Large Underground Water Seal Reservoir Jet Disturbance System

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Abstract. As crude oil is composed of colloidal solution, solid hydrocarbons, asphaltenes, and particulate sediments, in the long-term storage process, hydrocarbon mixtures and impurities in crude oil will gradually settle with gravity to form sludge, and underground crude oil reservoirs will be operated for a long time. There will be sludge deposits later. The high shear rate produced by the jet produces a large number of vortices and makes it entrained. This study combines the advantages of high-pressure jets, according to the actual operating conditions of underground storage, designed a set of reasonable jet disturbance system.

Introduction

According to the report of the US Energy Information Administration, China's total crude oil imports in 2017 were 8.4 million barrels per day, which exceeded the United State's 7.9 million barrels per day and became the world's largest importer of crude oil. With the rapid development of economy, energy demand has rapidly increased. The establishment of necessary strategic petroleum reserves has a very important role in ensuring national security, ensuring the sustainable development of the national economy, and responding to emergencies. In 2003, China officially launched the establishment of an oil reserve system.

Due to the advantages of underground water sealed oil storage caverne compared to other storage methods such as less land occupation, less investment, less loss, less pollution, low operating cost, high safety performance, and fast loading and unloading speed, this type of oil storage has been adopted by more and more countries [1]. When the crude oil is in a static storage state, the easy-to-coagulate substances in the crude oil carry the sediment under the action of gravity and deposit in the tank. The bottom forms semi-solid sludge deposits[2]. The long-term accumulation of sludge will not only affect the storage space, but also cause the oil quality to be uneven, which will seriously affect the economic benefits of the tank. With the enlargement of the tank capacity, this phenomenon will become more prominent. Crude oil stored in the ground will also deposit, and the problem of sludge deposition is more severe than that of storage tanks on land. For the management of the storage and transportation of large quantities of imported crude oil and long-term strategic reserves of crude oil, it is very important to reduce the sludge deposits.

Production of sludge in underground storage

Underground water sealed oil storage caverne are generally suitable for use as a reserve pool. Due to the low turnover frequency of crude oil and the long long period of standing of oil products, the quality of the oil within the caverne will be uneven. The underground giant cylindrical salt cave storage tanks in the United States are generally located 600-1200 meters underground. Due to the decrease of nearly 600 meters above and below the salt cavern, the natural temperature difference formed by the drop causes the oil to flow slowly in the well, so the crude oil always maintains good quality without precipitation and deterioration [3].The groundwater seal crude oil cavern reservoir is located below the groundwater table and is deeper than the ground surface. The drop in the cavern is generally 30 meters. When there is no oil in or out operation, the temperature field inside the reservoir is basically stable, which is not conducive to the slow flow of oil, therefore, the sludge deposits rate increases[4]. Based on the above characteristics, the production of oil sludge in underground water sealed oil storage caverne is unavoidable, and the sludge deposition becomes more and more inevitable over time.

Common oil sludge anti-deposition method for crude oil tanks

There are two common methods for solving sludge deposits on the ground tanks. One is to periodically clean the sludge. The other is to install a stirring device inside the tank to prevent sludge deposits.

Manual clearance method. After the oil tank is used for a period of time, the residual liquid in the tank is discharged, and the deposits on the inner wall of the tank and the bottom of the tank are cleaned through manual operations. The specific process is as follows Fig 1.

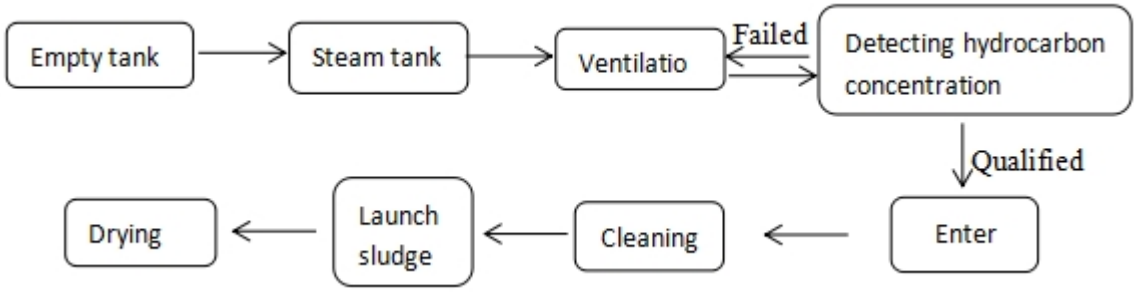

Fig. 1 flowchart of manual pigging process

This method will dispose of a large amount of useful resources as waste, resulting in extreme waste of resources, long artificial tank cleaning cycle, low efficiency, the safety of clear tank workers cannot be guaranteed, and it will cause serious pollution to the environment and cannot guarantee construction. The safety of the site and the avoidance of secondary disasters are gradually replaced by mechanical clearing methods [5-6].

