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PECULIARITIES OF FORMATION OF SALT PLUGS IN OIL AND GAS INDUSTRY HEAT EXCHANGERS

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ABSTRACT

Heat exchangers are a very important part of technological devices in the chemical industry and related fields. The share of heat exchangers in the oil and gas processing industry is 50%. This article is devoted to the study of the problem of formation of salt plugs in heat exchangers of the oil and gas industry

KEYWORDS

Salt plugs, shell-and-tube heat exchangers, plate heat exchangers, heat transfer, circulating water, salt deposits, carbonate salts, silicate salts.

Introduction

The rate of growth of industry and economic stability directly depends on the level of development of the country's energy sector. One of the main sectors of our economy is the oil and gas industry.

In recent years, along with positive achievements in the oil and gas industry, there are also problems. One of these problems is the reduction of the efficiency of the device due to the accumulation of salt plugs in the heat exchangers of the oil and gas industry. The waste associated with the formation of salt plugs causes problems related to the cost of replacement or repair of the heat exchanger, the cost of preventive maintenance, the increase of water, electricity and other costs. Currently, the solution to this problem is urgent, because in the oil and gas industry, as well as in other sectors of the country's economy, attention is being paid to the issue of energy saving and energy efficiency.

Today, all plants of the oil and gas industry, as well as all other sectors that use heat exchangers, face the following main problems:

- the formation of salt plugs on heat transfer surfaces, which leads to a decrease in heat transfer in heat exchange devices and, subsequently, excessive consumption of fuel;
- the intensification of corrosion processes is primarily determined by the increase in the concentration of aggressive compounds (sulfur dioxide, etc.) in the production environment.

The continuous growth of the production volume in the oil and gas industry leads to an increase in the water consumption of the chemical industry. In this regard, special importance is attached to the issues of rational and efficient use of water.

Many physico-chemical processes occur with the release of heat. In the technological system, heat exchange devices are used in order to increase the yield of the manufactured product and reduce the formation of additional substances. The circulating water treatment system is an important part of the oil and gas industry.

In the production process, shell-and-tube heat exchangers are used to transfer heat from one substance (liquid or gas) to another substance (liquid or gas). In this case, one of the substances heats up and the other cools down. The structure of the two-way shell-and-tube heat exchanger according to the internal space of the pipes is presented in Fig. 1. The device mainly consists of a shell and a set of pipes inside it.

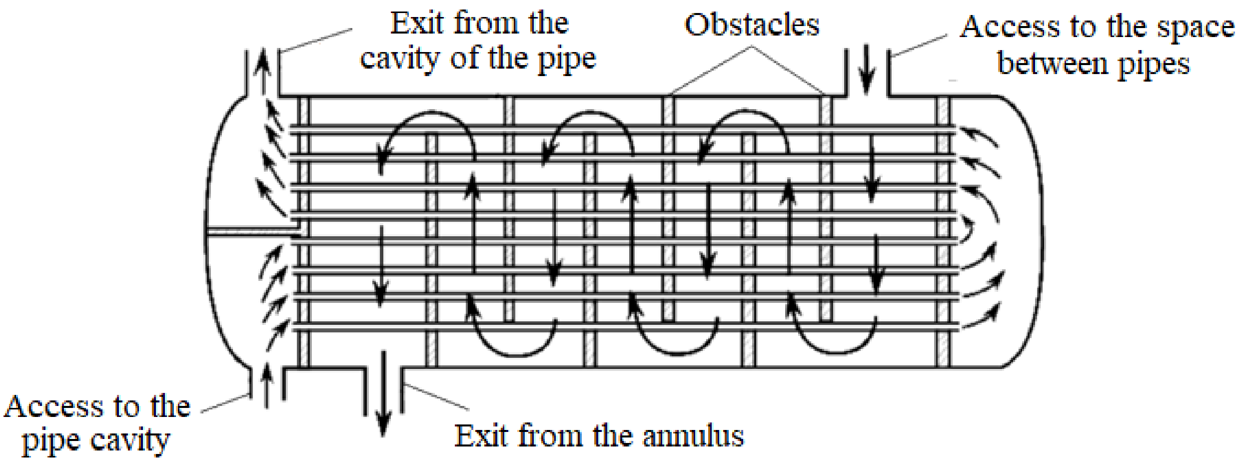


Figure 1. The principle of operation of the two-way shell-and-tube heat exchanger

