The Possibility of Using the Existing Large-Sized Equipment of the Units when Switching to New Oil Treatment Technologies

S V Ivanyakov¹, D A Kryuchkov², A S Pechnikov³

¹Candidate of Technical Sciences, Samara State Technical University
²Candidate of Technical Sciences, Samara State Technical University
³Candidate of Technical Sciences, Associate Professor, Samara State Technical University

E-mail: ivanyakov.serge@yandex.ru

Abstract. Oil treatment at field stabilization units allows preparing oil for storage and transportation, including by reducing the RVP and hydrogen sulfide content in oil. However, the use of direct fire heating of oil in pipe stills to maintain the thermal regime in the stabilization column may cause the formation of secondary hydrogen sulfide as a result of the thermal decomposition of heavy sulfur-containing hydrocarbons, which leads to additional financial losses for bringing the stabilized oil to the requirements of the current regulatory documents. A way to reduce the amount of secondary hydrogen sulfide is the transition from direct fire heating of oil to heating through an intermediate high-temperature coolant. In this case, the thermal regime of the stabilization column operation is maintained by heating in the reboiler, while it remains possible to use the existing unit columns and stills without their significant retrofitting.

1. Introduction

The use of the field oil stabilization units allows eliminating the loss of light hydrocarbon fractions during their storage and transportation. Also, this oil preparation technique allows increasing the volume of commercial oil due to the preservation of useful hydrocarbon components and reducing the content of hydrogen sulfide in it to that required by regulatory documents [1]. The standard stabilization unit flowsheet is given in Figure 1a. The column pressure is within 0.2÷0.5 MPa (based on the distillate condensation condition), and the bottom temperature is maintained at 170÷250 °C by the hot jet circulation through the still.

However, sulfur-containing compounds in oil may cause the formation of secondary hydrogen sulfide, when heated in a pipe still [2]. As a rule, the oil heating temperature in the stills is chosen to exclude the formation of secondary hydrogen sulfide, however, it can form in the thermal boundary layer on the inner surface of the coil pipes, where the local temperature can be significantly higher than the streamwise average [3]. Thus, a number of experiments have shown that after heating oil above 125 °C, at an initial hydrogen sulfide content of 50 to 175 ppm, in a pipe still, the hydrogen sulfide content increases by 25–35 ppm [2]. Also, overheating in the near-wall zone leads to thermal cracking of hydrocarbons with coke deposition on the inner coil walls.
2. Research objective
A way to reduce coking and the amount of secondary hydrogen sulfide is switching to an oil stabilization flow sheet with an intermediate coolant. Specifics of this flowsheet is heating of oil in a
reboiler by an intermediate high-temperature coolant, excluding direct fire heating in a pipe still. High-temperature coolants such as SYLTHERM 800 or analogs are used as intermediate ones. The flowsheet of such a unit is shown in Figure 1b.

Due to the exclusion of direct fire heating of oil, milder temperature conditions are ensured for the reboiler tube bundle material, while maintaining the main oil treatment process parameters, which allows using the existing large-sized equipment of the unit without significant retrofitting.

The most significant process mode change, associated with a change in the temperature regime of heating and productivity, with a slight change in thermal power will be observed in a pipe still.

3. Process simulation results

As an example, let us consider the operation of an oil treatment unit with a commercial oil yield of 626 t/h (5 million tons of oil per year). The composition of crude oil and that entering the column is given in Table 1.

