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INFLUENCE OF OPERATING FACTORS ON SAVING FUEL EXPENDITURE BY MOBILE STEAM GENERATOR UNITS OIL AND GAS INDUSTRY

Abstract: *The article deals with the issue of the scale of the scale on the heating elements of mobile steam generators (puus), which are widely used in the oil and gas industry for the deparaffination of wells, pipelines, oil and gas and other equipment with a high-pressure and low pressure steam, as well as for other domestic and industrial needs.*

Since the operation of steam generating units takes place in the field at a far distance from the main bases of their dislocation (storage and accounting), which leads to the forced consumption of physically and chemically unprepared feed water. Usually it is underground natural spring water, water from the year, lakes, ponds, etc. The work of steam generating units on untreated water leads to the formation of scum, which causes excessive fuel consumption and the operation of the boiler of the steam generator due to the burning of the coil. However, even during the work on prepared cooking water on the walls of the coil formed scale, which reduces the efficiency of its work and requires periodic removal with acid treatment in 48-72 hours of installations.

Operators, often themselves create conditions for the formation of thick layers of scale and significant fuel overrun to obtain the required amount of steam, compared with the regulatory data regulated instructions for the technical operation of installations.

The article analyzes the influence of the thickness of the scale of the scale on the heat losses of the boiler and the influence of the scale of the scale on fuel overload by a mobile steam generator. The mathematical dependence of excess fuel consumption on the thickness of the scale of the scale is obtained. It has been shown that the occurrence of scale causes not only economic but also environmental problems.

It is analyzed the effect of scum on fuel consumption by mobile steam generator units (STU) in the article. The methods of removal which aim to fuel economy are offered.

Keywords*: mobile steam generator units, thermal conductivity, fuel, heat transfer.*

Introduction

Mobile steam generating units (MSGU) are used in the oil and gas industry for depleting wells, pipelines, oil and gas and other equipment with saturated steam and for other domestic and industrial needs. The analysis of operating conditions shows that their number in the oil and gas industry is shattered (unconcentrated in one territorial or regional region). Oil and gas administrations or other enterprises that operate wells, store or transport oil or gas have one, and in the best case, two steam generators.

Such organizations are not entirely advisable to create special technological systems for the preparation of feed water, at best at small distances to the site of operation of plants, use feed water boiler units, which is consumed to heat the premises and other household needs, and they are different in physical and chemical properties for power supply of steam and hot water boilers.

Problem statement

Operation of steam generating units in the fields at a distance from the main bases of their dislocation (storage and accounting) leads to the forced consumption of physically and chemically untreated feed water, which is usually underground natural spring water, water from the rivers, lakes, ponds, etc. According to the physical and chemical properties, the mentioned water does not meet the requirements specified in the operating instructions [1-4], for which the hardness should be less than 10 μg-eq/kg. According to a number of sources [5-8], the hardness of natural unprepared water is from 0.5 to 5.0 mg-eq/l, which is at least 50 times more than it is provided by the instructions for steam generating units operation [1-4]. The work of steam generating units using row water leads to the formation of scum, which causes excessive fuel consumption and decommissioning of the steam generator boiler because of burning the coil.

Recent research and publications analysis

Operation description of the boiler

Steam boilers of the type PPUA are installed on mobile heat generating units. The scheme of steam boiler is depicted in figure 1 [1-4]. Boiler is vertical, cylindrical with twisted spiral tubes, direct flow with lower burner location.

The outer coil 5 in the upper part ends with a flat spiral coil 11. The ends of the outer tubing 5 and the inner coil 4 are joined by a loop 2. The opening is covered with a lid 3, which provides cutouts at the passageways of the loop pipes 2. The hole is covered with a lid 3, which provides cutouts at the passageways of the hinges 2. All coils are made of boiler tubes 28x3.5 according to Technical specifications 14-3-460-75, the material of pipes is steel 20. Space formed by cylindrical coils 4, 5 and a wall of the boiler's inner casing 6, serves as the passage of flue gases.

The two cylindrical casings 6 and 12 of the boiler make a ring chamber for passing air from the fan to the burner. For the passage of air from the annular chamber to the tray 10 there are openings 7 in its stand.

