Common failures and solutions of check valve in gathering and transportation of produced crude oil

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Abstract. In view of the problems in pumping wells in the No. 4 Oil Production Plant of PetroChina Huabei Oilfield Company, such as frequent failures of check valves in daily production, long shut-down time during maintenance, impact on crude oil production and high safety risk during maintenance, a new type of double-control check valve has been invented. This check valve has the dual functions of ordinary lift check valve and stop valve, which avoids the unsafety in the operation process, improves the well opening time rate of pumping wells, and has the advantages of simple operation, long service life, simple structure, convenient repairing and recycling, and considerable procurement cost is saved.

Keywords: check valve, new type, gathering and transportation

1. Introduction
During oilfield development, the pumping unit drives the sucker rod and unit piston to do up-and-down reciprocal movement to bring the crude oil continuously to the surface from deep underground. This produced oil is routed to the metering station through single well pipeline. In order to prevent the backflow of oil in single well pipeline caused by pumping unit stopping or oil well not producing oil, a lift check valve is installed on the oil pipeline of single well to prevent oil/gas backflow.

However, in daily use, this type of check valve frequently breaks down, which, on the one hand, leads to the decline of liquid production and low system efficiency; and on the other hand, when the wellhead valve fails or the sealing gasket is washed out, it cannot be disconnected from other parts of the gathering and transportation system, so it can only be replaced after all the wells in the same system are shut down for pressure relief, resulting in a large workload and long consumption of time. Also, the annual cost of purchasing check valves is very high.

2. Failure occurrence
First the environment of underground media is becoming more and more complex. The corrosion and
erosion caused by formation fluid with high salinity and high sand content aggravates the leakage of tubing and oil well pump to a great extent, resulting in the backflow of produced liquid. The crude oil production is much lower than the output calculated by the geologists according to the work chart, but the real reason for the production fluctuation cannot be figured out. In addition, the check valve is buried underground for a long time, so it is easy to get rusted, causing the bolt of check valve to rust, hence it is impossible to remove the bolt for internal cleaning and maintenance of the check valve. Therefore, when the check valve goes wrong, it can only be replaced after stopping the well for pressure relief.

The main problem in the process of replacing check valve is that more than ten wells in the same loop system must be shut down before closing the manifold valve in the metering station. Generally, it takes 3-4 employees and 2-3 hours on average to complete. This will increase the risk of well sticking and pipeline congelation, and seriously affect oil production and well opening time rate. During pressure relief, the team/station must do a good job in oil and gas recovery. The oil and gas recovery process is so complex that there will be a risk of environmental pollution in case of carelessness, so it is urgent to solve the problem of check valve failure.

3. Causes of failure
By dismantling the replaced check valve, it is found that there are mainly four reasons for check valve failure which are shown in Table 1 below:

| No. | Table Column Head                                                                 | Proportion |
|-----|-----------------------------------------------------------------------------------|------------|
| 1   | Damage to the valve clack, causing the check valve not to be closed tightly        | 3%         |
| 2   | Damage to the valve seat step, causing the check valve not to be closed tightly    | 6%         |
| 3   | There is dead oil and wax block between the valve clack and the valve seat, causing the check valve not to be closed tightly | 81%        |
| 4   | The clearance between the valve column and the rising column is too large, resulting in loose closing | 10%        |

It can be seen from Table 1 that there is dead oil and wax block between the valve clack and the valve seat, which causes the check valve not to close tightly, which is the main cause of check valve failure. This is mainly because the oil in Yongqing oil production area of No.4 Oil Production Plant is high pour point crude oil with high freezing point (about 43°C) and high wax content. Moreover, the geological conditions of the fault block are complex and the reservoir is discontinuous. Some blocks where pumping wells are located have been in the state of insufficient liquid supply, and the oil wells are frequently producing intermittently. In addition, the slurry production in oil wells in this block is serious. When the liquid is intermittently produced, the stroke of the valve clack is blocked due to the solidification after the wax block and crude oil are mixed with slurry, so the valve clack cannot return to its original position, resulting in the failure of the check valve.

4. Troubleshooting
A closing tool has been developed which can quickly push the valve plate onto the valve seat without changing the shape of the check valve, which solves the problems of high labor intensity and easy well sticking accident in replacing the check valve using the present techniques.

4.1 Way of thinking
The dead oil and wax block are viscous, so they have certain mobility and plasticity but no hard jam after being subjected to external force, and not harm can be done to the valve body when external force
is applied to it. When the check valve fails, the valve clack can be pushed back to the valve seat by applying external force. Therefore, a dual control check valve has been developed, which can not only turn on/off the technological process based on the system pressure difference, but also can quickly close the valve plate when the check function fails.

