearing gas wells, especially for horizontal wells of big-size production string and gas wells of low entrainment capability. Based on the characteristics of drainage gas recovery and the applicable condition analysis, drainage gas recovery technology of downhole small diameter tubing of the horizontal wells without well killing is put forward. The feasibility was analyzed theoretically, and field experiment was carried out with remarkable effect.

1. Introduction

Su 75 block is located in the northwest of Sulige gas field with area of 989 km². It is a typical low-permeability, low-pressure and low-abundance gas field. It was put into production in 2009, the annual gas production capacity is $8 \times 10^8$ m³. But most of gas wells produced water, which is the main reason for the production decline. After field survey analysis, the proportion of gas wells in Su 75 block increased from 30.2% to 89.6%, increasing year by year. The number of gas wells producing water was large, the gas-water relationship was complex, maintenance production of gas wells with water breakthrough was difficult, and loading liquid seriously affected the normal production of gas wells, which reduced the gas field development benefit.

The drainage gas recovery technology research and application was carried out in Su 75 block in 2012. With the improvement of development level, the formation energy attenuated, the impact of water production was increasingly serious, and the size of drainage gas recovery was expanded year by year. In the past three years, the increased gas productivity by drainage gas recovery is $1 \times 10^8$ m³, greatly improved the stimulation and stable yield effect. At the meantime, with the gradual development of gas field, formation pressure was declining, liquid carrying capacity of gas wells was lower and lower, different degree of wellbore loading liquid caused production reduction or shut down. Especially for horizontal well, the production string size was large and liquid carrying capacity was poor, other drainage gas recovery measures cannot effectively solve the problems. In production process of this kind well, new drainage gas recovery is badly in need to carry fluid continuously and produce gas stably. Su block 75 implemented experiments on downhole small diameter tubing of the
horizontal wells without well killing drainage gas recovery technology in 2016, achieving a prominent effect of stimulation and stable yield. It explored a new way for drainage gas recovery technology.

2. The design and optimization on drainage gas recovery technology of downhole small diameter tubing of the horizontal wells without well killing

2.1 tools equipment
The main tool equipment includes tubing plugging device, gas lift valve, small cross, macaroni tubing and tubing hanger, triple ram preventer, annular blowout preventer, the hydraulic control system, etc.

2.2 Technology Principal
When the gas field development entered the middle and later periods, if gas wells cannot establish the drainage gas working system with relatively stable pressure, gas production and gas water ratio, they will shift into batch production or halt production. By using the critical carrying fluid flow principle, the small diameter tubing is put into the original well tubing, making full use of their own energy to improve the critical flow velocity of carrying liquid and control erosion damage, so as to achieve the aim of drainage gas and long-term stable production. At the same time, through the calculation, different gas lift valve is installed in different depth of coiled tubing. When loading liquid causes water out of gas wells, small annulus is used to inject high pressure gas. Then a number of gas lift valve installed on the tubing string are started step by step, to reduce mixture density upper the valve hole, thereby restoring the water flooded gas wells to product.

2.3 Completion process
First, according to the design requirements, drifting operations is needed with steel rabbit wire, in order to make wellbore unobstructed and put tubing plugging device down to the desired location. After successful drifting, tubing plugging device is laid down to designed position with steel and set, to plug tubing. Then open lubricator purging valve, tubing will decompress and seal. After tubing pressure reliefs to 0MPa, observe the wellhead pressure 4 hours, to make sure no well control hazards. Close wellhead master valve, extract wellhead christmas tree, install wellhead small cross and BOP stack, and make pressure testing on small cross and triple ram preventer (BOP pipe ram) until qualified. Then lay small diameter tubing string with gas lift valve down to the designed depth, install a small diameter tubing hanger and recovery wellhead. Nitrogen cars or natural gas compressors are use to pressurize to make tubing casing annulus communicate. At last, weld ground process. Gas nipple is added to the ground process to prevent the freezing and walling, to control the production pressure.

2.4 Wellhead working diagram
In Figure 1, NO.1 is triple ram preventer, NO.2 is small cross, NO.3 is small cross, NO.4 is gas lift valve, NO.5 is casing, NO.6 is first tubing, NO.7 is second tubing, NO.8 is plugging device, NO.9 is plug retrieving tub; NO.10 is annular blowout provender.
2.5 Technology optimization

(1) Design the tubing plugging device, solving problems that well killing causes formation damage and affects the normal production of gas wells.

The tubing plugging device is put into the original string by steel to plug the tubing bottom. The borehole pressure is higher, the block is more closely. If the current production tubing string is changed to small diameter tubing (with gas lift valve), well killing must be carried out which will lead killing fluid to loss to the formation massively, damage formation, and even unable to return to normal. The method avoids this problem.

The velocity string drainage gas recovery (coiled tubing) has much weakness, for example, measures cost is high, string intensity is low, and when the formation pressure decreases to a certain extent, loading liquid can't discharge due to the inability to put the gas lift valve, even if the gas lift measure is taken. The process lays down small diameter tubing (with gas lift valve). After completing wellhead, the small piston inside the plug could be opened when pressure inner tubing grows up to the certain value, to establish connectivity between casing and reservoir.

(2) Design multistage gas lift valve and calculate opening pressure of gas lift valve. It solves the problem that wellbore fluid can't be discharged effectively because of big back pressure of the ground construction caused by high fluid column pressure.