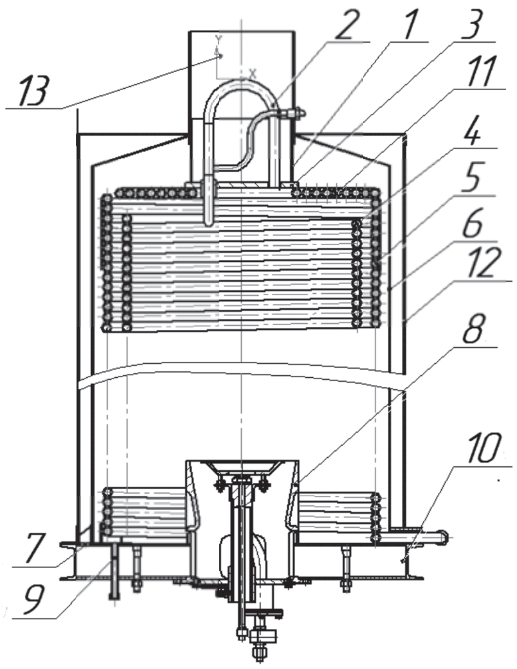

FIGURE 1. *Steam boiler: 1 – spark-guard, 2 – loop, 3 – cover, 4 – inner coil pipe, 5 – outer coil pipe, 6 – casing internal, 7 – hole, 8 – burner, 9 – connector, 10 – pallet, 11 – spiral, 12 – casing external, 13 –waste pipe*

The exhaust gases from the car engine are fed through the branch in the lower chamber and provide heating of the boiler and the pump in winter during distillation of the installation. The spark-guard of the mesh type 1 is installed in the boiler pipe.

Connectors 9 of the blower were brought out to the outside of the boiler pallet 10. At the bottom of the boiler there is a hatch in which the burner is installed. The waste gases from the boiler of the steam generator come out through the waste pipe 13.

Scum formation Sources

Generated in steam generators scale according to classification [9] may be divided into 5 groups:

- alkaline earth, that consist of Ca and Mg compounds;
- copper scum composed mainly of copper metal;
- iron scum, which is divided into silicate, ferrosilicate, phosphate and oxide;
- alumferrosilicate and silicate with the predominance of SiO_2 properties;
- scum from easily soluble salts: $NaPO_4$, Na_2HPO_4.

A formed layer (scum) can cause dangerous overheating of metal walls and it reduces the cost-effectiveness of the unit [10]. Figure 2 shows the coils pipes destroyed by overheating and external corrosion.

FIGURE 2. *Steam generator coil*

The purpose and objectives of the article

The purpose of this paper is to analyze the effect of the scale thickness on excess fuel flow and to find economically feasible and technically simple methods to remove the scum.

Effect calculation of the effect of scale on the fuel consumption of a mobile steam plant

As known, the scale crust has a very low thermal conductivity of 1.163-3.79 W/m·K [11], which leads to decreasing of heat transmitted from gases to water. This will increase fuel consumption with the same performance.

Let's calculate the change in fuel consumption from the scale crust thickness.

To simplify the calculation we will take a cylindrical tube of the steam generator boiler as a flat wall. Also, the following input data were accepted:

- the temperature of the gases in the middle of the boiler is 1000-1300°C [12], we accept 1120°C;
- the temperature of the gases at the outlet from the boiler is 160-180°C [12], we accept 180°C;
- the water temperature at the entry to the boiler is 70°C;
- the coefficient of heat transfer from gases to the wall is α_1 = 65 W/m²·K [2];
- coefficient of heat transfer from wall to water α_2 = 3500 W/m²·K [12];
- the coefficient of thermal conductivity of the steel wall of the coil is λ_1 = 46.5 W/m·K [2];
- the coefficient of thermal conductivity of the scale crust λ_2 = 1.163-3.79 W/m·K [11], we accept λ_2 = 1.7 W/m·K;
- lower heat of combustion of diesel fuel: Q_n = 42700 kJ/kg;
- coefficient of efficiency of a steam boiler: $\eta'_{\Pi\Gamma} = 80\%$.

Parameters of steam boiler cracking [3]:

- outer tube diameter: 0.028 m;
- wall thickness: δ_c = 0.0035 m;
- average diameter of the external coil: 0.652 m;
- average diameter of the internal coil: 0.568 m;
- number of turns: 49.

When transferring heat through a multilayer cylindrical wall, which consists of layers, the linear heat transfer coefficient will be:

$$k_l = \frac{1}{\frac{1}{\alpha_1 d_1} + \sum_{i=1}^{n} \frac{1}{2\lambda_i} \ln {d_{i+1}}/{d_i} + \frac{1}{\alpha_2 d_{n+1}}} \quad (1)$$

Estimated heat transfer coefficient of the heat exchanger:

$$k_P = \frac{k_l}{d_{cep}} \quad (2)$$

where d_{cep} = 0.0245 m.

