# MULTI-TIER ABSORBER FOR CLEANING OF EXHAUST GASES OF KILNS

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Shown multi-tier hollow absorber spray type. Inside the unit, rotating nozzles of high capacity (10–30 m³/h) are installed with a mechanical drive. This design allows them, without clogging, to work with contaminated and viscous liquids. *Key words:* multi-tier absorber, cleaning of exhaust gases.

**Багатоярусний абсорбер для очищення вихлопних газів вапняно-обпалювальних печей. Кузнецов С.І., Сакович Б.П.** Представлений багатоярусний порожній абсорбер розпорошувального типу. Усередині апарату встановлені форсунки великої продуктивності (10–30 м³/ч), що обертаються з механічним приводом. Така конструкція дає їм змогу працювати із забрудненими та в'язкими рідинами без забивання. *Ключові слова:* абсорбер, очищення вихлопних газів.

**Многоярусный абсорбер для очистки отходящих газов известково-обжиговых печей. Кузнецов С.И., Сакович Б.П.** Представлен многоярусный полый абсорбер распылительного типа. Внутри аппарата установлены вращающиеся форсунки большой производительности (10–30 м³/ч) с механическим приводом. Такая конструкция позволяет им работать с загрязненными и вязкими жидкостями не забиваясь. *Ключевые слова:* абсорбер, очистка отходящих газов.

**Problem statement.** In the practice of protecting an air basin from pollution by harmful substances, it is often necessary to encounter the need to clean gases, which simultaneously include several harmful components, an example is the flue gases from lime-kiln furnaces, where fuel oil is used as a fuel. The composition of the exhaust gases include $SO_2$, CO, soot. The choice of the method and equipment for cleaning gases from all components at the same time is difficult due to the complexity of the system and the tendency of limestone dust to grout the working surfaces of the equipment, as a result of which the equipment quickly fails.

**Actualization.** For purification of waste gases, a spray-type absorption apparatus has been developed. It is made in the form of a hollow cylinder, inside of which, in height, non-clogging nozzles with a mechanical drive are installed. A distinctive feature of nozzles is their high capacity up to 10–30 m³/h and the absence of narrow sections and channels, which allows working with polluted, viscous liquids and suspensions, while providing a uniform fine spray.

The environmental assessment of the investigated source of atmospheric pollution (Tables 1, 2) shows an excess of the MPC of dust and soot by 4,6 times, by the sum of acidic components by 2,49 times.

**Novelty.** Analysis of the calcined kiln flue gases showed that they contain both acidic ($SO_2$, $NO_X$) and alkaline (CaO, MgO, $CaCO_3$, $MgCO_3$) components. The quantitative ratio of alkaline and acidic components allows for their mutual neutralization. This circumstance
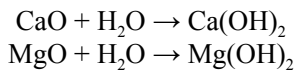
Table 1

## The composition of the exhaust gases of kilns

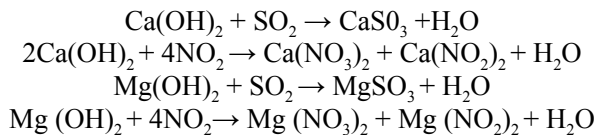| Components | Chemical formula | Exhaust gas content | | Amount | |
|---|---|---|---|---|---|
| | | % (vol) | g/m³ | kg/h | t/year |
| Sulfurous anhydride | $SO_2$ | 0,05 | 1,43 | 52,86 | 190,29 |
| carbon monoxide | CO | 0,6 | 7,5 | 277,55 | 999,18 |
| Nitrogen oxides | $NO_X$ | 0,01 | 0,205 | 7,6 | 27,36 |
| Hydrocarbons | $CH_4$ | 0,006 | 0,0858 | 1,58 | 5,68 |
| Total gaseous | | | | 339,59 | 1240,33 |
| Dust | CaO, MgO | - | 0,44 | 16,28 | 58,6 |
| Dust | $CaCO_3$ $MgCO_3$ | - | 0,655 | 24,6 | 88,52 |
| Soot | C | - | 1,235 | 45,7 | 164,5 |
| Total solid | | | | 86,58 | 311,68 |
| Total emissions | | | | 426,17 | 1552,01 |

Table 2

**Environmental assessment kiln exhaust gases**

| Component | Maximum concentration in the surface layer after dispersion, mg/m³ | MAC mg/m³ | Exceedance of maximum permissible concentration |
|---|---|---|---|
| Dust | 0,413 | 0,5 | 0,826 |
| Soot | 0,462 | 0,15 | 3,079 |
| Dust + Soot | 0,875 | - | 4,6 |
| $SO_2$ | 0,544 | 0,5 | 1,09 |
| $NO_2$ | 0,12 | 0,085 | 1,41 |
| $SO_2 + NO_X$ | 0,664 | - | 2,49 |
| CO | 2,854 | 3 | 0,95 |

is used by us in the development of the method of sanitary cleaning of gases. The essence of the method is that the flue gases of lime kilns are subjected to intensive irrigation with water in the hollow apparatus. When this reaction occurs:

$$CaO + H_2O \rightarrow Ca(OH)_2$$
$$MgO + H_2O \rightarrow Mg(OH)_2$$

Then the resulting products neutralize the acid gases:

$$Ca(OH)_2 + SO_2 \rightarrow CaSO_3 + H_2O$$
$$2Ca(OH)_2 + 4NO_2 \rightarrow Ca(NO_3)_2 + Ca(NO_2)_2 + H_2O$$
$$Mg(OH)_2 + SO_2 \rightarrow MgSO_3 + H_2O$$
$$Mg(OH)_2 + 4NO_2 \rightarrow Mg(NO_3)_2 + Mg(NO_2)_2 + H_2O$$

