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A Design of Explosion-Proof Heater of Bunched Pipeline

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Abstract:—Based on technology and economy, a design of explosion-proof heater of bunched pipeline is mentioned in this paper to solute the problems of the present heater which is used to heat crude oil in winter. The structure and working principle of this new heater are introduced. And the function of the new heater's swirl plate is described, before the heater power of the new heater is analyzed. The swirl plate makes crude oil spiral through heating tube leading to delay staying time inside of the heater. The heater has achieved the heat of the oil-water mixture in order to avoiding the phenomenon of oil-water separator and uneven heating. The principle of the heater is feasible. It has advantages of energy conservation and environment protection, and widely applied to crude oil wellhead heating.

Keywords:—explosion-proof heater; pipeline, swirl plate, crude oil.

I. INTRODUCTION

In the oil industry, there are many ways for heating crude oil, but the electric heating has been considered as the most convenient one. In recent years, with the rapid development of petroleum industry, the demand of explosion-proof heater is also growing rapidly. The electric heating device plays an indispensable role in crude oil extraction, transportation, measurement, oil refining and deep processing. In the winter, the mined crude oil has the poor liquidity due to the characteristics that high wax content, high viscosity, but it can flow only to ensure that the temperature of crude oil is heated at least to above 40℃. Therefore, there should be equipped with different kinds of liquid heater [1].Therefore, different types, different types, different uses and specifications of the heating device have appeared for many years on the market, such as explosion-proof electrical heater of bunched pipeline, explosion-proof far infrared heater etc.

When the electric heaters are used in a flammable and explosive gas or steam environment, they must not only keep the characteristics such as simple structure, easy to use, good quality, long service life, but also more important is in use period, always maintain good explosion-proof performance and thermal efficiency, in order to achieve the purpose of safety and energy saving. Therefore the paper has designed a kind of explosion-proof heater of bunched pipeline, and the device structure and working principle, performance were studied. These studies have shown that the heater heating effect is good, energy saving, and have certain stimulation effect.

II. HEATING WAY SELECTION

Disadvantages of common heater:

*(1).*Great power consumption, easy to produce scaling, coking phenomenon, short service life.

*(2).*The heating effect is poor, and it cannot meet the design requirements.

(3). Heating exists dead Angle, and steam can't be discharged rapidly, have the hidden trouble in safety.

Based on the deficiency of the ordinary heater, the paper presents the design of a new type of heater which has the following advantages: long service life, less power consumption. The swirl plate is firstly introduced in the heating pipe, which can make crude oil spiral through heating tube leading to delay staying time inside of the heater. The heater has achieved the heat of the oil-water mixture in order to avoiding the phenomenon of oil-water separator and uneven heating, prevent coking, scaling effectively, achieve the purpose of safety and energy saving.

III. SYSTEM COMPOSITION AND WORKING PRINCIPLE

A. System composition

This explosion-proof heater of bunched pipeline includes Explosion-proof junction box 1, pressure gauge 2, keeping shell body 3, heating pipe 4, swirl plate 5, crude oil exit 6, safety valve 7, out valve 8, Explosion proof control box 9, insulated cable 10, Explosion-proof regulation power box 11, mud hole 12, crude oil entrance 13 and control system. Crude oil flows into the heating chamber from the crude oil entrance, then the swirl plate makes crude oil spiral through heating tube leading to delay staying time inside of the heater, and finally they are sufficiently heated, the gas generated during the heating process is discharged from the out valve, the solid particles of mud and other impurities are firstly effectively precipitated before they are discharged from mud hole. Heated crude oil is discharged from Crude oil exit. Explosion-proof regulation power box can automatically change heater power at any time though the date provided by the temperature sensor so that the temperature in the heating chamber will not be changed greatly, and improve the ability of controlling temperature. The whole heater structure is shown in Figure 1, 2.