Area of convective heat transfer, m²:

$$H = \pi d L \quad (3)$$

where:

d – outer diameter of the coil tube, m;

L – the length of coil tube, L = 187.7 m.

An average temperature pressure:

$$\Delta t = \frac{\Delta t_m - \Delta t_l}{\ln \frac{\Delta t_m}{\Delta t_l}} \quad (4)$$

where:

Δt_m – the highest temperature difference, °C;

Δt_l – the lowest temperature difference, °C;

Then: Δt = 369°C.

Heat transmitted from gases to water considering the absence of scum:

$$Q = Hk\Delta t \ \ [\text{J/s}] \tag{5}$$

Fuel overrun:

$$\Delta B = \frac{\Delta Q}{Q \cdot \eta'_{\Pi\Gamma}} \ \ [\text{kg}] \tag{6}$$

Calculation for a scum of 0...2 mm is carried out using the Mathcad environment. The calculation results are given in table 1.

Table 1. *Calculation results of the effect of scum thickness on fuel consumption*

Scum thickness, mm	Heat transfer coefficient, $W/(m^2 \cdot K)$	Loss of heat, J/s	Excessive fuel consumption, kg/h	Excessive fuel consumption, %
0	72.095	0	0	0
0.1	71.722	2274.362	0.24	0.518
0.2	71.349	4547.909	0.479	1.035
0.3	70.976	6820.756	0.719	1.552
0.4	70.603	9093.022	0.958	2.069
0.5	70.23	11364.824	1.198	2.586
0.6	69.857	13636.287	1.437	3.103
0.7	69.485	15907.534	1.676	3.62
0.8	69.112	18178.694	1.916	4.137
0.9	68.74	20449.895	2.155	4.654
1	68.367	22721.271	2.395	5.17
1.1	67.994	24992.958	2.634	5.687
1.2	67.622	27265.093	2.873	6.204
1.3	67.249	29537.821	3.113	6.722
1.4	66.876	31811.285	3.352	7.239
1.5	66.503	34085.634	3.592	7.756
1.6	66.129	36361.022	3.832	8.274
1.7	65.756	38637.604	4.072	8.792
1.8	65.382	40915.542	4.312	9.311
1.9	65.008	43194.998	4.552	9.829
2	64.634	45476.144	4.793	10.348

The results of calculations prove that there is significant effect of scum on fuel consumption, even with its insignificant thickness it leads to significant overfuel, especially in large plants where many steam installations are in use.

So here we came up with the conclusion that the usage of water with a stiffness of less than 10 mkg-eq/kg, and timely rinse the boiler, will significantly extend a proper operation of the installation and reduce the cost of its operation.

Measures to prevent the scaling on the inner surface of the coil heat generator

In order to remove the scale (scum) from the walls of the coil it is offered to use an improved device created basing on the method described in [13]. The device consists of a purifying element placed in the middle of the coil (a boiler tube) and the cleansing element itself consists of twisted into the tube corrugated tins plates inserted into the inside of the coil (boiling tubes). In the consequence of implementing such an element, the scale will be laid out on the surface of the inserted corrugated tube, which can be removed and replaced by the second one in case of scumming. However, the complexity of its manufacturing and operation as well as the reduction of the thermal conductivity that can be artificially formed on the double coil surface, the offered design was not widely used in thermal power engineering.

The task of preventing the scaling may be solved by designing such a device (fig. 3) which will have on the inner surface of the heat generator coil a purifying element located in the middle of the coil (boiling tubes).

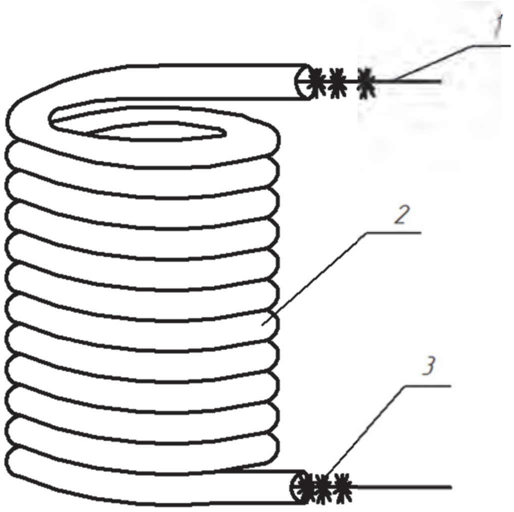

FIGURE 3. *Device for preventing scaling on the internal surface of the heat generator coil*

The device consists of a pipe 1 of heat generator which is inserted into the pipe 1 for the entire length of the purifying element, which contains a flexible line 2, placed and fixed to the wire line 3, made from a softer material than the coil tube. In this case line 2 together with wires 3 form a flexible line-jar.