Mechanical clearing method. The mechanical stirring method is a clearing method in which sludge is suspended in oil by agitation with external force. For oil tanks with small amount of oil sludge and small volume, propeller stirrers are often installed at the lower part of the tank; large tanks are equipped with multiple rotatable nozzles at the lower part, and they are used to inject water with pressure or use oil as jet agitation. The commonly used agitators are lateral thrusting agitator, rotary jet agitator, jet agitator and so on[7]. The mechanical clearing method effectively

solves the problem of sludge deposits in the storage tank, shortens the clearing cycle, does not cause environmental pollution and waste of crude oil, and is used in large quantities in actual production.

Compressed air method. A distribution pipe is installed at the bottom of the storage tank, a pipe hole is provided on the pipe, air is pressurized and then injected into the oil storage tank, and the oil is stirred by the pressure released by the air. This stirring method is simple and cost-effective. As the air is easy to make the oil stored in the tank oxidize, it can easily cause the volatilization of the oil, and the static voltage up to 1000V is generated, and the safety risk is large. Therefore, this method is not often used [8].

Lateral extension into the agitator. The laterally extending agitator is mainly composed of a motor, a speed reducer, a main shaft, a spindle support sleeve, a bracket and a propeller, and is mounted on the side wall of the oil tank through a flange connection. The working principle is to use the rotation of a single propeller blade in a motor-driven can to drive the medium in the oil tank to form an axial and circumferential flow in the direction of the propeller. According to the size of the tank diameter, multiple stirrers can be installed in the tank to ensure the omni-directional mixing of the oil in the tank [9]. The method overcomes the disadvantages of the past using compressed air blending, and has the characteristics of less investment, high efficiency, convenient operation, low power consumption, high quality of blended product oil, and low static electricity generated in the medium. However, there are different degrees of oil leakage problems during operation of this method.

Rotary Jet Mixer. The rotary jet agitator is mainly composed of a rotary nozzle, a turbine, a turbine shaft, a gear box, a housing, and the like, in addition to a circulating oil pump, a filter, a draft tube, and other accessories. The rotary jet agitator is generally installed at a relatively central position on the bottom of the tank. A circulating oil pump is used to transfer the oil to drive the turbine to rotate, and the transmission drives the fuselage to rotate. The oil is injected at high speed through the nozzle into the tank and passes through the jet beam to the surroundings. The suction and disturbance of the fluid achieve the effect of dissolving the sludge. Since the jet direction of the nozzle deviates from the center of the nozzle, the nozzle will be rotated 360° automatically due to the counter-power of the jet, so that the oil product will generate a turbulent flow and dissolve the sediment, which will act as an omnidirectional stirring. However, as the speed of the nozzle jetting fluid increases, the nozzle rotation speed also increases. Due to the nozzle rotates too fast, this will reduce the impact of the oil on the sediment and thus affect the stirring effect, so it is usually necessary to install a deceleration device[10].

Underground crude oil cavern jet perturbation device

The ground tanks are small in diameter, and underground tanks are not suitable for underground caverns due to their long length. The development of jet agitation on ground storage tanks has been relatively mature, but it is rarely involved in underground storage. Combining the advantages of jet agitation, a set of jet agitation system is designed. The cross section area of underground caverns is generally 600m^2, wide 20m, height 30m, length has different designs depending on the terrain. Therefore, it is of great significance to study a set of disturbance devices suitable for large-scale groundwater reservoirs.

System Components. A complete set of groundwater seal crude oil reservoir disturbance system is composed of three parts: high pressure jet disturbance system, monitoring system and ground control system. The high-pressure jet perturbation system consists of centrifugal pumps, filters, valves, nozzles, process tubes and accessories. It is a physical anti-deposition system that uses the same type of oil product and is fully mechanically circulated in a fully closed state. Two rows of

high-pressure jet lines are arranged at the bottom of underground caverns. Jet nozzle devices are installed on the pipelines. The nozzles are installed at 30 degrees clockwise. The shaft is connected to a centrifugal pump set for pressurizing the jet line and controlling the injection pressure of the jet system with the number of pump sets. Connect the filter before the centrifugal pump to prevent impurities in the oil from clogging the pipeline. The monitoring system is composed of an oil and gas concentration detector, an oil sampler, and an oil concentration detection device. The oil sampling device and oil and gas concentration detection device are installed in the shaft to feed back the information in the hole library to the ground control system. The ground control system is a system that collects feedback information from the monitoring system and regulates jet disturbances. The schematic diagram of the jet disturbance system of the groundwater sealed crude oil reservoir is as shown in Fig 2.