In a shell-and-tube heat exchanger, heat is transferred through the walls of the tubes. Heat carriers that do not pollute the surface and do not form deposits are required to be sent from the space between the pipes.

The reasons for the decrease in the capacity of the shell-and-tube heat exchanger are the accumulation of salt plugs, foam, oil and tar on the heat exchange surface of the pipes, as well as metal corrosion.

If salt plugs accumulate in the device in large quantities, for cooling (heating) it is necessary to pass an excess amount of heat carrier through the heat exchanger, which leads to an increase in electricity consumption.

RESEARCH METHODOLOGY

When studying the formation of salt plugs in a shell-and-tube heat exchanger, samples of cooling water and high-temperature substances in a certain amount of the system were analyzed, as well as heat exchangers that failed due to the accumulation of salt plugs. A series of experimental data was obtained that revealed the reasons for the failure of heat exchangers.

Performance characteristics of the studied heat exchanger:

- parameters of the environment inside the pipes: cooling water, T = 50...80°C; P=490 kPa
- pipe size and material: Ø 20×2.0 mm, steel 09Г2С;
- parameters of the space between pipes: high-temperature heat carrier, T=118...83°C; P=910 kPa

According to the results of visual inspection after opening the shell-and-tube heat exchanger, salt growths with a diameter of up to 10 mm were found on the outer surface of the tube set in the lower part of the device (Fig. 2). At the top of the pipe set, a uniform layer of salt with a surface thickness of up to 0.5 mm was found.