| Flow                  | Unit of Measure | Crude Oil | Oil Entering the Column |
|-----------------------|-----------------|-----------|-------------------------|
| Flow rate             | kg/h            | 1,578,500 | 646,420                 |
| Temperature           | °C              | 20        | 105                     |
| Pressure              | atm. abs.       | 4         | 5.8                     |
| Composition           |                 |           |                         |
| Hydrogen sulfide      | % wt.           | 0.0016    | 0.0011                  |
| Methyl mercaptan      | % wt.           | 0.0001    | 0.0004                  |
| Ethyl mercaptan       | % wt.           | 0.0005    | 0.0018                  |
| Carbon dioxide        | % wt.           | 0.0224    | 0.0057                  |
| Nitrogen              | % wt.           | 0.0478    | 0.0002                  |
| Methane               | % wt.           | 0.1836    | 0.0046                  |
| Ethane                | % wt.           | 0.2488    | 0.0958                  |
| Propane               | % wt.           | 0.7582    | 0.9488                  |
| Isobutane             | % wt.           | 0.2488    | 0.4548                  |
| Butane                | % wt.           | 1.0948    | 2.1819                  |
| Isopentane            | % wt.           | 0.7058    | 1.5921                  |
| Pentane               | % wt.           | 1.0525    | 2.4222                  |
| Cyclopentane          | % wt.           | 0.1467    | 0.3436                  |
| Residue               | % wt.           | 64.9866   | 91.9470                 |
| Water                 | % wt.           | 30.5018   | 0                       |

Process simulation of the oil stabilization parameters was performed using the M&R P&A software package [4], which allows simulating the oil treatment unit operation with the accuracy required for design [5].

To stabilize the composition and remove hydrogen sulfide from oil, the column bottom temperature is maintained at 144 °C at a pressure of 5 atm. abs. To do this, the hot jet in a pipe still is heated to 177 °C (the still coil wall temperature is 198 °C, the maximum temperature of the outlet coil tube wall, considering the irregularity ratio of heating the pipe along the length and circumference (with a coke deposition thickness of 2 mm) is 220 °C). Heating oil to such a temperature leads to accelerated deposition of coke on the coil walls and the formation of secondary hydrogen sulfide. As a result, the commercial oil quality deteriorates (type 2 oil according to GOST [6] instead of the planned type 1).
When implementing the oil stabilization technology with an intermediate coolant, two horizontal reboilers with a total surface of 1,500 m² are required to heat oil in the column bottom. The SYLTHERM 800 coolant is heated in the existing pipe still. Switching to a flow sheet with an intermediate coolant allows reducing the reboiler wall temperature (the maximum heat exchange tube wall temperature is 189 °C) while maintaining the oil heating temperature. In this case, the stabilization column operating mode does not change (see Table 2), which allows using it in a new flow sheet without retrofitting.

**Table 2. Oil Stabilization Column Design Parameters in Various Oil Treatment Schemes.**

| Parameter                              | Unit of Measure | Flow Sheet without Intermediate Coolant | Flow Sheet with Intermediate Coolant |
|----------------------------------------|----------------|-----------------------------------------|-------------------------------------|
| Feed flow rate                         | kg/h           | 646,420                                 | 646,420                             |
| Feed temperature                       | °C             | 105                                     | 105                                 |
| Flow rate of gas at the column top     | kg/h           | 43,600                                  | 43,599                              |
| Column top temperature                 | °C             | 55.9                                    | 55.9                                |
| Column top pressure                    | atm. abs.      | 5.0                                     | 5.0                                 |
| Reflux flow rate                       | kg/h           | 23,422                                  | 23,422                              |
| Reflux temperature                     | °C             | 40.3                                    | 40.3                                |
| Hot jet flow rate                      | kg/h           | 603,821                                 | 603,821                             |
| Hot jet temperature                    | °C             | 177.0                                   | 177.0                               |
| Flow rate of oil at the column output  | kg/h           | 1,230,063                               | 1,230,064                           |
| Column bottom temperature              | °C             | 141.9                                   | 141.9                               |
| Column bottom pressure                 | atm. abs.      | 5.2                                     | 5.2                                 |
| Hydrogen sulfide content in commercial oil, secondary hydrogen sulfide not included | ppm | < 20 | < 20 |

In contrast to the column equipment, the change in the pipe still operating parameters is more significant (see Table 3). As can be seen from Table 3, the still operating conditions have changed, however, they are within the permissible limits for heaters, which allows concluding that the existing still can be used when changing the oil refining technology.