Reactions between acid gases and suspensions of $CaCO_3$ and $MgCO_3$ are also possible. As a result of the reactions taking place, the exhaust gases are completely neutralized without the use of chemical reagents from outside.

Effective absorption of gas components in the apparatus is achieved due to the developed mass transfer surface, which is formed due to the spraying of a liquid and a high velocity of gas-liquid flows. This also contributes to the repeated absorption of the absorbed gas through the nozzle nozzles, which in this case work as high-performance Venturi nozzles.

Effective gas cleaning from dust and soot is achieved due to wetting of solid particles with finely dispersed dropping liquid, as well as using the method of steam condensation. For this process, water vapor is introduced into the gas stream. In the process of mixing vapor with a dropping liquid, it cools and volumetric condensation, and fine dust and soot particles serve as condensation centers, which leads to their coarsening and separation from the gas stream.

A diagram of an industrial, installation for cleaning exhaust gases from lime kilns is shown in Fig. 1.

The device is a hollow cylinder with a diameter of 2 m and a height of 11 m, mounted on the supports 10. In the upper part of the device there is a drop separ-
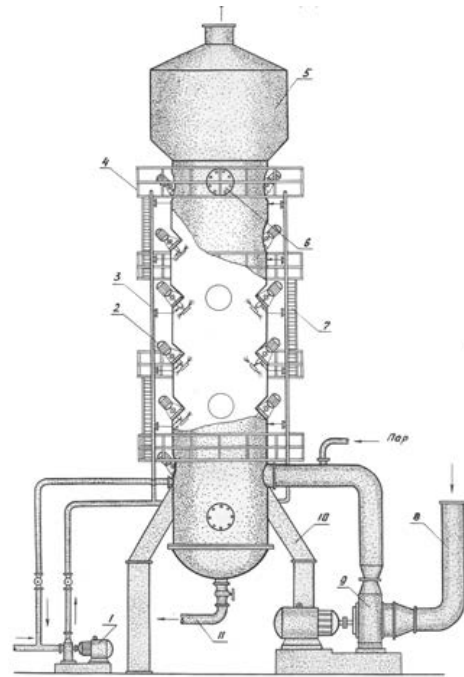


*Fig. 1. 1 – pump; 2 – electric motor; 3 – collector of serve of solution; 4 – platform; 5 – corps; 6 – hatch; 7 – stair; 8 – entrance union coupling; 9 – ventilator; 10 – supports; 11 – union coupling for the exit of liquid*
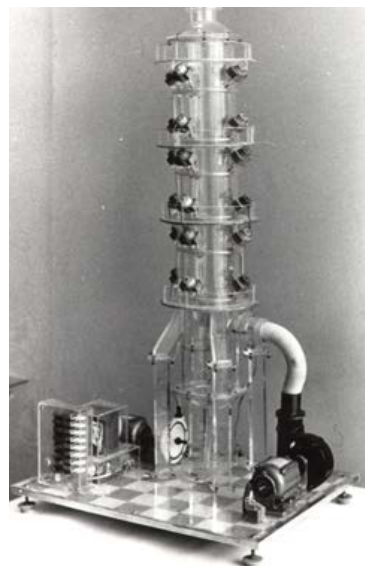