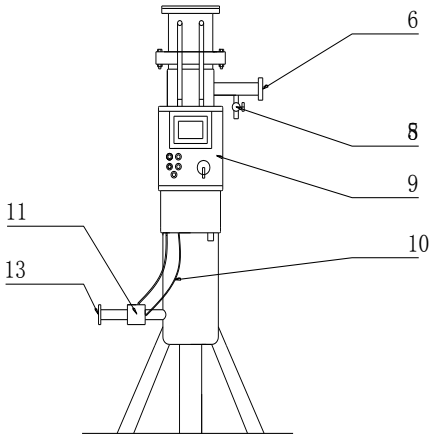

Figure 1. Front Profile

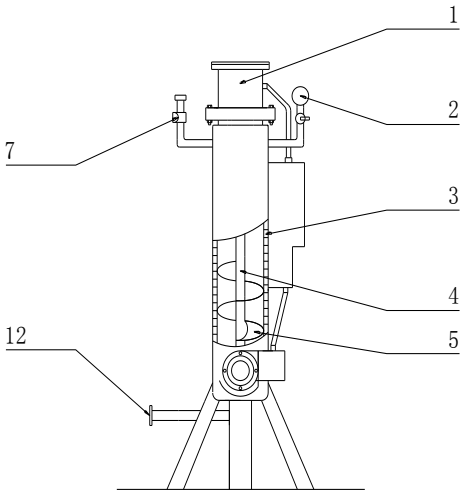

Figure 2. Left Profile

1 Explosion-proof junction box, 2 pressure gauge, 3 keeping shell body, 4 heating pipe, 5 swirl plate, 6 crude oil exit, 7 safety valve, 8 out valve, 9 Explosion Proof Control Box , 10 insulated cable, 11 Explosion-proof regulation power box, 12 mud hole, 13 crude oil entrance.

B. The structure of the heating device and heating principle

Based on liquid swirling flow principle, this heater is equipped with swirl plate, which makes crude oil spiral through heating tube. Vortex flow field induced by swirl plate can enhance the effect of heat convection, the contact between heating tube and inner wall is also beneficial to heat transfer enhancement [2].

The heater has achieved the heat of the oil-water mixture in order to avoiding the phenomenon of oil-water separator and uneven heating so that heater can always maintain high efficiency heating. Rotational flow scours and destroys the fluid viscous boundary layer, which makes fluid velocity increases; it includes both axial velocity and tangential velocity. The fluid particle in the heating chamber is forced to strengthen the mixing between boundary layer fluid and the mainstream fluid and the disturbance and pulsation of boundary layer fluid so that it's beneficial to promote heat conduction between the heating pipe and fluid [3]. The swirl plate makes crude oil spiral through heating tube leading to increase distance traveled and delay staying time inside of the heater. After fluid flowing through swirl plate, turbulent diffusion is occurred, and then fluid impacts on the wall. It is more conducive to heat transfer owing to the similar impact on the inner wall at the point of contact surface.

C. Heater working principle

During the process of oil production, the moisture content in crude oil is very low at the beginning of the process, and the moisture content in crude oil is very high at the end of the process. Common heater is easy to form the phenomenon of oil-water separator and they can't be fully heated. With the increase of time, the heat efficiency is drastically decreased. Now the swirl plate is firstly introduced in the heating pipe, which can make crude oil spiral through heating tube leading to delay staying time inside of the heater so that heater can always maintain high efficiency heating. Furthermore, the device has a temperature proof monitor, which can effectively avoid the explosion accident caused by abnormal temperature detonating surrounding flammable gases or steam.

IV. HEATER POWER SELECTION AND CALCULATION

Parameters [4] of liquid in a certain oil-field's oil well: specific heat capacity of produced water $C_w = 4183\mathrm{J/(kg\cdot ^\circ C)}$, density $\rho_w = 1000\mathrm{kg/m^3}$; specific heat capacity [5] of produced crude oil $C_o = 2838\mathrm{J/(kg\cdot ^\circ C)}$, $\rho_o = 860\mathrm{kg/m^3}$; composite water cut of produced liquid is 94.1%. Specific heat capacity and density of produced liquid [6] can be concluded by using a linear fitting.

$$C = C_w \times 94.1\% + C_o \times 5.9\% = 4103.6\mathrm{J/(kg\cdot ^\circ C)}$$

$$\rho = \rho_w \times 94.1\% + \rho_o \times 5.9\% = 991.7\mathrm{kg/m^3}$$

Assume that the heat exchange efficiency is 92%, we can calculate the electric heater power:

Based on the heat transfer equation [7]:

$$Q = Pt \times 0.92 = Cm\Delta T = C\rho v\Delta T$$

$$P = Q/0.92t = C\rho v\Delta T/0.92t = 17.6\mathrm{kW}$$

Where, m represents quality, kg; Q represents heat, J; t represents time, h. According to the power definition, assume that t=1h; P represents power, kW; C represents specific heat capacity, $C = 4103.6\text{J/(kg} \cdot \text{°C)}$; ρ represents density, $\rho = 991.7\text{kg/m}^3$; v represents liquid-producing capacity of a well per hour, $v = 0.4\text{m}^3/\text{h}$; ΔT represents quasi heating temperature, the lowest oil temperature of a well in the oilfield is 19.1 °C, considering the temperature and other adverse factors, assume that the final heated temperature is 55 °C, $\Delta T = 55 - 19.1 = 35.9\text{°C}$.

