Optimization of the design of the scrubber separator slug catcher

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Abstract. The article discusses the equipment of a system for collecting and preparing well products. The equipment is made in the form of a slug catcher separator, the design of which is the product inlet capacity. Its main element is a cyclone-type scrubber with a swirl, in which the product is separated into gas, liquid and impurities. As a result of design optimization, the entrainment coefficient and the degree of product purification are improved.

1. Introduction

In the process of lifting liquid from wells and transporting it to the central point of collection and preparation of oil, gas and water, pressure gradually decreases, and gas is released from the oil. The volume of gas released as the pressure in the system decreases, and usually several tens of times greater than the volume of liquid. Therefore, at low pressures, their joint storage, and sometimes collection, becomes inappropriate. Have to carry out their separate collection and storage.

The technological process of collecting and preparing oil and gas consists in the subsequent change in the state of production of an oil well and consists of several stages:

1) the collection of oil and gas;
2) bringing oil and gas to normalized properties.

The collection of oil and gas refers to their movement from the metering units to the points of their preparation. The separation of gas from oil is the process of separation from the liquid phase (oil) of the gaseous phase. Separation occurs when pressure decreases and temperature rises, as well as due to molecular diffusion of hydrocarbon and other components contained in oil into the space with their lower concentration located above the oil [1-3].

The separation of oil from gas and water in various separators is carried out with the aim of:

1) receiving petroleum gas, which is used as a chemical raw material or as fuel;
2) reducing the mixing of the oil and gas flow and reduce due to this hydraulic resistance;
3) reduce foaming (it is enhanced by the released gas bubbles);
4) reduction of pressure pulsations in pipelines during further oil transportation from separators of the first stage to the oil treatment unit (OTU) [4, 5].

2. Methods and materials

A two-phase hydrocarbon mixture is transported through the oil and gas pipeline, where the role of the liquid phase is played by oil and water, the role of the gas phase is associated petroleum gas. The basic structure of a gas-liquid flow is cork, which is formed due to the difference between the average
velocities of the liquid and gas phases, that is, the velocity of the phase at which a homogeneous medium occupies the entire pipe section [6–8].

When operating a commercial oil and gas pipeline in a plug mode of product flow, it is necessary to determine the required volume of slug catcher at the point of reception of the hydrocarbon mixture. The maximum plug sizes will be observed when the scraper passes through the pipeline (“projectile” plugs), while the dimensions of regularly passing plugs have a significant effect on the vibrations and vibrations of above-ground pipelines. Thus, when designing the objects of oil and gas gathering systems, it is necessary to calculate the values of both “shell” and regular cork structures [9–12].

The separation of gas from oil is carried out under the influence of gravitational, inertial forces and due to the selective wettability of oil. Inertial separation occurs during sharp turns of the gas-oil flow. As a result, the liquid, as the most inertial, continues to move in a straight line, and the gas changes its direction. As a result, they are separated. Based on this principle, the operation of the slug catcher separator product inlet unit is constructed by feeding the gas-oil mixture to the scrubber, in which the liquid is discharged to the inner surface and then flows down into the slug catcher separator tank, and the gas moves in the center of the scrubber.

The slug catcher separator is designed for preliminary gas purification from dropping liquid and mechanical impurities, as well as for receiving volley flows of liquid carried by gas from lowered sections of gas pipelines.

The main elements of the slug catcher separator (Figure 1) are: product inlet capacity; separator; light output system; heavy fraction withdrawal system.

For maintenance, the unit is equipped with service platforms and stairs with fences.

The slug catcher is a vertical cyclone scrubber combined with a horizontal tank for receiving the liquid phase and with a system for removing solids

The formation mixture from the installation of the input loop blocks enters the cyclone scrubbers, in which the blades of the vortex tube rotate the gas-liquid flow. Inside each scrubber are placed: a vortex tube with blades, a conical chipper that prevents the entrainment of a droplet liquid with a stream of purified gas and anti-rotation plates that stop the rotation of the liquid.

