Laboratory Reactor for Processing Carbon-Containing Sludge

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Abstract. The paper describes a reactor for high-temperature pyrolysis of carbon-containing sludge with the possibility of further development of environmentally safe technology of hydrocarbon waste disposal to produce secondary products. A solution of the urgent problem has been found: prevention of environmental pollution resulting from oil pollution of soils using the pyrolysis process as a method of disposal of hydrocarbon waste to produce secondary products.

1. Introduction

Oil extraction process results in contamination of the soil, not only within the fields themselves, but also in the surrounding areas. The problem of oil and oil products getting into the soil exists at all stages of field development and production: drilling, recovery, gathering and transportation of produced fluids.

Oil and oil products cause almost complete depression of the functional activity of flora and fauna. Emergency spills on oil pipelines lead to high concentrations of oil in confined areas, resulting in the formation of depression-oil sectors of terrain characterized by strong oil contamination, disturbance of the lower levels of the geosystem.

The high toxicity and flammability of oil and oil products considerably exacerbate the implications of oil pollution.

The problem of protection and restoration of land contaminated with oil is very relevant, especially for the northern regions, since it is here that the main oil production complexes are concentrated and the climate of this region does not allow restoring the land after the oil pollution in the shortest time.

2. Methods, results and discussion

One of the possible solutions to the problem of disposing of sludge containing organic compounds is proposed in Industrial University of Tyumen (oil sludge, contaminated soils, etc.) [3,5]. The essence of this technology lies in the high temperature pyrolysis of the organic waste component in an environment similar to that created in furnaces with a "fluidized" bed. In this method, to sustain the pyrolysis process an electric arc of direct or alternating current is proposed to be used as a source of heat in the reactor.

The laboratory unit includes a reactor designed for the disposal of sludge containing organic compounds and is an electric arc furnace of indirect action. In this case, the arc burns between the horizontally arranged electrodes, and the salvage material acquires heat from the arc by radiation, convection and conduction [4]. The reactor is fabricated as a sealed cylindrical metal tank in the top part of which is a waste loading hatch, and at the bottom there is a hatch for discharging ash residue. Hatch covers are removable; their tight closure is done by bolting. The reactor has a cooling water jacket designed to control the desired temperature for the reaction process. Figure 1 shows the internal arrangement of the pyrolysis reactor laboratory unit for studying the process of organic sludge disposal.
Inside the reactor has two electrodes 3, 10 connected to the tap of the welding transformer which initiate the pyrolysis process. Electrodes are supplied manually with the help of a screw feeder 9.

![Diagram of the reactor](image)

**Figure 1.** The internal arrangement of the reactor.

1 – cooling jacket; 2 – dielectric insulating rings; 3 – thick electrode; 4 – dash plate; 5 – mechanical coarse filter; 6 – pressure gauge; 7 – loading hatch; 8 – reactor vessel; 9 – thin electrode feeder; 10 – thin electrode; 11 – coolant; 12 – activator wheel; 13 – salvage material; 14 – bunker bowl; 15 – bottom (discharge) hatch.

Along the height of the reactor wall sockets for temperature sensors are located. The first thermocouple located in the middle of the unit at a height of 155 mm from the bottom of the reactor is designed to determine the temperatures in the reaction zone; the second one at a height of 300 mm is used to control the temperature of the pyrolysis gas. Temperature measurement is possible at various points of the unit by moving the thermocouple socket relative to the heat source.

This unit allows us to carry out research on the physical and chemical processes of waste disposal.

Parameters of the electrical current supplied to the electrodes contribute to the high temperatures of about 3000 K. This prevents the formation of highly toxic compounds in the exhaust pyrolysis gas and, therefore, reduces the impact on the atmosphere [4].
Figure 2 shows the isotherms of the temperature field built according to the experimental data obtained during sludge disposal. In this case, the electrodes 14 mm in diameter were used; the power of the supplied electric current was ≈ 5400 W.

Figure 2. The approximate view of the isotherms of the temperature field in the pyrolysis reactor.

1 – 5 – isotherms at 1200, 1125, 880, 810 and 725 ºC, correspondingly.

The reactor is a batch operation unit in which processing of sludge is carried out in batches. Loading of the reactor is carried out through the top (loading) hatch. The volume of salvage material is determined based on the degree of filling of the reactor - the loading level should be below the electrode placement. Thus the possibility of mineral waste component sintering at the initial stage of the electric arc operation is eliminated. When disposing of organic sludge the mass of the salvage material loaded simultaneously is an average of 200 - 400 g. An important condition is that loading of the unit must be done with the short-circuited electrodes in the central part of the reactor. This eliminates the likelihood of occurrence of the dielectric layer from the salvage sludge between the electrodes. Pretreatment of sludge (grinding, fractionating, drying) is not required. Then, tight closing of the loading hatch is performed.