Nitrogen gas (gas) is injected to the annular space between small tubing and original tubing until the pressure (differential pressure) of gas lift valve increases to the designed value. Open the gas lift valve step by step and discharge liquid inner wellbore and on the well bottom. Later, by using this well energy and annulus differential pressure, the gas lift valve will open by itself, prolonging flowing life of gas wells.

Table 1. Technical parameters of gas lift valve

| parameter                  | CQT-66         |
|----------------------------|----------------|
| external diameter (mm)     | φ66            |
| overall length (mm)        | 550            |
| Inner drift diameter (mm)  | 26(17)         |
| bore diameter of seat (mm) | 3.2            |
differential pressurization (MPa) 35
primary gas lift valve (MPa) 4.859
Secondary gas lift valve (MPa) 6.288
Triple gas lift valve (MPa) 6.624
Quarternary gas lift valve (MPa) 6.964

(3) Optimize the production string size and improve liquid carrying ability of gas wells.
When natural gas production is higher and the velocity of vertical flow is greater than the critical point, the gas could bring water to the ground. When the velocity is lower than the critical point, some of water slips to the wellbore. When the wellbore fluid reaches a certain level, it will cause waterflooding. So liquid carrying ability of gas well is to solve the relationship among liquid yield, the critical flow velocity and sectional area of tubing.

Based on actual production situation of Su 75 block, the critical liquid carrying velocity of gas well in the normal production is:

$$u_g = 3.15 \left[ \frac{\sigma (\rho_L - \rho_G)}{\rho_G^{0.25}} \right]$$

$u_g$ is the critical flow velocity of carrying liquid, $\sigma$ is interfacial tension, $\rho_L$ is liquid density, $\rho_G$ is gas density.

Liquid yield = the critical liquid carrying velocity × sectional area ×time.

When production decreases, if flowing production for a long time is desired, only lessening the cross-sectional area of string can ensure the critical carrying fluid velocity constant.

In the gas well production string optimization, multiple factors are generally needed to be considered: tubing liquid carrying ability, tubing erosion degree and pressure loss, the pipe string strength, pipe string service life, the proration range and so on. The tubing liquid carrying ability and tubing erosion degree are two important factors which must be considered.

Through the string carrying fluid calculation and the erosion degree safety analysis, in combination with the wellbore pressure test results in recent years of Su 75 blocks, the production string is optimized that within tubing of 88.9 mm (76 mm of inner diameter), small diameter tubing of 33.4 mm (26.64 mm of inner diameter) is laid.

3. Field application effect evaluation
In 2016, two wells in Su 75 block applying coiled tubing technology of horizontal well in drainage gas recovery are successfully experimented. After 2 months production, the cumulative production gas volume is 404 ×10^4 m^3.

3.1 application effect of well Su 75-1H
Horizontal well Su 75-1H is put into production in 2012. In early deliverability test, orifice is 27 mm. Under the condition that the average gas production is 5.0347 ×10^4 m^3/d, oil pressure is 15.56MPa, casing pressure is 17.05MPa, daily fluid production is 9.2m^3. The chloridion content is 30520 mg/L. The open flow capacity is 19.25 ×10^4 m^3, the pressure coefficient is 0.73, the flowing pressure is 21.84MPa/3300m, the static pressure is 24.60MPa/3300m.

The proration is 4.0×10^4 m^3. In the production process liquid is loading slowly. On April 13, 2016, the liquid level is measured. the tubing liquid level is 1540 m, casing liquid level is 2291 m. On May 7, capacity is verified, differential pressure transmitter is checked. Oil pressure increases from 1.29MPa to 1.31MPa, casing pressure is 9.08MPa constantly. On May 12, intermittent drainage is implemented. After 25 days of well off to recover pressure, oil pressure rises from 1.33MPa to 2.42MPa, casing...
pressure rises from 9.15MPa to 9.54MPa, the output is zero. Later, salvage choke, After 25 days of well off to recover pressure, oil pressure rises from 2.29MPa to 2.9MPa, casing pressure rises from 9.5MPa to 10.13MPa, gas production is zero when opening well. From analysis, due to the loading fluid is to a certain extent, water flush is cause and this well stops producing.

Figure 2. Production curve of Su 75-1H

On October 11, 2016, after implementing coiled tubing technology of horizontal well in drainage gas recovery technology, air tap of 6 mm is put into production on the ground. Before well open, the oil pressure is 10.83Mpa, casing pressure is 9.86Mpa. After opening well, the oil pressure is 4.04Mpa, casing pressure is 9.86Mpa. Daily gas production is $35000 \times 10^4 \text{m}^3$. Currently, the oil pressure is 1.38Mpa, casing pressure is 6.76Mpa, daily gas production is $16000 \times 10^4 \text{m}^3$. The measures effect is remarkable.

4. Conclusions and recommendations

(1) The drainage gas recovery technology can significantly reduce slip loss, reduce the bottom loading water, and significantly extend the gas well production cycle.

(2) In the production process, airtight annular space formed by first tubing and second tubing is used to produce, and can also be directly produced by small tubing (second tubing). With the extension of production time, when the formation pressure decreases to a certain extent and new loading liquid forms on the well bottom, nitrogen/natural gas compressor is used to kick off. When pressure reaches a certain value, the gas lift valve within second tubing is opened. Then loading liquid at the bottom is expelled, so as to realize recycle gas drainage gas recovery.

(3) The technology operates simply and works in short time with safety, reliability and no damage to formation.

(4) The successful application of coiled tubing technology of horizontal well in drainage gas recovery explores a new way for drainage gas recovery technology.

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