Under the action of the emerging centrifugal force, droplets of liquid and solid particles are directed to the walls of the cyclone, where they form a liquid film moving to the lower part of the cyclone scrubber.

The most effective and technically advanced separator is one from which droplet liquid and gas bubbles cannot be carried out, while the delay time of the oil in the separator and the metal consumption for its manufacture should be minimal. In addition, a phase equilibrium between gas and oil should be established in such a separator.

When separating oil and gas in a separator, one should strive to create a large contact surface between the phases and not to allow excessive entrainment of the droplet liquid and acclaimed gas bubbles from the separator. The increase in the contact surface between oil and gas significantly reduces the time to achieve the equilibrium state of the system at a given temperature and pressure.

Therefore, the effective gas evolution from oil in the separator can only be in the finely dispersed state of the oil and gas mixture, which is provided, as a rule, with nozzle nozzles or with special dispersants. In this case, a finely dispersed oil and gas mixture is formed in the separator volume, consisting mainly of oil droplets ranging in size from 1 to 2 mm. The size of oil droplets in the separators is a function of the ratio \( \sigma/\Delta \rho \), where \( \sigma \) is the interfacial tension, and \( \Delta \rho \) is the difference in phase densities.

Droplets of this size are successfully captured in the drop trap section, which is set as a gas-dynamic module.

The highest degree of purification in gas pre-separators, with a louvred nozzle and inclined shelves at a relatively wide speed range. At high speeds of the medium (gas) being cleaned, a gas-dynamic module works very efficiently from liquid droplets, which can beat off a suspension of 10 microns in size. In third place in terms of efficiency is a hydrocyclone separator and in fourth is a separator with shutters, but without tilted shelves, and finally, the most ineffective separator is a gravitational type without shelves and louvred nozzles.
In a centrifugal separator, centrifugal force is widely used to separate oil from gas. Consider the centrifugal force and the separation factor of the mixture.

When the body rotates, a centrifugal force \( C \text{ in kg} \cdot \text{m} / \text{s}^2 \) arises, directed along the radius from the axis of rotation and equal to the product of the body mass \( m \) in kg by the square of the peripheral speed \( W \) in m/s divided by the radius of rotation \( r \) in meters.

### 3. Results

The analysis of the separator-slug catcher (Figure 1) revealed the following disadvantages:

1) A gas plug at the entrance to the product inlet tank has an impact on its entire structure. Cyclic impacts contribute to the accumulation of fatigue stresses, which leads to premature damage and subsequent destruction of the product input capacity.

2) Entrainment of the separated liquid into the gas outlet line from the product outlet tank by the ascending vortex flow of the separated gas, which reduces the separation efficiency.

3) Insufficiently effective separation of the gas-liquid flow into gas and liquid.

![Figure 1. Separator slug catcher: 1 – product inlet capacity; 2 – separator; 3 – light output system; 4 – heavy fraction withdrawal system](image)

To eliminate this problem, it is proposed to change the design of the product inlet container with a scrubber installation (Figure 2). The scrubber is used to separate the liquid from the gas stream and to protect equipment downstream, and also removes mechanical impurities from the stream.

As a result of the implementation of this technical solution, the pressure drop across the inlet capacity of the separator product was halved while maintaining the same degree of separation. The calculations showed that, despite the change in the geometric characteristics of the separator, the degree of separation efficiency has not changed.

The product inlet capacity is designed to capture gas plugs formed during oil transportation, gas-liquid mixture separation on CPF.

The capacity includes the following elements:
- nozzle type washer for sand;
- slowing down solid partitions;
- defoamer of low shear pulses at the input;
- defoaming perforated partition;
- a device for separating gas and water from oil.

The apparatus is a horizontal cylindrical vessel with hemispherical bottoms mounted on two saddle supports.