The electric motor drive of the activator wheel is launched. When the electric current passes from the transformer through the electrodes and the electric arc discharge occurs in the interelectrode space, the sludge recycling process begins. The temperature of the arc is determined by the power characteristics of the electric arc.

The activator rotation causes uplifting of material portions from the bottom of the bunker bowl and tossing them up. The activator wheel speed is determined experimentally for each type of sludge, based on the maximum residence time of the salvage material in the high-temperature "near-electrode" zone. Thus, an effect is achieved similar to that on which the work of the furnace with a fluidized (boiling) bed is based. However, unlike the latter, where this effect is achieved by supplying air or inert gas into the unit, there is no dilution of the produced, as a final product, fuel gas with foreign
impurities and polluting toxic compounds resulting from partial oxidation of the salvage material by air oxygen.

Application of the technology of the so-called "fluidized" bed in the laboratory unit is due to the fact that as the test salvage material was selected oil-contaminated soil with a high content (over 90%) of the mineral part which consists primarily of silicates. As a consequence, when it enters the area of high temperature (more than 1800 K) the mineral component passes into the melt that forms a solid glassy mass when cooled. In a stationary mode of sludge pyrolysis this leads to the formation of the so-called "gin poles" that "glue" electrodes together, envelop them with a dielectric film and form "sinters". Thus, if in the sinter itself the degree of material processing (in organic part and humidity) approaches one hundred percent, outside the sintered area due to its low thermal conductivity the level of processing does not exceed 10-15%. Application of the "fluidized" method of disposal leads to the vitrification of only individual sand grains and prevents them from sticking together to form "sinters". Small pieces of the sintered material adhering to the electrodes are easily degraded. The degree of sludge processing (in organic part and humidity) reaches 97-99%.

Combustible gas formed during pyrolysis of the organic part of the sludge rises to the top of the reactor. It passes through the labyrinth channel of inclined dash plates so that it is cleaned from large solids. The gas temperature downstream of the reactor in its upper part is 380 - 400 K. Then, the gas through the fine mesh filter, where small dust-like inclusions are separated, enters the refrigerator, an air-cooled helical tube. In the refrigerator gas desiccation takes place by separating water vapor and a resinous component which, when cooling down, condense and together with the gas enter the condensate tank where they remain. And the gas passing through the fiber filter and finally clean from residual moisture and solids enters the gas line. Through it the gas enters the gas meter to account for its amount and then is fed to the torch where it is burnt.

The main product of the sludge processing in the reactor of this type is a combustible gas, whose calorie content is 12 - 13 MJ. The share of gas output is 0.5 l/g, due to high levels of mineral components content.

A by-product of processing is a solid mineral residue containing less than 3% of the organic part, which means that it can be used as an aggregate for asphalt mixtures and for other construction purposes.

3. Summary
In Industrial University of Tyumen scientists have developed technologies that reduce the impact of the oil industry on the environment, with obtaining the secondary products of processing (fuel gas). They used an integrated system approach to the problem of oil-contaminated hydrocarbon waste disposal by a high-temperature pyrolysis process.

References
[1] Medvedev A V, Korovin I O and Shantarin V D 2002 A study of optimum parameters of the pyrolysis process of organic wastes in the installation with arc heating Proceedings of the scientific and technical conference "Oil and Gas: Challenges of subsoil use, production and transportation" (Tyumen) 156
[2] Voychenko A A, Medvedev A V and Oparin V V 22.07.2002 Installation for the thermal processing of sludge. Patent for invention RUS 2229060
[3] Medvedev A V, Korovin I O and Bagabiev R R 2003 The reactor for processing organic sludge Proceedings of the higher educational institutions. Oil and gas (Tyumen: Publishing House TSOGU) 3 111-14
[4] Medvedev A V, Bagabiev R R and Korovin I O 2003 Installation for recycling organic sludge with a high content of mineral components Proceedings of the higher educational institutions. Oil and gas (Tyumen: Publishing House TSOGU) 3 109
[5] Medvedev A V 2014 Study of the possibility of using the pyrolysis method for the disposal of waste oil Online magazine Naukovedenie 5(24) 10