**Table 3. Design Pipe Still Operating Parameters in Various Oil Treatment Schemes.**

| Parameter                              | Unit of Measure | Flow Sheet without Intermediate Coolant | Flow Sheet with Intermediate Coolant |
|----------------------------------------|----------------|-----------------------------------------|-------------------------------------|
| Feed type                              |                | oil                                     | coolant                             |
| Feed flow rate                         | kg/h           | 603,821                                 | 451,380                             |
| Inlet temperature                      | °C             | 141.9                                   | 170.4                               |
| Outlet temperature                     | °C             | 177.0                                   | 240.0                               |
| Net heat output                        | MW             | 16.85                                   | 16.79                               |
| Flue gas temperature at the still pass | °C             | 704                                     | 716                                 |
| Fuel gas flow rate                     | kg/h           | 2,109                                   | 2,054.8                             |
| Radiant coil tube heat release rate    | W/m²           | 30,434                                  | 31,550                              |
| Average radiant tube wall temperature  | °C             | 198                                     | 241                                 |
FC (flameless combustion) type pipe stills used in oil treatment units were originally developed by VNIINEFTEMASH to heat petroleum products. These furnaces are represented in several standard sizes with a heat output of 8 to 24 MW [7], meeting the needs of petroleum product heating units of various capacities. The stills apply double-sided heating of double-row tube coils using flameless or wallfired burners located in solid or alternating rows in the side radiating walls. The burners are designed to burn high purity natural or dry industrial gases and ensure uniform and highly efficient heating of the screen heating surface. Such heating allows operating the still with high pipe surface heat release rate and reducing the still size by 1.5 times as compared to other box-type and cylindrical furnaces of equal heat output.

With a sufficiently developed technique of their thermal calculation [8] and retrofitting individual nodes (increasing the heating surface in the radiant and convection chambers, using modern highly efficient burners of AGB (automated gas burner) type [9] instead of wallfired ones, using sharply-bent branches to connect product pipes instead of return bends) create wide opportunities for their further use with a significant change in the petroleum product heating task.

4. Conclusion
As a result of corresponding thermotechnical calculations, the possibility of effective using the existing stills and columns of the unit has been shown at the existing need to heat a high-temperature coolant in a pipe still for subsequent heating of oil in a reboiler under milder temperature conditions.

5. References
[1] Zemenkov Y D, Aleksandrov M A, Markova L M, Dudin S M, Podorozhnikov S Yu, Nikitina A V 2015 Technique and technology of collection and preparation of oil and gas: Textbook (Tyumen: Publishing House) 160 p
[2] Gilaev G G, Ostankov N A, Kozlov S A, Pashkevich K L, Rtishchev A V, Grigoryan L G, Ignatenkov Yu I 2018 A method for reducing the formation of secondary hydrogen sulfide during oil preparation and a device for its implementation Patent of Russia RU 2 666 543 C1 11.09.2018 Byul. No 26
[3] Grigoryan L G 2013 Method for assessing the intensity of secondary hydrogen sulfide formation when heating oil in furnaces Bulletin of the Samara State Technical University. Series "Engineering Sciences" 3 pp 227-229
[4] MiR P&A Access mode: http: // http://mirpia.ru/
[5] Kryuchkov D A 2019 The use of the MiR P&A software complex for modeling the operation of an oil treatment unit Ashirovskie readings: Sat. Proceedings of the Intern. scientific-practical conference (Samara: Samar. state tech.un-t) pp 227-229
[6] GOST R 51858-2002 Oil General technical conditions (with amendments No. 1, 2) (M :: Gosstandart of Russia) 10 p
[7] Tubular furnaces Catalog, 5th edition, rev. and add (M :: TSINTIKHIMNEFTEMASH) 1998 29 p
[8] RTM 26-02-40-77 Regulatory method of thermal calculation of tube furnaces (M :: VNIINEFTEMASH) 1978 645 p
[9] Sharikhin V V, Pechnikov A S, Stepanchuk V V, Sharikhin A V 2004 Modernization of tubular furnaces in the oil and petrochemical industry SamSTU Bulletin. Oil series-the basic business Issue 28 pp 185-188