THE SIZE OF OXIDATIVE EQUIPMENT FOR ASPHALT PRODUCTION

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The principle of minimizing metal consumption was the basis for selecting the ratio of the height and diameter of oxidative equipment ("stills"). The size of oxidative equipment (towers) for new plants is determined by other criteria: the diameter is based on the required output and acceptable load with respect to air, and the height is based on ensuring the safety of the oxidation process and minimizing the costs for compressed air and pumping of feedstock and asphalt.

In our country, asphalts for different applications are primarily manufactured by oxidation of vacuum resid or mixtures of vacuum resid with asphalts from deasphalting and extracts from selective treatment with air. This process is still fundamental and will remain so, at least for the near future, since exhaustive refining of crude oil for changing to production of asphalts (residual) during exhaustive vacuum distillation is slow.

In addition, construction asphalts are usually only obtained by oxidation (regardless of the degree of refining of the crude at the refinery). Finally, in active (GOST 22245 – 90) and developing [1, 2] standards, relatively high requirements for heat and cold resistance are set for paving asphalts, and oxidation products best satisfy these requirements.

In light of the above, the analysis of the effect of the size of oxidative equipment on the efficiency of the process is of practical interest, especially since a comparative analysis has not been published in widely available publications.

So-called stills and hollow oxidation towers are used as oxidative units in the industry. Stills, vertical cylindrical vessels with a low ratio of height to diameter, are used in relatively old asphalt plants for conducting the process periodically.

Oxidation towers – vertical cylindrical vessels with a much higher height-to-diameter ratio are installed in new plants and in revamping old plants, and the oxidation process is conducted continuously. The previously relatively widely used tubular coil reactors are not examined here, since they are now only used in isolated cases due to their elevated power requirements.

We can hypothesize that the differences in the designs of stills and oxidation towers are due to the different criteria for assessing the process efficiency in different years. There were no principles for use of theoretical solutions for “old” asphalt plants for many years, and these decisions (for example, on the ratio of the still height and diameter) now seem unsubstantiated and unworthy of attention.

We [3] reconstructed the existing situation with the important feature of the low requirement for environmental protection and safety engineering. It was hypothesized that planners should start with the necessity of saving on metal in selecting the oxidative “still” height and diameter ratio.

In a first approximation, consider the bottom of the still to be flat and the thickness of the walls and bottom to be the same. In this case, metal consumption is proportional to the area of the vat. The area $F$ and volume $V$ are determined by height $H$ and diameter $d$ or radius $r$:

$$F = 2\pi r^2 + 2\pi rH$$
$$V = \pi r^2 H$$
For a certain (assigned) volume, the height and diameter or radius will be in a certain ratio, for example:

\[ H = \frac{V}{\pi r^2} \]

so that the area of the unit can be expressed by the dependence on the diameter or radius alone:

\[ F = 2\pi r^2 + \frac{2V}{r} \]

Differentiating this dependence with respect to the radius, setting the first derivative to zero, and determining the sign of the second derivative, we find that the area of the unit operating with total filling is minimal when the height and diameter are equal.

When the unit has a gas space, the calculation is slightly more complicated. In practice, “stills” with a diameter of 5.3 m and a wall height of 9.6 m [4] are more widely used, and the gas space height is usually 2-2.5 m.

The calculation shows that in this case, the area of the still is minimal for a wall height of 9.3-10.3 m. The real value of the still wall height falls within the calculated range. As a consequence, the dimensions of the oxidation still satisfy the metal-saving requirement.

The oxidation towers had a wide variety of sizes in the initial period of operation: diameter from 2.2 to 3.8 m, height from 10 to 30 m; most of the oxidation towers had a diameter of 3.4 m and a height of 20-25 m [4]. This ratio is far from optimum with respect to minimizing metal consumption. However, the efficiency of the process was assessed with other indexes in this period: output, safety, and to some degree, energy requirements.

The tower diameter predetermines its output to a significant degree. For calculating the maximum output, it is necessary to know the acceptable tower load with respect to air. It was shown in [5] that this load (in terms of the area of the complete section of the tower) is: in the reaction zone: 0.26 and 0.13 m³/(m²·sec) in production of paving and construction asphalts, and a maximum of 0.08 m³/(m²·sec) in the separation zone.

Effective absorption of atmospheric oxygen takes place in the reaction zone with such loads, and drops of asphalt are not entrained from the separation zone. These load values are recommended for use in calculating the tower diameter, which can be smaller for the reaction zone than for the separation zone.

Tower height \( H \), more precisely, height \( h \) of its reaction zone, which should be 2-3 m less than the total height, affects the residual oxygen content \( c \) in oxidation gases:

\[ c = 21e^{kh} \]

where \( k \) is a constant which is a function of the oxidation temperature and softening point of the asphalt obtained [4].

As a consequence, the height affects consumption of air for attaining a given degree of oxidation of the asphalt and also the degree of inflammability and explosiveness of the process. The required height can be determined with the dependence indicated above based on the conditions of process safety and minimization of power outlays for compressed air.

In accordance with the safety engineering rules in the oil refining industry, the concentration of oxygen in oxidation gases should not exceed 4 vol. % previously (1973). The tower height at which this requirement is satisfied was obtained at the same time as comparatively low compressed air requirements.

Now the acceptable concentration of oxygen in oxidation gases is 8 vol. % and planners must decide whether the tower height is sufficient for satisfying this requirement alone or whether it would be better to have a higher tower to reduce compressed air costs despite the additional capital investments.

A low concentration of oxygen in oxidation gases can be obtained not only by increasing the tower height and oxidation temperature but also by using methods that increase the contact area of the reacting phases, although bubbling processes are also characterized by a high contact surface area. Different designs of equipment for additional mixing of the reacting phases are described in [6, 7].