*Fig. 2. Model and industrial absorber is set at the Kherson plant*
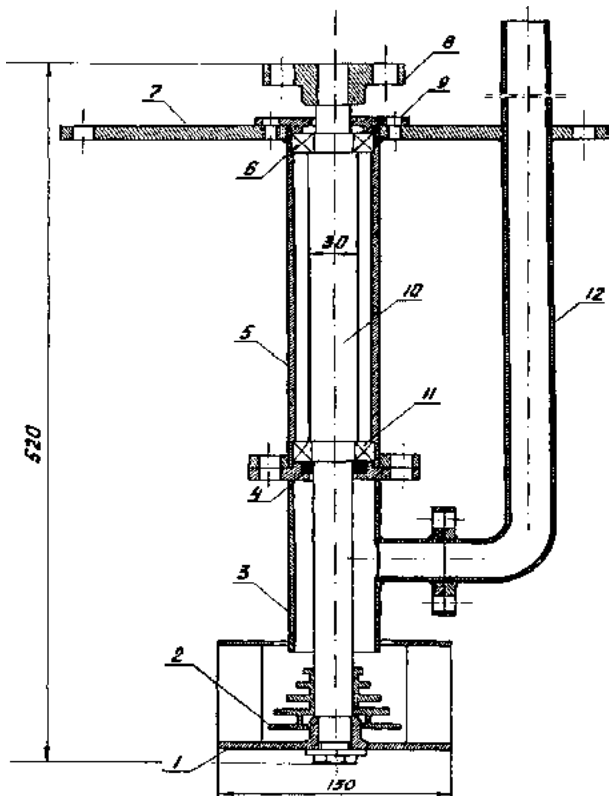
*Fig. 3. Chart of industrial mechanical sprayer by the productivity of 3 м³/h: 1 – nebulizer; 2 – distributive device; 3 – union coupling; 4 – compression; 5 – corps; 6 – bearing; 7 – flange; 8 – muff; 9 – lid; 10 – billow; 11 – bearing; 12 – union coupling for a liquid*
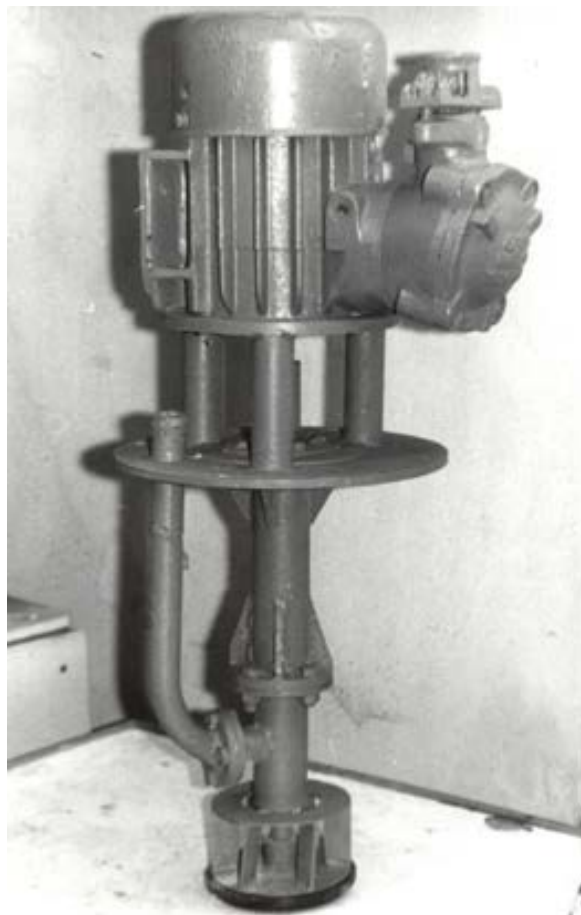


*Fig. 4. Industrial sprayer by the productivity of 3 м³/h*

Table 3

**Characteristics of the waste gas cleaning unit of the limestone kiln**

| Indicator | Value |
|---|---|
| Productivity, m³/h | 20 000 |
| Diameter, m | 2 |
| Height, m | 11 |
| Gas linear velocity, m/s | 1,63 |
| Number of irrigation tiers | 6 |
| The number of nozzles in the device | 24 |
| The number of nozzles in the tier | 4 |
| Nozzle performance, m³/h | 3 |
| Nozzle engine power, kW | 1,5 |
| Amount of the sprayed liquid, m³/h | 72 |
| Irrigation density, m³/m²·h | 23 |
| Steam consumption, kg/h | 200 |
| Hydraulic resistance, Pa | 810 |
| Fresh water consumption (feed), m³/h | 0,02 |

| Gas composition, m³/h | Input | Output | Cleaning level, % | Parts catching, tons in year |
|---|---|---|---|---|
| $SO_2$ | 1,5 | 0,03 | 98 | 193 |
| $NO_2$ | 0,2 | 0,04 | 80 | 26 |
| CO | 7,5 | 6,75 | 10 | 34 |
| Dust | 1,2 | - | 100 | 174 |
| Soot | 1,2 | 0,06 | 95 | 82 |
| Sludge is formed in terms of dry product, $CaSO_4$ | | | | 500 |

ator 5. Gas is supplied to the cleaning through the flue 8 by means of the fan 9. The sludge is drained by fitting 11. The clarified liquid is returned to irrigation, and the sludge is used in the same production. In the apparatus on six tiers, non-clogged nozzles 2 with a capacity of 3 m³/h are installed, four pieces in each. Total of 24 sprayer.

Presenting main material. For even dispersion of liquid in the volume of vehicle of sprayer set under the corner of 45°. The chart of sprayer is shown on Fig. 4. The feed of sprayers comes true by a pump 1 on a collector 3. By means of gas analyzers it is possible to manage work of sprayers, automatically disconnecting tier, if concentration of harmfulness on the exit of the below set level. It assists the economy of electric power.

The concentration of harmful substances in off-gas after cleaning does not exceed maximum possible. The caught dust is used for creation of bricks. Of long duration exploitation of setting showed her high reliability and efficiency.

**Conclusions.** Hydrodynamic and aerodynamic descriptions of vehicle are investigational, optimal correlations of structural parameters are educed, basic conformities to law of aleak in him processes and condition of industrial application are certain, efficiency of the worked out equipment is shown.

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