The optimized scrubber (Figure 3), by the principle of operation, is a cyclone type scrubber. Scopes of a cyclone-type scrubber:

1) separation of liquid (water, hydrocarbons) from gas (associated gas, etc.),
2) downstream equipment protection (separator elements, etc.),
3) removal of mechanical impurities from the stream (dust, sand, etc.).
Figure 2. Product input capacity:
1 – capacity body; 2 – product entry; 3 – scrubber; 4 – shank; 5 – anti-swirl

Figure 3. Scrubber: 1 – swirl; 2 – guide; 3 – disk; 4 – transition; 5 – bottom; 6 – chipper; 7 – a pipe; 8 – pipe; 9 – flange

Figure 4. Swirl

Figure 5. Chipper
The blades of the optimized geometric shape of the scrubber drive the combined phase flow into rotation.

The resulting centrifugal force directs liquid droplets and mechanical impurities to the walls of the apparatus, where they form a liquid film moving down the scrubber. Gas leaves the scrubber through the central gas outlet. The baffles at the bottom of the cyclone stop the rotation of the fluid and the secondary entrainment of the fluid by the gas stream. Thus, efficient phase separation is provided.

When using the optimized scrubber of the separator, a gas-liquid stream is supplied to the scrubber with its subsequent separation into gas, liquid and impurities. As a result, the gas-liquid flow feeds into the inlet pipe located on the scrubber body, after which they give the stream a rotational movement by feeding it to a spiral surface located between the inner surface of the body and the outlet pipe. Then, a rotating gas-liquid flow is directed to the walls of the scrubber body, thereby separating the liquid from the gas due to the density difference and the action of centrifugal and gravity forces, while ensuring that the separated liquid moves down the body walls, and the released gas moves upward through the outlet pipe. At the same time, to prevent the ingress of fluid flowing along the walls of the scrubber body and located in the center of the rotating flow, conical belts are used inside the outlet pipe, which are installed on the outer surface of the body of the outlet pipe in its inlet part and with the help of which liquid is drained from the inlet part.

The rotating stream is directed downward to the liquid collecting tank, providing during its movement from the inlet pipe to the lower part of the scrubber body the liquid is separated from the gas.

Then, to exclude the entrainment of liquid from the stream of purified gas, the gas-liquid stream is slowed down by expanding along the boundaries of the base of the cone, which is installed in the lower part of the housing, while liquid and splashes are not allowed to enter the inlet of the outlet pipe using this cone and conical belts installed on the outer surface of the body of the outlet pipe, then in the lower part of the scrubber body the flow is directed to the ribs of the device to prevent rotation of the flow, which are located in the lower parts of the casing, preferably below the cone, mainly on the inner wall of the casing parallel to the vertical axis of the casing, then the fluid flow having an axial velocity component is sent to the fluid collecting container, where it is accumulated, sand and solids are removed from the liquid by sedimentation under the action of gravity and the subsequent periodic removal of the collected fluid and these foreign particles.

During the analysis of scrubber optimization, it was revealed:
1) a change in the design of the scrubber allowed to reduce the pressure drop in the separator by 50%;
2) the calculations showed that, despite the change in the geometric characteristics of the separator, the degree of separation efficiency has not changed.

Benefits of an optimized scrubber:
1) allows you to remove the restrictions imposed by the small dimensions of gas and liquid devices;
2) are not subject to clogging;
3) excellent work with slug flow mode;
4) small size and weight, which is especially important when used on offshore installations;
5) does not require regular maintenance;
6) quick payback by increasing system throughput

4. Conclusion
The optimized scrubber design has the following advantages:
1) the small size and weight of the apparatus, due to the high value of the permissible gas load;
2) ease of maintenance: the absence of channels and transfer pipes of small diameter, capable of clogging;
3) excellent cork flow;
4) large working range.
5) does not require regular maintenance;
6) quick payback by increasing system throughput
With the introduction of this technical solution, the average annual economic effect will amount to 175044 rubles, and the profit remaining at the disposal of the enterprise 140035 rubles.

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