By calculating, the paper chooses the electric heater that its power is 17.6kW, which can meet the requirements of oil well's heating and gathering. But considering the influence of the oil temperature, daily fluid production rate and other factors, the Electric heater power is determined as 18kW. The heater power can be determined by the practical situation of oil field as a result of each oil field production situation is different. Therefore in order to calculate, this paper selects three different oil wells in one oilfield, the results are as given in table 1.

Table-1 heater power under different conditions

Daily fluid production rate $Q(t/d)$	Inlet temperature $T_1(\text{°C})$	outlet temperature $T_2(\text{°C})$	rated power $P(kW)$
8.7	19.1	55	18
18.6	27.0	55	26
29.6	35.6	55	36

By computing and analyzing, the rated power of heater is initially set to three gears in this paper. Explosion-proof regulation power box can automatically change heater power at any time though the date provided by the temperature sensor.

The biggest characteristics of this heater is that it is equipped with the new heater's swirl plate, which makes crude oil spiral through heating tube leading to delay staying time, extending distance inside of the heater, which is three times longer than common heater, so it's more energy saving. Now the paper assumes that the time of unit volume of crude oil flowing through the common electric heater is t1, so the time of unit volume of crude oil flowing through this electric heater is 3t1. In the same conditions, the power of making crude oil increase the same temperature is P_1, $1/3P_1$respectively, we can get table – 2 by calculating.

Table -2 comparison of the heater powers

heating method	rated power	energy saving rate
common heater	P_1	0
cyclone heater	$1/_3\,P_1$	66.7%

The calculations show that cyclone heater can save 66.7% energy and has a broader application prospect.

V. SYSTEM PERFORMANCE AND ECONOMIC BENEFIT

The paper can achieve the following main performance index of system by analyzing.

a) The inner wall of explosion-proof heater of bunched pipeline adopts processing technology that the surface is coated with anti-scale building materials, which can prevent coking, scaling effectively, and improve the application effect and prolong the service life of the heater.

b) The explosion proof device adopts the following technology, electronic control, no ball float liquid level controller and flow locking device and mechanical components, so it is easy to control, long service life. The special structure and control design makes the equipment without emptying procedures; it can be directly sending work only to avoid the emptying scheduler, avoid all kinds of accidents caused by inadequate emptying.

c) The exine of heater is set with vacuum cover protective layer that is 50mm thick, which can avoid heat transfer caused by air convection effectively, therefore thermal conductivity will be reduced greatly, with good heat insulation performance at the same time [8].

d) Heater is designed to heat medium by forcing them to spiral through heating tube, the medium can be fully heated; besides, steam can be discharged from the out valve rapidly, which eliminates the gas block phenomenon thoroughly, achieve the purpose of safety and energy saving.

e) Application of new electronic control system:

i. *Soft start is introduced, which can make the power increase gradually, and reach to the full power finally.*
ii. *Explosion-proof regulation power box can automatically change heater power at any time though the date provided by the temperature sensor so that the temperature in the heating chamber will not be changed greatly, and improve the ability of controlling temperature.*
iii. *Due to pipe heater power for the promise sliding power, make the heating pipe eliminate the frequent startup fundamentally; reduce the damage on the power grid and electric heater electrical parts for pipeline.*

The most characteristic is energy saving, common heater's power is 30KW.One well's electricity consumption per day is 720 KW·h, this explosion-proof heater of bunched pipeline can save 480 KW·h , a well can save almost 115200 RMB when working for 300 days per year. From the perspective of energy, the application of this new heater will bring great economic and social benefits.

VI. CONCLUSION

At present, the domestic crude oil heating device still has many defects, such as uneven heating, great power consumption, etc. The heater designed by this paper avoids the problems on common electric heater, what's more, this explosion-proof heater of bunched pipeline achieves the purpose of energy saving and emission reduction, and works efficiently, crude oil in the heating chamber can be sufficiently heated at the same time. Although this paper gives a simple explanation and calculation for heater principle and power, the results will have the extremely vital significance in extending the more extensive application of swirl in the oil industry. Believe that the application of the explosion-proof heater of bunched pipeline will produce great economic and social benefits.

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