4.2 Components and structure
The double control check valve is composed of PTFE seal ring, gasket for securing the flange at the upper part of the check valve, column guide flange, valve clack quick ejector pin, ejector pin anti-theft wrench, quick safety ejector pin cap, stainless steel anti-rust protection cylinder at upper part of check valve, protection cylinder fixing screw, protection cylinder quick pulling wrench, etc. (Fig.1)

![Fig.1 Schematic diagram of double-control check valve structure](image)

1- valve body; 2- valve clack; 3- column guide cover; 4- column guide flange; 5- valve clack quick ejector pin; 6- PTFE seal ring; 7- pure copper sleeve; 8- anti-rust protective barrel; 9- anchor nut; 10- pulling wrench on protective barrel; 11- screw cap on ejector pin

4.3 Material
The lead screw is the main stress component in the combined tool. Due to its small diameter, long length and capability of withstanding large pulling force, the high-quality 45# medium carbon steel is selected for processing to ensure stable performance of the tool and avoid bending or fracture, and the surface quenching is carried out after preparation and treatment to improve the thread hardness and other mechanical properties [1]. PTFE is used to seal the upper cover of check valve and quick ejector pin because it is a good self-lubricating material with high density, good resistance to high temperature, acid and alkali corrosion, insolubility in most solvents and small friction coefficient.

4.4 Working principle
The double control check valve retains the structural characteristics of the lift check valve and has the working principle of the stop valve. While the oil well is in normal production, the energy generated at the bottom of the well is high. After the self-weight valve clack of the check valve is jacked up, the liquid flows from the wellhead to the main manifold through the check valve clack. When the main manifold pressure is higher than the wellhead pressure, the valve clack will be pushed back to the valve seat by its own weight and the pressure of fluid backflow, so as to cut off the backflow of liquid. Once the valve clack is stuck, and according to the principle that the thread pair has the sealing function and converts the rotary motion into the axial linear motion and transfers the force, the circular motion force is applied to the quick ejector pin of the valve clack, and the valve clack is pressed down to the valve seat to cut off the fluid. As the dead oil, wax block and slurry have a certain fluidity under stress, the valve clack and valve seat will not be damaged and their strength will be reduced. Moreover, mechanical seal is used to prevent corrosion of fastening parts.

4.5 Development of key components
The most ideal structure for applying external force to the clack of check valve is the thread fitting structure, because the thread fitting surface can transmit the force and play a sealing role as well. As the
check valve is buried underground for a long time, the thread part must be well sealed to keep the fitting surface clean and lubricated. Otherwise, the screw thread will be corroded and damaged in the harsh underground environment, and the unclean soil will be brought into the thread fitting surface to destroy the screw thread. Therefore, the design scheme of the key parts is to process the internal thread of the column guide flange and the external thread assembly of the valve clack quick ejector pin, and add the ejector pin protection nut on the top of the column guide flange to prevent moisture and protect the thread actuator. In addition, in order to better protect the clack quick ejector pin, PTFE sealing sleeve is installed at the junction of the column guide valve cover and the column guide flange, which avoids the cutting effect between hard metals when the quick ejector pin of the valve clack passes through the interface of the two parts, and well protects the mechanical strength of the quick ejector pin. A stainless steel anti-rust protection cylinder is installed on the upper part of the check valve, which is connected with the screw thread of the lower flange of the check valve to realize double corrosion proof. The upper cover bolt is not easy to rust. In case of leakage, the crude oil will be sealed in the protection barrel, which will not contaminate the environment.

5. In-situ test and application effectiveness
After the successful development of the new double control check valve, it has been installed in some oil wells in Yongqing oil production area of the No.4 Oil Production Plant (Fig.2). Practice has proved that if the pressure cannot be released after each shutdown, it takes 3-4 employees 2-3 hours to stop pumping all wells on the loop line for pressure relief before repairing or replacing wellhead valves. In order to prevent oil and gas leakage from polluting the environment during the pressure relief process, employees also need to take various measures to recover oil and gas. After using the new double control check valve, only one staff member is required to excavate the soil layer on the surface of the check valve, remove the check valve anti-rust protection cylinder and the top protection nut on the ejector pin, and use a quick wrench to directly push the valve clack onto the valve seat, thus forcing the process to be cut off. It can be completed in 5 minutes without pressure relief, which not only reduces the labor intensity of employees, but also improves the work efficiency, effectively prevents environmental pollution, eliminates unsafe factors, effectively solves the actual problems in production, and achieves good economic and social benefits.

Fig.2 Schematic diagram of double-control check valve structure

6. Conclusions
- The double control check valve has the advantages of simple structure, reasonable design and convenient and quick operation. The operation time is cut down from 1-2 hours to 5 minutes, which greatly reduces the labor intensity of workers.
• With double protective cover, the probability of corrosion of stressed parts is greatly reduced, and the service life of valve is long.
• The key parts are above the valve body, which is convenient for repairing and recycling, and greatly saves the purchase cost.
• It effectively avoids the problems of long shut-down time, well sticking and other factors affecting crude oil production caused by maintenance and replacement of check valves. At the same time, the valve is safer, ensuring the normal production of oil wells and meeting the HSE requirements of enterprises.

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