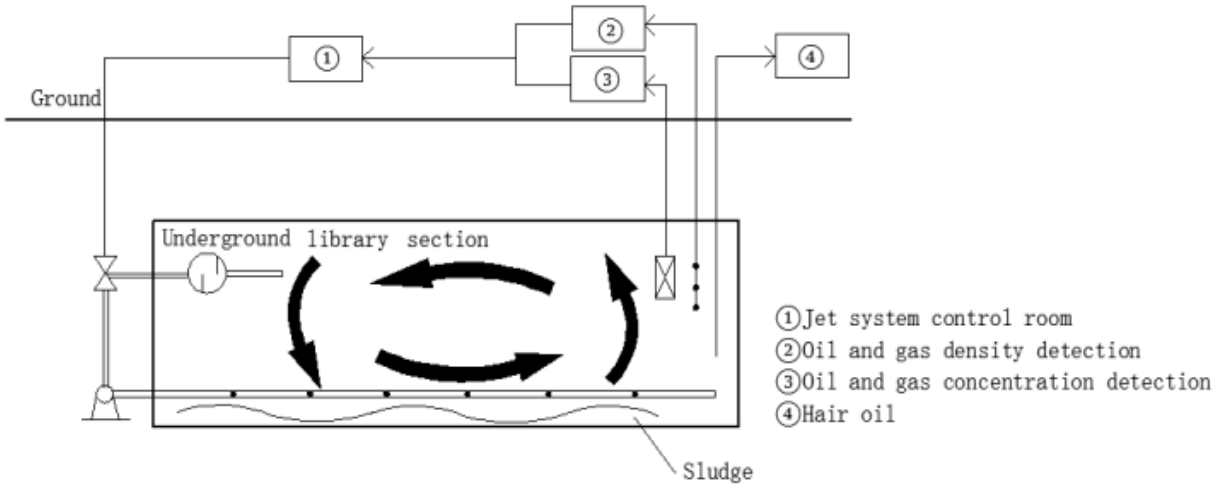

Fig 2 Schematic diagram of jet disturbance system of underground water seal crude oil reservoir

Introduction to Jet Perturbation System. The high-pressure jet perturbation system process uses the oil at the upper part of the reservoir to pressurize and discharge the fluid to the bottom of the cave. The sediment at the bottom of the reservoir under the impact of the high-pressure jet breaks the sludge accumulated in the reservoir. The solution dissolves and convections the crude oil in the reservoir due to the jet flow, thereby achieving a full range of agitation. The sludge at the bottom of the reservoir gradually breaks down from the state of the entire slab, and then dissolves to a standard quality crude oil. The mixing principle of jet agitation is: High-speed jets produce forward propulsion, pushing the sludge forward, and at the same time producing high shear rates at the jet boundary, forming a large number of vortexes with entrainment effect, bringing the surrounding stationary sludge rolls suction into the jet area, so that the jet develops and promotes mixing. The system has a simple structure and strong durability. The system is basically composed of a pipeline structure. As long as it can ensure the smoothness of the pipeline, the system can work effectively, can complete the stirring and dissolution in a short time, and can reduce the workload of maintenance, so the operating cost is low.

Operation Process. The underground oil reserve is mainly used for receiving, storing, and

delivering crude oil. The operating flow of the groundwater reservoir disturbance system when the oil is discharged is as follows.

Before the oil is discharged from the warehouse, the oil sampler with a monitoring system is used to sample the upper, middle, and bottom oils in the warehouse to analyze the difference in the relative density of the oil within the warehouse. According to the difference in density, the ground control system turns on the pump set corresponding to the jet disturbance system.

After the jet disturbance system is operated for a period of time, the upper, middle, and bottom oil samples of the reservoir are sampled again, and the relative density difference is analyzed. If the density difference is large, jet mixing is continued.

When the density difference is within the specified range, stop stirring. The oil and gas concentration in the reservoir is detected by the oil and gas concentration detection device.

If the concentration of oil and gas meets the discharge regulations, the crude oil is pressurized by the submersible pump and pumped to the inlet of the ground pump. During the lifting of the oil, the pressure is controlled by the pressure regulating valve on the pipeline, and at the same time, the interior of the cavern is supplemented with inertia. The gas ensures the internal pressure of the gallery and reduces the loss of oil and gas during the process of oil production.

The pressurized oil from the external pump flows through the flow meter and is sent to the refinery or dock tanker via the oil pipeline.

Conclusions

Underground water sealing caverns started relatively late in China. At present, there is a lack of relevant engineering design experience. Underground crude oil cave deposit sludge mud prevention equipment is also a concept and has not yet been applied. By summarizing and drawing on similar engineering processes in domestic and abroad, proceeding from the design process of water seal caverns, combined with the land tank clearing technology and actual construction conditions in China, a set of underground crude oil cavern deposit prevention devices was designed. It is composed of three parts: high-pressure jet disturbance system, monitor system and ground control system. The sedimentation of oil deposits in underground crude oil reservoirs is an inevitable problem. The application of anti-deposition techniques in underground oil storage caverns will surely become more mature and complete in the future.

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