The cleaning element made as a flexible line 2 is equipped with wires which are made of milder material than the material of the coil. The length of the wires and their fixing on the line enables the strain placement of the purifying element in the coil.

The implementation of a cleaning element in the form of a linen which is equipped with wires makes it similar to a jersey, that will be moving while producing the steam, and its wires will contact the inner surface of the coil thus preventing the scaling on the walls of the coil.

The production of purifying element wires from a milder material will not be depreciating in the process of its interaction with the inner surface of the coil tube. The implementation of a flexible line in the construction of a purifying element on the entire length of the coil in the process of manufacturing steam will prevent the scaling throughout the length of the coil.

In the process of manufacturing a pair of heat generator in the coil, line 2 is driven (the drive in the figure is not shown) and the wires mounted in 3 come into contact with the inner surface of the coil tube 1. Since the wires 3 are mounted on line 2 in such a way that in pipe 1 they are placed with a tension, then in contact with the inner surface of the pipe 1, if the scaling is possible it will be removed from the surface and washed with a steam-water mixture in the coil. When steam is open the scale in the form of a slime will be taken from the tube 1 of the coil.

An offered device for preventing the scaling on the inner surface of heat generators coils will allow to reduce the cost of manufacturing steam.

Conclusions

Basing on the performed calculations we came up with the decision and an influence pattern of the scale layer on fuel overexposure by steam generating units. There was also offered the device for minimizing the effect of scale on the boiler performance as well as on the cost of producing steam.

A device is proposed to minimize the effect of scum on boiler performance and cost of steam production. Application of the proposed device will save up to 10.5% of fuel (approximately 121.5 kg/h).

It is also important that the economical fuel consumption will also reduce the environmental load.

Thus, the problem discussed in this article is quite relevant for enterprises in the oil and gas industry.

References

[1] Ustanovka promyislovaya parovaya peredvizhnaya PPUA-1200/100. Tehnicheskoe opisanie i instruktsiya po ekspluatatsii (25.00.00.000 TO), 1989, 72 s.

[2] Ustanovka promyislovaya parovaya peredvizhnaya PPUA-1600/100. Rukovodstvo po ekspluatatsii (TU 26-02-987-85), OAO «Nalchikskiy mashinostroitelnyiy zavod» Nalchik : KBR, 2005, 73 s.

[3] Parovaya peredvizhnaya ustanovka PPU-3M : Katalog – M. : Nedra, 1971, 43 s.

[4] Baybakov N.K., *Termointensifikatsiya dobyichi nefti*, N.K. Baybakov, V.A. Bragin, A.R. Garushev, I.V. Tolstoy. M.: Nedra, 1971, 280 s.

[5] Ochistka kotlov i teploobmennikov [Elektron. resurs]. – Rezhim dostupu : http://tehgidro.com.ua/rus/truby.

[6] Okocha A.I., *DovIdnik po palivu I mastilnih materIalah*. A.I. Okocha, Ya.Yu. BIlokon. K. : Urozhay, 1988, 184 s.

[7] Kolesnik P.A., *Materialovedenie na avtomobilnom transporte*. M.: Transport, 1987, 271 s.

[8] Instruktsiya po analizu vodyi, para i otlozheniy v teplosilovom hozyaystve. M.: "Energiya", 1967.

[9] Malkina N.N., *Fiziko-himicheskie protsessyi v parovom tsikle elektrostantsiy*. M.: "Energiya", 1997.

[10] *Bolshaya sovetskaya entsiklopediya*, tom 17 pod redaktsiey A.M.Prohorova. M.: "Sovetskaya Entsiklopediya", 1974.

[11] Pavlov K.F., Romankov P.G., Noskov A.A., *Primeryi i zadachi po kursu protsesov i aparatov himicheskoy tehnologi*. Uchebnoe posobie dlya vuzov. L.: Himiya, 1987, 576s.

[12] Chastuhin V.I., *Teplovoy raschet promyishlennyih parogeneratorov*. Kiev: "Vischa shkola", 1980.

[13] A.S. 33537 SSSR, klas 13a,30. Prisposoblenie dlya preduprezhdeniya otlozheniya nakipi na stenkah kipyatilnyih trubok parovyih kotlov. P. N. Myasoedov. - # 128296; zayavl. 04.05.1933g.; opubl.31.12.1933 g.