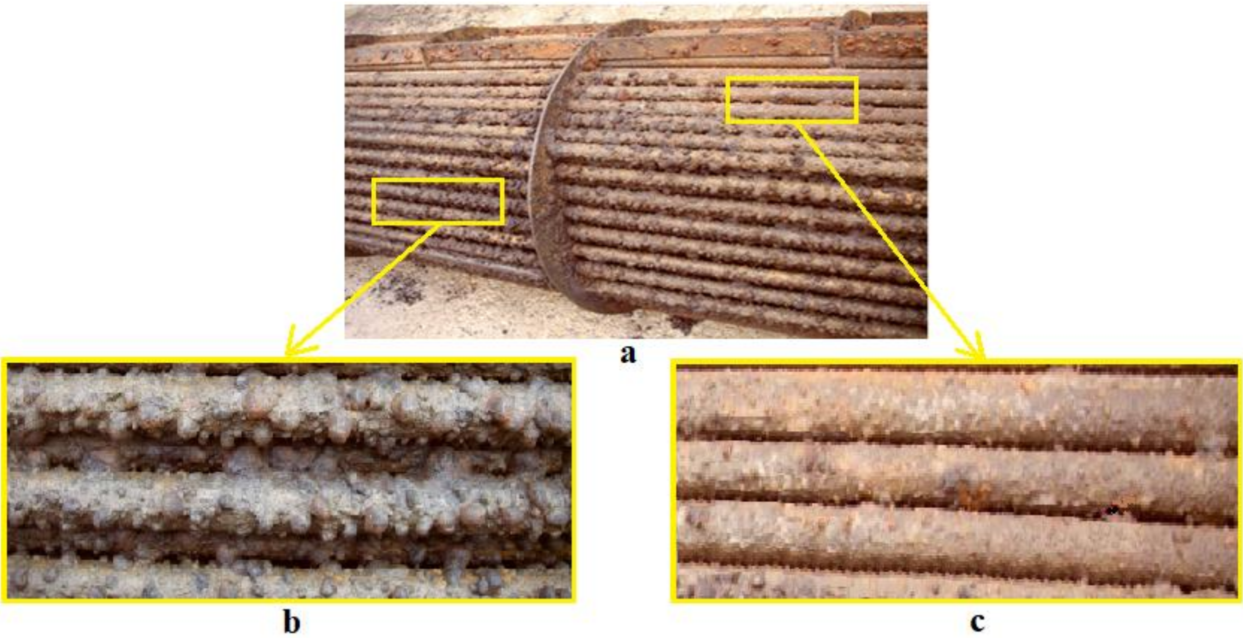


Figure 2. A shell-and-tube heat exchanger is a set of pipes

a -general view of a set of pipes; b- salt growths at the bottom of the pipe stack; c- a uniform layer of salt at the top of the pipe stack

In recent years, plate heat exchangers with a very high heat transfer coefficient have been widely used in the oil and gas industry.

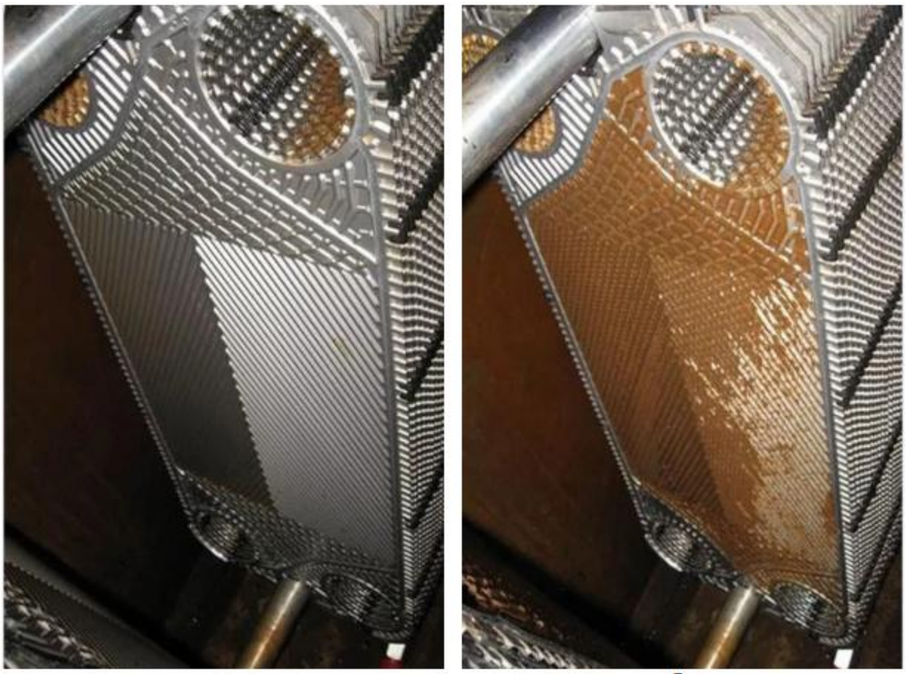
Plate heat exchangers are made of several rows of parallel corrugated plates made of thin metal sheets, which are clamped between movable and fixed plates with the help of screws. The advantage of this device is that the plate is made of a thin (1–1.5 mm) sheet, and the heat transfer coefficient has a large value due to the high speed of the currents.

When using a plate heat exchanger for 2-3 years, a salt coating appears on the surface of its plates. As a result, the efficiency of the device decreases due to the difficulty of moving the heat carrier in the channels on the plates. The reason for this is the presence of Ca^{2+} and Mg^{2+} salts in the water used as a heat carrier in the heat exchanger.

Clogging can occur in plate heat exchangers for the following reasons:

1. deposition of carbonate salts;
2. silicate salts;
3. corrosion deposits of metals;
4. a mixture of hard salt plugs;
5. rubber particles.

Most industrial enterprises do not have a high-cost chemical water treatment system. When cleaning the plate heat exchanger from salt clogs, the device case is opened and the sediments accumulated in the channels of the plates are cleaned (Fig. 3). However, after using the device at high pressure and cleaning the plates, there is no possibility to ensure the appropriate density between them.



a b

Figure 3. View of the channels of the plates of the plate heat exchanger in a clean state (a) and covered with salt plugs (b)

When salt plugs appear on the plates of plate heat exchangers, the following consequences can occur:

- the salt layer conducts heat poorly, and when it appears, the heat exchanger begins to lose its main function. The thicker the salt layer, the lower the heat transfer coefficient.
- the channels of the heat exchanger plates are gradually clogged with salt plugs and the movement of the heat carrier is completely restricted.

DISCUSSION AND RESULTS

The formation of salt plugs in heat exchange devices depends on the type and amount of salts dissolved in the heat transfer agent.

"Water hardness" occurs due to the dissolution of various salts in water, especially those containing Ca^{2+} and Mg^{2+} ions. Water hardness refers to the amount of Ca^{2+} and Mg^{2+} salts dissolved in 1 liter (1000 ml) of water in "mg·equiv" (milligram×equivalent). The water quality in the system was analyzed by studying the composition of a certain amount of water samples. A number of experimental data were obtained that reveal the causes of the formation of salt plugs in heat exchangers (Table 1).

Table 1

Analysis results of water from industrial circulation sources

№	Indicator names	1-ITS	2- ITS	3- ITS	4- ITS	5- ITS
1	pH	8,70	8,55	8,40	8,80	8,55
2	Mass concentration of salts, mg/dm^3	1360,0	770,0	1260,0	680,0	2300,0
3	Mass concentration of solids, mg/dm^3	35,4	24,6	38,0	145,0	88,4
4	General alkalinity, mmol/dm^3	4,6	3,5	3,0	4,2	0,6
5	Mass concentration of chlorides (Cl^-),mg/dm^3	280,0	130,0	280,0	130,0	260,0
6	Mass concentration of sulfates (SO_4^{2-}), mg/dm^3	1260,0	500,0	2520,0	800,0	1400,0
7	Mass concentration of total iron (Fe), mg/dm^3	0,5	0,27	0,39	0,77	0,93
8	General hardness, mmol/dm^3	27,0	16,5	25,0	18,0	37,0
9	Calcium hardness (Ca^{2+}), mmol/dm^3	18,0	10,0	14,0	10,0	20,0
10	Mass concentration of orthophosphate (PO_4^{3-}) ion converted to P_2O_5, mg/dm^3	0,44	0,35	1,29	0,71	1,12
11	Ability to oxidize permanganate,mgO/dm^3	2,4	2,32	6,72	2,56	36,15
12	Mass concentration of nitrites (NO_2^-), mg/dm^3	67,0	1,3	83,0	0,56	48,0
13	Mass concentration of nitrates (NO_3^-), mg/dm^3	192,0	106,0	144,0	30,0	740,0
14	Copper ion mass concentration (Cu^{2+}), mg/dm^3	0,0060	0,0070	0,0060	0,0060	0,0037
15	Mass concentration of silicic acid (SiO_3^{2-}), mg/dm^3	32,0	20,0	28,0	22,2	1,02
16	Mass concentration of total ammonia, mg/dm^3	1,26	1,32	no	no	240,0
17	Stability indicator, mg/dm^3	1,1	1,2	1,01	1,12	1,1
18	Mass concentration of active chlorine, mg/dm^3	no	no	no	no	no

SUMMARY
Salt plugs adhere firmly to the surfaces of heat exchangers where the heat transfer agents move. Even liquid streams cannot dislodge the salt layer. As a result, due to the hardness of the water, the layers grow and thicken. Therefore, the use of inhibitors against the formation of salt plugs in heat exchangers is an economically and technologically important solution to the above wide-ranging problems.

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